The lost years: long-term movement of a maturing loggerhead turtle in the Northern Pacific Ocean

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Loggerheads are a highly migratory circumglobal species. Analysis of mitochondrial DNA (mtDNA) has shown that loggerheads make transoceanic movements in both the Atlantic and the Pacific oceans (Bowen et al. 1995, Bolten et al. 1998). The life history of loggerheads from hatchlings on nesting beaches to their return to coastal benthic foraging habitats has been known as the "lost year" (Carr 1982). The growth rates of Atlantic and Pacific pelagic stage loggerheads suggest that a "lost decade" is more likely (Bolten and Balazs 1995, Zug et al. 1995). Recent satellite tracking of loggerheads incidentally caught by commercial fishermen in the Hawaii-based longline fishery have indicated that pelagic juvenile and sub-adult loggerheads in the North Pacific move along temperature isotherms of frontal zones swimming against weak geostrophic currents based on tracks from 1-10 months in duration (Balazs et al. 2000, Polovina et al. 2000). In this paper, we examine the movement of an exceptional sub-adult loggerhead over a 20-month period in relation to frontal zones, temperature, and currents.

In March of 2000, a 60-cm straight carapace length (SCL) sub-adult loggerhead was incidentally captured in the Hawaii-based commercial longline fishery. This turtle was cataloged as deeply hooked hence the hook could not be safely removed from the turtle. A Telonics ST-18 satellite transmitter (ID 22150), with a duty cycle of 12 hours on and 48 hours off, was attached to the carapace by trained National Marine Fisheries Service observers using fiberglass cloth and polyester resin. Positional data were received through the Argos system. Distance traveled was computed using a great-circle formula for distance with LC 0, 1, 2 or 3 positions (150->1000m accuracy). One position from each 12-hour period was used, roughly one position every three days. Speed of travel was computed using the calculated distance data and the time between each position used and speeds were averaged. Geostrophic currents were computed from satellite altimetry data from TOPEX/Poseidon with a 10-day and 0.5 degree of latitude and longitude resolution. Sea surface temperature (SST) data were multichannel SST (MCSST) from the GODAE server. A composite of daily SST data were created for the month of September 2001.

Loggerhead 22150 was followed via satellite telemetry for nearly 20 months from March 2000 to October 2001 across the Central North Pacific Ocean (Fig. 1). The turtle covered a distance of approximately 13,900 km, traveling at a mean speed of 1.0 km/hr. Seven months were spent traveling near the 17°C SST isotherm, within the Subtropical Frontal Zone in the Central North Pacific Ocean. During March - June 2000, the turtle traveled at an average speed of 0.8 km/hr, likely swimming against a weak geostrophic current. Loggerhead 22150 exhibited a north-south movement seen in Fig. 1 that followed the seasonal north-south movement of the 17°C SST. In July and August 2000, a month was spent in an eddy around 165°W as the turtle traveled at an average speed of 1.0 km/hr before continuing to move westward. Another month was spent in a meander around 170° W during October-November before continuing west (Polovina et al., in press). In January 2001, after a total of 10 months of travel, the turtle reached the area of the Emperor Seamounts and stopped its direct westward travel. Here, 22150 spent an extended period traveling within eddies created by the Kurishiro Extension Current (KEC) around 170°E and 165°E (Fig. 2, Polovina et al., in press). The average speed of travel for January to September 2001 was 1.0 km/hr. During this time increases in speed were seen when the turtle was traveling eastward with the currents (average turtle speeds of up to 2.6 km/hr). The turtle also continued a seasonal north-south movement and was found near the 20°C SST isotherm during the end of August and beginning of September (Fig. 3a). During the latter part of September 2001, the turtle started to again move on the edge of an eddy (Fig. 3b). In October of 2001, loggerhead 22150 moved into a direct stream of the KEC and moved eastward for about a week before traveling directly northward continuing to move within the eddy created by the KEC. During the eastward movement in the KEC, travel speeds up to 3.0 km/hr were attained; the current accounted for 1.8 km/hr of this with the turtle swimming at a rate of 1.2 km/hr.

