BIOLOGY LETTERS

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Research

Cite this article: Mate BR, Ilyashenko VY, Bradford AL, Vertyankin VV, Tsidulko GA, Rozhnov VV, Irvine LM. 2015 Critically endangered western gray whales migrate to the eastern North Pacific. *Biol. Lett.* **11**: 20150071.
http://dx.doi.org/10.1098/rsbl.2015.0071

Received: 29 January 2015
Accepted: 23 March 2015

Subject Areas:
behaviour

Keywords:
western gray whale, migration, satellite tracking, stock structure, endangered species, wide-ranging species

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THE ROYAL SOCIETY
PUBLISHING

Marine biology

Critically endangered western gray whales migrate to the eastern North Pacific

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Western North Pacific gray whales (WGWs), once considered extinct, are critically endangered with unknown migratory routes and reproductive areas. We attached satellite-monitored tags to seven WGWs on their primary feeding ground off Sakhalin Island, Russia, three of which subsequently migrated to regions occupied by non-endangered eastern gray whales (EGWs). A female with the longest-lasting tag visited all three major EGW reproductive areas off Baja California, Mexico, before returning to Sakhalin Island the following spring. Her 22 511 km round-trip is the longest documented mammal migration and strongly suggests that some presumed WGWs are actually EGWs foraging in areas historically attributed to WGWs. The observed migration routes provide evidence of navigational skills across open water that break the near-shore north–south migratory paradigm of EGWs. Despite evidence of genetic differentiation, these tagging data indicate that the population identity of whales off Sakhalin Island needs further evaluation.

1. Introduction

Gray whales (*Eschrichtius robustus*) occur in both the eastern and western North Pacific Ocean [1]. Considered separate populations, both were severely depleted by commercial whaling. Eastern gray whales (EGWs) have recovered and are now thought to be near carrying capacity [2]. Western gray whales (WGWs), once thought to be extinct, currently number approximately 130 individuals and are listed as critically endangered by the International Union for Conservation of Nature [3]. Historically, widely ranging along the Asian coast, contemporary WGW aggregations are known primarily from summer feeding grounds off Sakhalin Island (SI), Russia [4]. WGWs were thought to winter off southern China [4], but current winter reproductive areas and migratory corridors are unknown. Here, we use satellite-monitored tracking data to conduct the first investigation of WGW migratory corridors and breeding areas to better evaluate threats to the population. The tag data reveal extensive migrations to traditional EGW breeding habitats, calling into question the identity of the WGW stock.

2. Material and methods

The International Whaling Commission's WGW Satellite Tagging Steering Committee established tagging protocols followed throughout two expeditions [5,6]: from 1 September to 7 October 2010 and 21 August to 22 September 2011. Only adult males in good body condition [7] were considered 2010 tagging candidates. Prior to a tagging approach, we visually identified whales from unique pigmentation patterns,

