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New information on the gray whale migratory movements between the western and eastern North Pacific.

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ABSTRACT

Gray whales have traditionally been considered to consist of two populations, one in the western North Pacific (WNP) and the other in the eastern North Pacific (ENP). The ENP population ranges from wintering areas off Baja California, Mexico, to summer feeding areas in the Bering, Beaufort, and Chukchi Seas. The WNP population feeds off Sakhalin Island and southeast Kamchatka, Russia. Historical evidence indicates that the South China Sea may have been used as a wintering ground in the WNP. Genetic, telemetry and photo-identification comparisons between the ENP and the WNP show some degree of population mixing during the winter. Here we present a multinational effort to evaluate trans-Pacific movements of gray whales identified in both the ENP and WNP. Images of 379 whales identified on the summer feeding grounds off Russia (316 from Sakhalin; 150 from Kamchatka), were compared to 10,685 individuals identified in the wintering lagoons of Baja California, Mexico (1,590 from Laguna Ojo de Liebre; 7,151 from Laguna San Ignacio; and 1,994 from Bahia Magdalena). A total of 43 matches were found, including: 14 Sakhalin-Kamchatka-Mexico, 25 Sakhalin-Mexico, and 4 Kamchatka-Mexico. These matches consist of 22 females, 13 males, and 8 whales of unknown sex. Thirteen whales were observed making round trips (summer-winter-summer), 11 with winter in Mexico and the following summer in Russia, and 6 with summer in Russia and the following winter in Mexico. The others were matched in non-sequential years. These 43 matches, in combination with 11 previous matches, result in 54 gray whales being linked between Russia and Mexico. Movements between the WNP and ENP represents 14.2% of gray whales identified off Sakhalin Island and Kamchatka, and the 0.5% of the gray whales identified in the breeding lagoon of the west coast of Baja California peninsula Mexico.

INTRODUCTION

The gray whale (*Eschrichtius robustus*) has been historically considered to consist of two populations, the western North Pacific (WNP) and eastern North Pacific (ENP) populations (Reilly *et al*., 2008). The ENP population ranges from calving areas off Baja California, Mexico, to feeding areas in the Bering, Beaufort, and Chukchi Seas. The WNP population feeds in the Okhotsk Sea off Sakhalin Island, Russia, and in nearshore waters of the southeastern Kamchatka Peninsula, historical evidence indicates that areas in the South China Sea were used as wintering grounds (Weller *et al*. 2002).

The Western stock is listed as critically endangered whereas the Eastern Pacific population is of least concern (Reilly *et al*., 2008). Both stocks were extensively harvested during commercial whaling (Henderson 1984, Weller *et al*. 2002, Reeves *et al*. 2010). The ENP population is currently estimated at 19126 (cv= 0.071) individuals (Laake *et al*. 2009. The most recent assessment of the WNP subpopulation in the Okhotsk Sea (Sakhalin Island + east coast of Kamchatka), using a Bayesian individual-based stage-structured model, resulted in a median 1+ (non-calf) estimate of 321-412 individuals, and 130-170 for Sakhalin feeding whales in 2016 (95% confidence interval) (Cooke *et al*. 2016).

Research on gray whales in the WNP has been ongoing since 1995, predominantly on the primary feeding ground off northeastern Sakhalin Island, including the Piltun area (52°20' N–53°30' N), stretching 120 km along the shore of Piltun Bay, and the Offshore area, located further offshore from Chayvo Bay (51°40' N–52°20' N) (Weller *et al*. 1999, 2012; Bradford *et al*., 2008; Yakovlev *et al*., 2009; Lang *et al*. 2011), and more recently off southeastern Kamchatka (Vertyankin *et al*. 2004, Tyurneva *et al*. 2010, Burdin *et al*. 2011). These studies monitor gray whales using photo-identification methods, as gray whales are individually identifiable based on unique, permanent pigmentation features (Darling 1984). These studies have documented a pronounced seasonal site fidelity and inter-annual return of known individuals in the Sakhalin coasts (Weller *et al*. 1999, 2002, Bradford 2011); as well as movements of individuals, including reproductive females and calves, between the coastal waters off Sakhalin and the southern and eastern coast of Kamchatka (Tyurneva *et al*. 2010, 2018; Burdin *et al*. 2011).

