A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag

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ABSTRACT

A gray whale (*Eschrichtius robustus*) tracked with an Argos satellite-monitored radio tag travelled 1,794km during the northbound migration season from San Ignacio Lagoon (SIL), Baja California Sur, Mexico to north of San Francisco from 8–23 February 1996. The migration route was predominately nearshore and in water < 100m deep, with 75% of the Argos-acquired locations averaging 7.3 ± 1.22km from shore. Distances > 20km from shore and water depths > 100m were encountered only when the whale crossed Vizcaino Bay or through the Channel Islands. During migration, the whale maintained an average speed of 5.6km h^{-1}, suggesting a coastal migration of 49 days from SIL to the Bering Sea.

INTRODUCTION

Scammon (1874) was the first to recognise gray whales as long-distance migrants when he found Alaskan hunting implements in gray whales harvested in Mexico. Gray whales feed predominately in the Bering Sea during the summer and autumn and migrate in winter to selected Pacific lagoons in Baja Mexico to breed and calve (Rice and Wolman, 1971; Swartz, 1986). Their reputation as a nearshore species during these migrations has enabled researchers using shore-based counts during daylight hours to examine the numbers and timing of both the northbound and southbound migrations (Reilly, 1984; Buckland and Breiwick, 2002). While a few estimates of travel speeds have been made for individual whales over short distances (< 10km) from shore-based theodolite measurements (Perryman *et al.*, 1999), or by following VHF radio-tagged individuals by boat for up to a few hours (Swartz *et al.*, 1987), little has been determined about the route and speed of individuals over longer distances. This study used a satellite-monitored radio tag to identify the route and speed of a gray whale migrating north from the winter breeding and calving area in San Ignacio Lagoon, Baja California Sur, Mexico.

METHODS

On 8 February 1996, a lone adult gray whale of unknown sex (10m long) was tagged in San Ignacio Lagoon (26°43'N, 113°16'W) with an Argos (satellite-monitored) radio tag. The Argos Data Collection and Location Service (ADCLS) was used to acquire whale locations based on Doppler-shifted messages received by the polar-orbiting NOAA TIROS-N weather satellites (Argos, 1984). The tag, attachments and method of deployment were identical to those used on humpback whales (Mate *et al.*, 1998) and blue whales (Mate *et al.*, 1999).

The tag was applied to the whale's dorsum 34cm to the left of the midline and about 4m behind the blowhole. The tag was programmed to transmit every 20 seconds when its conductivity switch was above water during alternate 6h periods (0900 to 1500, and 2100 to 0300 GMT).

Distances and speeds were calculated along the straight line between consecutive whale locations, except for a few segments, which were modified to deviate around coastal promontories whenever straight lines crossed them. All locations were subjected to editing criteria, which allowed an 11.5km error radius around each location and eliminated those locations which resulted in speeds > 10km h^{-1}. Experiments (Mate *et al.*, 1997 and Mate *et al.*, 1999), determined that an 11.5km error radius would encompass two standard deviations (95%) of all Argos Class 0 locations from their true location. Means are reported with standard errors.

RESULTS

A total of 41 Argos locations were recorded during the next 14.5 days, 36 of which (Fig. 1) met the editing criteria (2.5 locations per day). The whale stayed in San Ignacio Lagoon and the adjoining nearshore region of Bahía Ballenas for only two days before migrating north. There was no evidence that the whale stopped at Laguna Ojo de Liebre, another breeding and calving area *en route*, as it moved north.

Overall, the whale travelled at least 1,794km to an area north of San Francisco, California (38°17'N, 123°10'W) at a minimum average speed of 5.2km h^{-1}. After leaving Bahía Ballenas, the overall average distance travelled per day was 134km (5.6km h^{-1}), while the average of speeds calculated from distances and times between locations was 5.7 ± 0.3km h^{-1} ($n = 31$). There was no significant difference found between average speeds of 5.6 ± 5.3km h^{-1} ($n = 18$) for night and 5.7 ± 2.6km h^{-1} ($n = 19$) for the day (t-test, $p = 0.94$).

Locations were an average of 21 ± 4.6km ($n = 36$) from shore. However, only nine locations were > 20km from shore. The latter occurred as the whale crossed Vizcaino Bay ($n = 3$) and through the California Channel Islands ($n = 6$). The average distance of the other 27 locations from shore

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was 7.3 + 1.22 km. Six of the locations in the Channel Island area were in water between 100 and 1,800m deep ($\overline{X}$ = 948 ± 310.8m). The remaining 30 locations occurred in water < 100m deep ($\overline{X}$ = 39 ± 4.9m).