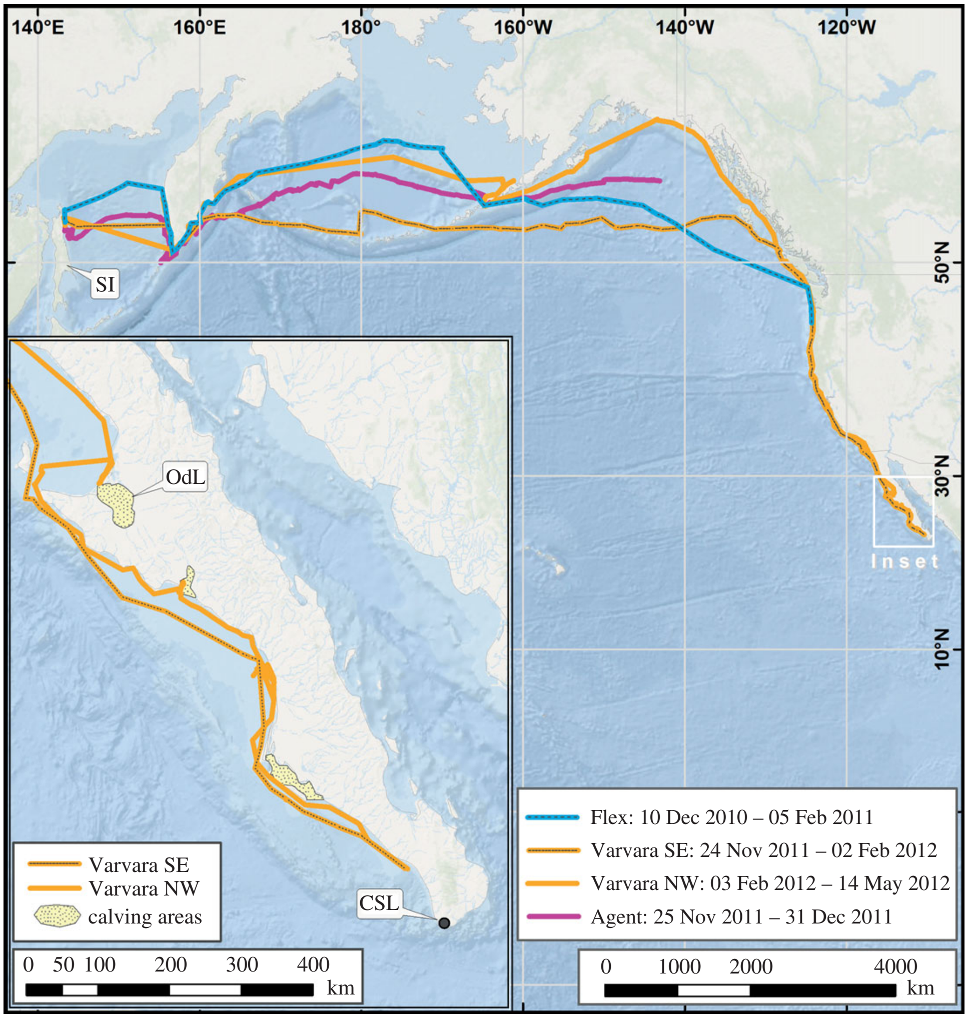

Figure 1. Routes of three western gray whales migrating from Sakhalin Island, Russia, to the eastern North Pacific. The legend depicts departure and arrival/end dates. Varvara visited all three major eastern gray whale reproductive areas off Baja California, Mexico (inset). (Online version in colour.)

using a WGW photo-identification catalogue. Sex is known for almost 80% of catalogued individuals from previous biopsy sampling, and many individuals were photographed as calves allowing age determination. Initially in 2011, only juveniles less than 6 years and females that had calves that year were not candidates. The latter criterion was later amended to allow tagging of females in good body condition that had weaned a calf.

We conducted tagging from a variety of small (less than or equal to 7 m) vessels powered by inboard diesel or four-stroke gas outboard engines, which were launched from the 50 m *Igor Maximov* support ship. We deployed tags from a distance of less than 4 m using a modified air-powered line-thrower [8]. Photos and videos were taken of tag deployments to document whale identity, tag penetration and location.

Tags consisted of a Wildlife Computers Spot-5 Argos transmitter and three Saft A-cell lithium batteries cast in an epoxy-filled stainless steel cylinder. The implantable tags were 28.2 cm long and 2.0 cm in diameter with attachments similar to those used for tagging other large whales [8]. To reduce the likelihood of infections, we partially coated tags with 2.5 g of Gentamycin sulfate, a broad-spectrum antibiotic, in a bio-soluble methacrylate for long-term release of the antibiotic into the tag site. Tags were sealed in gas-permeable bags for 12 h of ethylene-oxide sterilization.