Current data from the historical migratory corridor(s) of the WNP are limited, and data from the presumed wintering area(s) are essentially unavailable (Weller *et al*. 2012). There is only one known photographic match of a fatally entrapped female in set nets along the Pacific coast of Honshu, Japan in January 2007 who was photographed as a calf in Sakhalin feeding ground in July and August 2006 (Weller *et al*. 2008).

Lang (2010) reported that two adult individuals from the WNP, sampled off Sakhalin in 1998 and 2004, matched the microsatellite genotypes, mtDNA haplotypes, and sexes of 2 whales sampled off Santa Barbara, California, USA. This report was the first to suggest that some level of interchange might be occurring between the WNP and ENP.

During the summers of 2010 and 2011, seven adult gray whales were tagging in Sakhalin Island, three of them transmit long enough to document their migration route. These three whales went across the Bering Sea to the Gulf of Alaska, one of them, "Varvara," traveled south within 103 km of Cabo San Lucas, Baja California Sur, México, and return to Sakhalin Island after 172 days of tagging (Mate *et al*., 2015)

Using photographic comparison of photo-identified gray whales, Weller *et al*. (2012) report the first ten matches between the WPN and ENP, six between whales photographed in Sakhalin Island and Vancouver Island, Canada, and four between Sakhalin Island and San Ignacio Lagoon, Mexico.

Following a recommendation of the Scientific Committee of the International Whaling Commission, Urbán *et al*. (2012; 2013) reported the results of the *Collaborative Pacific wide study on population Structure and Movement patterns of North Pacific gray whales*, where 23 photographic matches between the WNP and the breeding lagoons from the Baja California Peninsula, Mexico, were found.

Here we present new information on trans-Pacific movements of gray whales photo-identified in both the ENP and WNP.

METHODS

The comparison was made base on the following sources:

Russia (Fig 1):

Sakhalin Island:

- *Burdin, M.A., Weller W. D., Sychenko, A.O. and Bradford, L.A. Western gray whales off Sakhalin Island, Russia: A catalog of photo-identified individuals. (1994-2016) 261 individuals.* ***(WGW)***
- *Tyurneva. Y.O. and Yakovlev, M.Y. The Western Pacific gray whales of Sakhalin island (2002-2011) Learning about a population of whales through photographs. 172 individuals.* ***(KOGW)***

Kamchatka Peninsula:

- *Tyurneva, O. and Vertyankin, V. The North Pacific Master gray whale catalogue (2004-2011). 150 ids. 150 individuals.* ***(KamGW)***

Mexico (Fig 2):

- *Conner. L. and Hillman E. Studies Field School Gray whale photo ID catalog (1998-2010). Bahía Magdalena. 233 individuals.*
- *Catalogues from Bahía Magdalena and Bahia Almejas. Universidad Autónoma de Baja California Sur and Laguna San Ignacio Ecosystem Science Program (2012-2018). 1944 individuals.*
- *Catalog from Laguna San Ignacio. Universidad Autónoma de Baja California Sur and Laguna San Ignacio Ecosystem Science Program (2005-2019). 7151 individuals.*
- *Catalog from Laguna Ojo de Liebre. Universidad Autónoma de Baja California Sur and Laguna San Ignacio Ecosystem Science Program (2001-2003, 2013-2015). 1590 individuals.*

The comparison was done with the software "Hotspotter" (http://www.cs.rpi.edu/hotspotter/), and we did the comparisons twice: Mexican vs Russian, and Russian vs Mexican photographs. Sometimes this software cannot find the match in one way, depending on the photo-id quality.

RESULTS

The comparison among the three catalogs from Russia (316 from Sakhalin; 150 from Kamchatka) result on: 229 individuals from Sakhalin, 63 from Kamchatka, and 87 from both Sakhalin and Kamchatka, with a total of 379 photo-identified whales from Russia (Fig 3).

These 379 whales from Russia were compared to 10,685 individuals photo-identified in the wintering lagoons of Baja California, Mexico (1,590 from Laguna Ojo de Liebre; 7,151 from Laguna San Ignacio; and 1,994 from Bahia Magdalena). A total of 43 matches were found, including: 14 Sakhalin-Kamchatka-Mexico, 25 Sakhalin-Mexico, and 4 Kamchatka-Mexico.

These matches consist of 22 females, 13 males, and 8 whales of unknown sex. 13 whales (6 females, 6 males and one of unknown sex) were observed making round trips (summer-winter-summer), 11 whales (9 females and 2 males) with winter in Mexico and the following summer in Russia, and 6 whales (4 females, one males and one of unknown sex) with summer in Russia and the following winter in Mexico. The other whales matched were in non-sequential years. (Tables 1, 2 and 3)

These 43 matches, in combination with 11 previous matches, result in 54 gray whales being linked between Russia and the eastern North Pacific (Table 4).