The 10 months 22150 spent west of the Emperor Seamounts suggests that this area is an important foraging region for pelagic juvenile and sub-adult loggerheads. Zug et al. (1995) skeletochronology of Pacific loggerheads suggests that 40-cm SCL loggerheads are nearly 8 years of age and evidence is accumulating that some loggerheads in the Pacific are mainly pelagic until they become sexually mature and return to their nesting beaches, after which the decades old adult loggerheads most likely start a benthic existence. This hypothesis is supported by the track length of this 60-cm SCL loggerhead which spanned 20 months, and also by data compiled from 1994-2000 in the Hawaii-based commercial longline fisheries in which relatively few large adult-sized loggerheads were captured (N=163, mean 57.7 ± 11.5 cm, range 38-90 cm SCL). More research involving tracking pelagic movements over extended periods of time will help to better understand loggerhead behavior, ecology, and life history to protect this declining species in the Pacific.

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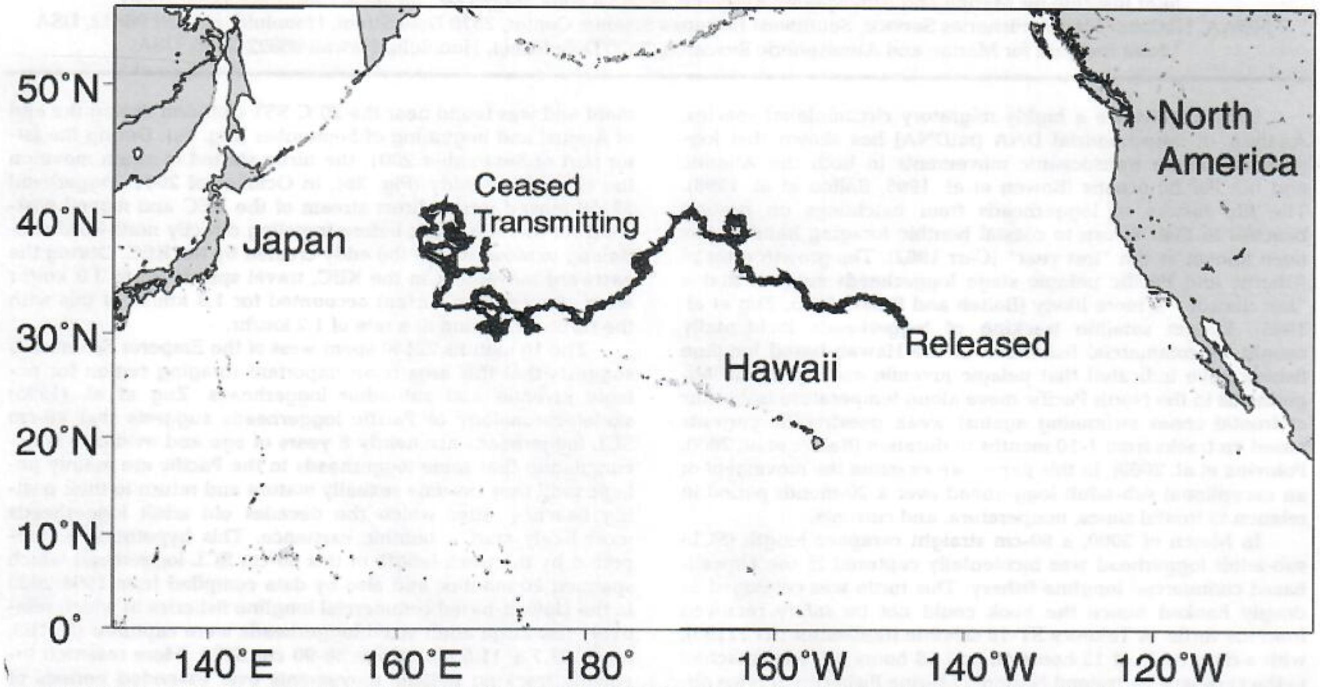

Fig. 1. Movement of 60 cm loggerhead 22150 as it traveled 13864 km across the Central North Pacific Ocean for 20 months during March 2000 to October 2001, from 31°N 146°W to 38°N 169°E, at an average speed of 1.0 km/hr.