Tags were programmed to transmit during four 1 h periods daily, coinciding with good satellite coverage over a broad range of possible North Pacific migration paths and destinations. Service Argos calculated locations with estimated accuracy based on the timing and number of transmissions received during individual satellite passes [9]. Three of seven location classifications have specific accuracies from less than 150 m (LC 3) to approximately 1 km (LC 1) [10]. We filtered unreasonable data by removing poor quality locations and limiting swim speeds to less than 10 km h^{-1} [8]. Distances travelled and swim speeds were calculated using ArcGIS 10.1 and are minimum estimates calculated from straight lines between consecutive locations.

3. Results

Three of seven tagged adult WGWs off SI during the two expeditions transmitted long enough to document migration away from SI after 68–89 days of near-shore movements: a male (13 year old 'Flex') in 2010 and two females (6 year old 'Agent' and 9 year old 'Varvara') in 2011. Each whale took different outbound routes across the Bering Sea, through the Aleutian Island chain, and across the Gulf of Alaska (figure 1), travelling an average of 6.2 km h^{-1} (table 1).

Tags attached to Flex and Varvara functioned long enough to document the whales entering the EGW southbound migration corridor. The last received location from Flex was 5 February 2011 off Lincoln City, OR, USA, after

Table 1. Tracking summary information of three western gray whales instrumented with satellite-monitored radio tags off Sakhalin Island, Russia.

whale	tracking segment	start date	end date	distance km (nmi)	days	speed km h^{-1} (nmi h^{-1})
Flex	feeding	4 Oct 2010	10 Dec 2010	938 (506)	68.0	0.6 (0.31)
Agent		28 Aug 2011	24 Nov 2011	2600 (1403)	88.7	1.2 (0.66)
Varvara		31 Aug 2011	24 Nov 2011	1280 (691)	84.2	0.6 (0.34)
Flex	southeast migration	10 Dec 2010	5 Feb 2011	7661 (4137)	56.1	5.7 (3.1)
Agent		24 Nov 2011	31 Dec 2011	5464 (2950)	36.3	6.3 (3.4)
Varvara		24 Nov 2011	2 Feb 2012	10 880 (5875)	69.5	6.5 (3.5)
Varvara	reproductive areas (end of migration—Ojo de Liebre)	2 Feb 2012	26 Feb 2012	1147 (619)	24.0	2.0 (1.1)
Varvara	northwest migration	26 Feb 2012	14 May 2012	10 484 (5661)	78.8	5.5 (3.0)

travelling at least 7661 km. Flex was re-sighted in good body condition during the 2011 SI tagging expedition. Varvara departed SI on 24 November 2011, 17 days earlier than Flex, and passed Lincoln City on 8 January 2012, during the peak of the EGW southern migration. She travelled 10 880 km south to within 103 km of Cabo San Lucas, Baja California Sur, Mexico (CSL), on 2 February 2012, 69.5 days after departing SI (figure 1). Varvara spent 42 days off Baja California, Mexico including 32 days of generally northward movement, passing all three major EGW reproductive areas [11]. From CSL to the northernmost breeding area at Laguna Ojo de Liebre (OdL), Varvara travelled 1147 km, averaging 2.0 km h^{-1} (figure 1, inset). Her 10 484 km migration from OdL back to SI followed a different route from her eastward trip, crossing the eastern Bering Sea near the southerly face of the retreating ice edge and took 79 days, ending on 14 May 2012. Some slower movement segments were recorded along the north side of the Alaska Peninsula and while crossing the Bering Sea. The overall average speed for her spring migration was 5.5 km h^{-1}. The entire 22 511 km round-trip migration lasted 172 days.