Movements between the WNP and ENP represents 14.2% of 379 gray whales identified off Sakhalin Island and Kamchatka, Russia, between 1994 and 2016, and the 0.5% of the 10,685 gray whales identified in the breeding lagoon of the west coast of Baja California peninsula, Mexico, between 1998 and 2019.

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Figure 1. Photographic catalogues from the feeding areas in Russia

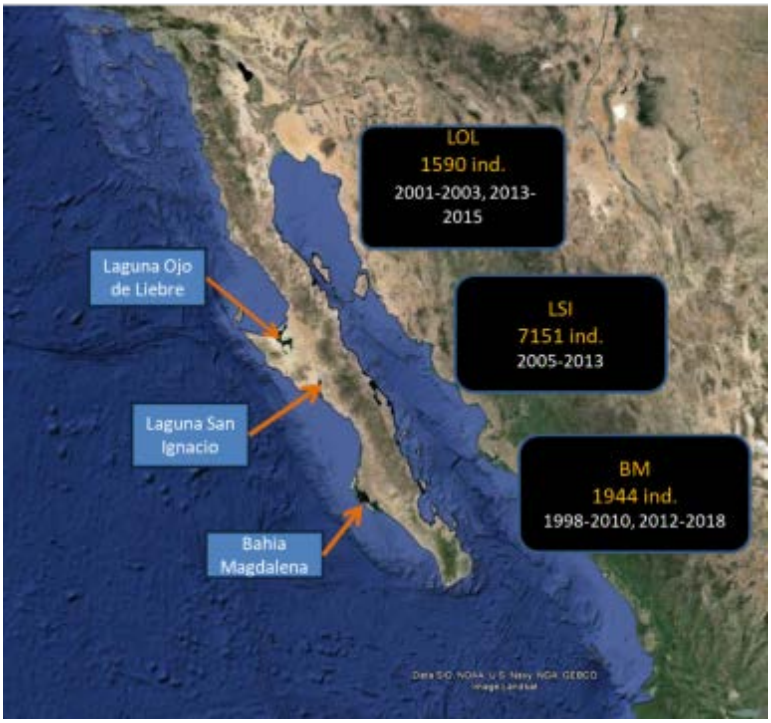

Figure 2. Photographic catalogues in the breeding grounds in Mexico

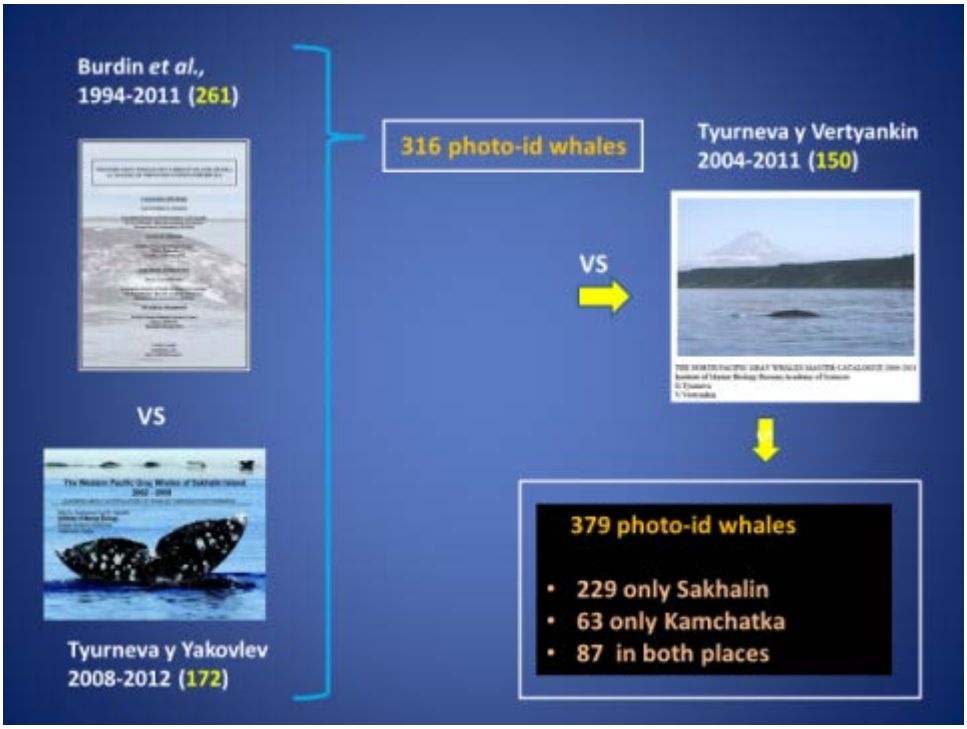

Figure 3. Catalogs comparison in Russia.