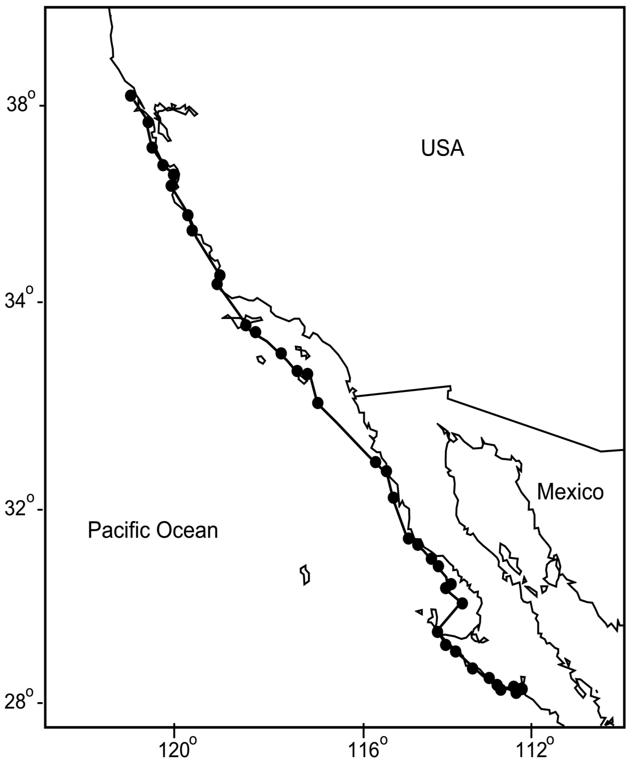

Fig. 1. The track of a satellite-monitored radio-tagged gray whale as it migrated north from San Ignacio Lagoon to central California between 8 and 23 February 1996.

DISCUSSION

The gray whale is the only baleen whale with a conspicuously nearshore migration along much of its route, but how it navigates is still uncertain. The tagged whale in this study did not follow a specific depth contour or maintain a specific distance from shore. We speculate that gray whales may migrate in part by passively listening to simple acoustic cues. By merely keeping the sound of the surf to their right side, northbound migrants from Mexico could reach Unimak Pass, Alaska (the eastern end of the Aleutian Islands), to enter the population's main feeding area, the shallow Bering Sea Shelf. Rice and Wolman (1971) described gray whales taking the most direct route when crossing bights or coastal indentations, such as the Channel Islands and Vizcaino Bay. Listening to surf sounds of the outer California Channel Islands may also explain how some gray whales navigate through this area. There has been speculation that gray whales in southern California now migrate farther offshore than in the past, due to increased harassment from nearshore vessel noise. It is not possible to address that issue in this paper, but we suggest a route between the outer Channel Islands is direct and makes good energetic sense regardless of human activities. During the spring migration northward in 2000 and 2001, gray whales were observed in the western Santa Barbara Channel occasionally feeding on surface swarms of krill, alongside feeding blue and humpback whales (Le Boeuf *et al.*, 2000). Krill aggregations are not common nearshore in the Southern California Bight, but are quite regular along the northwestern parts of the westerly Channel Islands (Fiedler *et al.*, 1998).

The northward migration of gray whales is divided into two parts: single animals (males and adult females without calves) depart Mexico first, followed 4-6 weeks later by females with calves (Herzing and Mate, 1984; Poole, 1984). The tagged whale's departure from the lagoon in early February is consistent with the mid-February decline of single whales in San Ignacio Lagoon observed by Jones and Swartz (1984).

The distances between locations reported here are minimum estimates of the actual distance travelled and thus also minimum estimates of the whale's swimming speed. The average migration speed of this animal (5.6km h^{-1}) is faster than the speed of a gray whale tagged with a VHF radio transmitter in 1979 moving from San Diego to Coos Bay, Oregon (3.5km h^{-1}) but very close to its average speed of 5.3km h^{-1} (assuming a nearshore route) from Oregon to Unimak Pass, Alaska (Mate and Harvey, 1984). The speed of the northbound tagged whale is only slightly less than the 6km h^{-1} estimated for southbound whales tracked with VHF radio tags for up to 13.5h and 81k off the central California coast (Swartz *et al.*, 1987). If the satellite-monitored whale had maintained its average speed as it continued north, it would have reached the central Oregon coast by 1 March. The northbound migration in Oregon starts in mid-February, and 25% of the single whale population has typically passed north by 1 March (Herzing and Mate, 1984). Presuming a coastal route, the tagged whale could have reached Unimak Pass (3,700km from Oregon) by 28 March (49 days after tagging), when early migrant gray whales are usually observed (Rugh, 1984). Whales could save time and energy if they cut across the Gulf of Alaska, but it is not known if this occurs and seems doubtful from shore-based observations in Alaska.

The data suggest a consistent migration speed. The motivation, and hence the speed, of individual whales to get to the feeding grounds might differ depending upon their age, sex, reproductive status and energy stores. While some migrant whales stop to mate or feed for short periods along the California and Oregon coasts, most do not (Herzing and Mate, 1984). Observations of feeding are not common along the Oregon coast until May, well after the March/April peak of single migrants (Sumich, 1986).

This is the first detailed description of the route and rate of speed for an individual gray whale during its northbound migration. The data support the long-standing belief that gray whales are nearshore migrators. Since they travel so close to shore, the population may be at some risk from catastrophic anthropogenic events (such as an *Exxon Valdez*-sized oil spill) along their migration route. Thus, whilst eastern gray whales have fully recovered from exploitation (IWC, 2003), they are still potentially at risk from industrial developments and accidents. However, as gray whales are no longer listed under the United States Endangered Species Act (ESA), developers do not presently need to take gray whales into consideration when drafting Environmental Impact Statements (EIS) for proposed activities in gray whale habitat. It may be appropriate for a mechanism to be developed (e.g. a new category of 'in jeopardy' be added to the existing ESA terminology of 'threatened' and 'endangered'), which would require developers to address special risks associated with gray whales (or other 'numerically recovered' species) in an EIS describing a proposed project, when significant risk to the entire population is feasible.

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