4. Discussion

Varvara's 10 880 km autumn migration constitutes the longest recorded distance travelled during a mammal migration [12]. The linear travel segments over deep water made by tagged whales in this study indicate excellent navigation abilities [13] in sharp contrast with the slower-paced, near-shore and shallow-water migration of EGWs along North America [11]. Varvara's near-shore spring migration route until reaching the Bering Sea was typical of EGWs. However, her more northerly westward route across the Bering Sea indicates she was not obliged to return by the same specific route of her eastward migration, further reinforcing a strong ability to navigate. The occasional slow movement segments observed along the Alaska Peninsula and during the western crossing of the Bering Sea may indicate opportunistic feeding.

New-born gray whale calves follow their mothers during the spring migration to the mother's foraging area, where weaning occurs in late summer [11]. Juvenile and adult WGWs first identified as calves off SI have returned there to feed [4], indicating a very strong allegiance to their mother's migratory destination. Similar natal philopatry has been observed in humpback whale calves, in the North Pacific and elsewhere, returning to their mothers' migratory destinations [14]. Thus, the three migratory tracks documented by this study strongly suggest the tagged whales were born in EGW reproductive areas.

The utilization of feeding areas in the western North Pacific by whales that winter in the eastern North Pacific raises questions about the present status of WGWs. Since these tracking data became available, a preliminary comparison between WGW and EGW photo-ID catalogues discovered 10 WGWs have been photographed near British Columbia and in San Ignacio Lagoon, Baja California, Mexico [15]. Those sightings, combined with two genetic matches, further strengthen the linkage between these two presumed stocks and question whether the present WGWs came from the population previously thought to be extinct or from recovered EGWs with an expanded range [16].

Recent evidence that 'true' WGWs (i.e. whales breeding in Asian waters) are extant includes: four fishing net deaths off the Pacific coast of Japan between 2005 and 2007, including a yearling first observed as a calf off SI [17]; a gray whale stranded in November 2011 off the Fujian Province in southern China [15], adjacent to the region speculated to serve as a reproductive area for WGWs [17]; and a March 2012 live sighting in Mikawa Bay, Japan [15]. EGWs have been sighted well outside their established ranges [18], so it is possible that WGWs are extinct and these western North Pacific sightings represent a wider EGW foraging range, and more variable migratory timing than is presently thought. It is also possible that the SI region is a foraging area where EGWs and a smaller-than-estimated 'true' WGW population co-mingle, with the latter group making a southerly migration along the Asian coast to an as yet undiscovered breeding area or that spatial and temporal concentrations of whales from SI, during their occupancy in the regular winter range of EGWs, allow them to maintain genetic separation from other EGWs. Overall, the tagging and photo-ID data indicate that the population identity of whales off SI needs further evaluation.

Ethics statement. The procedures used in this study were reviewed and approved by the International Whaling Commission's Western Gray Whale Satellite Tagging Steering Committee and the Oregon State University Institutional Animal Care and Use Committee.

Data accessibility. Data for this study are archived at the International Whaling Commission (http://iwc.int/data-availability) and at the Oregon State University Marine Mammal Institute.

Acknowledgements. We are grateful for multiple Russian permits that authorized this research. We thank C. Hayslip, T. Follett, and the scientists and crew aboard the *Igor Maximov* for assistance. We appreciate valuable scientific advice offered by the IWC WGW Satellite Tagging Steering Committee and individual life history data for tagged whales provided by A. Burdin.

Funding statement. Contracting for this research was undertaken by the International Whaling Commission with funds provided by Exxon Neftegas Limited and Sakhalin Energy Investment Company, as well as the Office of Naval Research for data recovery costs and donors to the OSU Marine Mammal Institute.

Author contributions. B.M. participated in the conception, design and coordination of the study, participated in field work and drafted the manuscript. V.I. participated in the conception, design and coordination of the study and reviewed the manuscript. A.B. participated in the design of the study, participated in field work and reviewed the manuscript. V.V. led the field work. G.T. participated in the design of the study and participated in the field work. V.R. participated in the conception, design and coordination of the study and reviewed the manuscript. L.I. participated in the field work and reviewed the manuscript. All authors gave final approval of the version to be published.

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