Table 1. Females

Catalog: WGW: Burdin-Weller *et al* (Sakhalin 1994-2016), KOGW: Tyurneva and Yakovlev (Sakhalin 2002-2008), KAMGW: Tyurneva and Yakovlev (Kamchatka 2004-2011). W: Whales without calf, MC: Mother with calf, S: Laguna San Ignacio, O: Laguna Ojo de Liebre, B: Bahia Magdalena. Cells with color: Whales seen in Mexico/ and Russia. Orange: Mother with calf, blue: whale without calf.

WGW	KOGW	KAMGW	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	7						W					W			MC		MC		MCS	
3	114					W	W	W			W		MCS/ MC		MC		MC			
29	28	45	W	W	W	W	W		W		W	MCS/ W	W	W						
30	8		W		MCB/ MC			W												
38	64	60	W	W	W	MC	WB/ W	W	MC			W	W	MC	W	MC		MCB/ W		
42	90	1			W	W	W				WS		W	MCS/W	W			W		MCS
63	47	13	W	W			W		W	MCS/ W		W	MC		W		W	W		MCS-MCB
76	62		MCO/ W	W	MC	W	MC	W	MC	W	W	W	MC	W	MC		W			
85	51		W	W		W	W			MC/ MCS	W	WS	W	MCS	W		MCS			
87	40	113	W		MCO/ MC	W	W			W			W							
92	15		MC	W			W	W	MC		MC		MC	W	MC		MC/ MCS			
103	119		W	W		W	W		WS				MCS/ W		W					
107	108			AC	W	W	W	W					MC		MCO/ MC		MC			
116				W													MCS			
129	77	73			W				W			W	W		WB					
135	95	8				AC									W			W		WS
206	204												W				MCS			
207	212												WS	W	MCS				MCS	
	122															MCO				

		106													MCS			MCS			
		117											MCS								

Table 2. Males.

AC: Accompanied calf, UC: Unaccompanied calf

WGW	KOGW	KAMGW	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
20	80					W	W	W		WS	W		W		W		W						
27	2		W	W	W	WO/W		W	W	W	W		W	W	W								
28	59		W	W	W		W	W	W	WS/W	W		W		W	W	W	W	W				
33	116		W	W	W	W	W	W	W	W	WB/W		W			W	W						
47	9		W	W	W	W	W	W	W		W	W		W	W	WS/W	W						
52	26		WS/W	W	W	W	W		W	W	WS	W	W	WS/W	W	W	W	W	W	W			
68	43	118	W		W			W	W	W	W						W						WS
69	113			W	W	W	W	W		WS		W	W		W	W	W	W					
82	25	132	W	W		W		W	W		W		WS		W	W		WS/W					
84	29		W	W	W	W	W	W	W	W	W	W	W	W	W		W						
91	137	42		UC					W		W	W	W		WS/W		W	W					
110	132	2				AC			W					W	WS/W		W						
112	81					AC	W	W	W	W	W	W	W	W	W		W	W	W		WS		

Table 3. Unknown

WGW	KOGW	KAMGW	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
50	100										WO					
94	57		WS	W				W								
181	172					W	W	W		W	W		W			WB
200	191							AC	WS/W							
	166					WS										
		36							WS	WS						
		114						WS								
		134						WS								

Table 4. Matches between Russia and the eastern North Pacific. (Source: 1 Weller at al. 2012; 2 Lang, 2010; 3 Mate et al. 2015; 4 not reported).

WGW	KOGW	KamGW	Sex	Place	Technique	Source
2	17		M	Pacific North West	genetic/photo	1
4	35		M	California	photo	4
16	11		M	Santa Barbara	genetic	2
32	68		M	Pacific North West	Sat tag/photo	3
35	94		M	Pacific North West	photo	1
78	41		?	Pacific North West	photo	1
102	1		?	California	photo	4
119	75	26	F	Pacific North West	photo	1
166	152	50	M	California	genetic/photo	4
		81	?	Pacific North West	photo	4
		100	?	California	photo	4