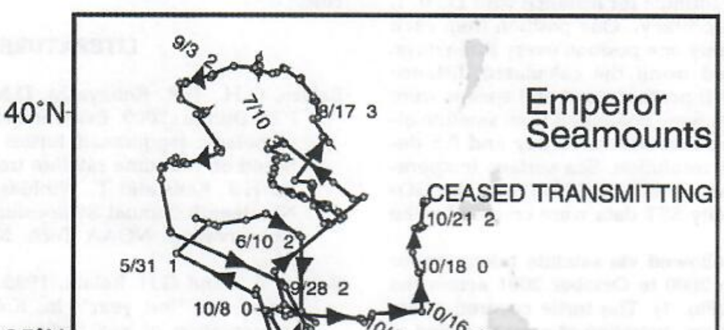

Fig. 2. Movement of loggerhead 22150 within eddies created by the Kurishiro Extension Current. Small arrows on track show direction of travel for loggerhead 22150 and large arrows show the direction and area of the Kurishiro Extension Current.

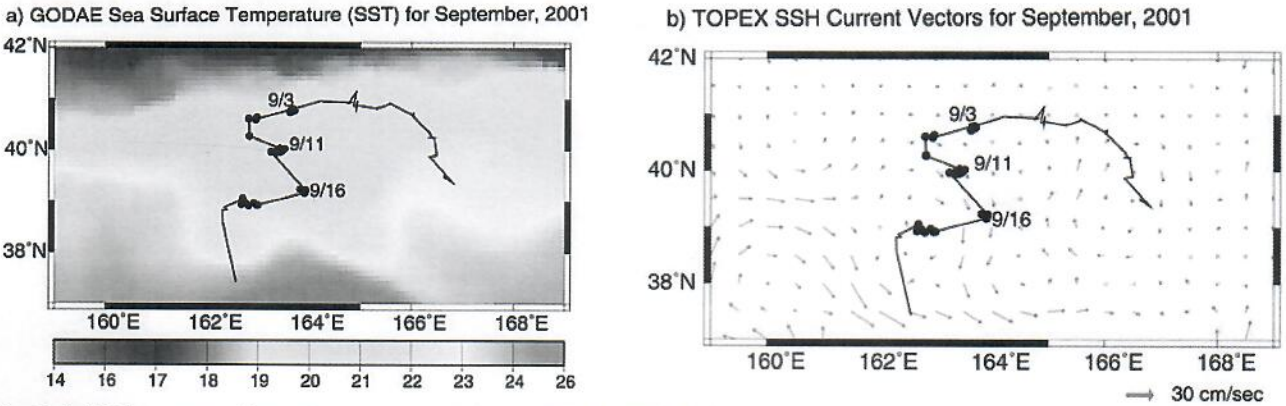

Fig. 3. (left) Movement of loggerhead 22150 during August-September 2001 together with sea surface temperature (SST) during the month of September 2001. (right) Movement of loggerhead 22150 during August-September 2001, together with geostrophic currents during 9-16 September 2001. Large circles on the track lines indicate position of the turtle during the same period for which the geostrophic currents were calculated. Arrows on the track lines show turtle movement direction.

A long journey: a Kemp's ridley sea turtle (*Lepidochelys kempii*) visits the Mediterranean Sea

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INTRODUCTION

The Kemp's ridley (*Lepidochelys kempii*) is the most endangered sea turtle species (Márquez 1994). In the second half of the 20th century the nesting population decreased from some 50,000 individuals to less than 5,000, with only a few hundred turtles nesting each season. However, a slow recovery of the nesting population has been detected in the last decade (Garundo Dionate et al. 2000). Nesting areas of this species are restricted to the Gulf of Mexico, mainly in Rancho Nuevo, Mexico, where mass nesting ("arribadas") occurs (Márquez 1994). Sporadic nesting also occurs in Veracruz (Mexico), and in the U.S. coast, particularly in Padre Island, Texas (Manzella and Williams 1992) and along the Florida coast (Johnson et al. 2000). Feeding grounds and nursery and developmental areas are distributed principally along the Gulf of Mexico and the Atlantic coast of the U.S. (Manzella et al. 1988). There is evidence of transoceanic migrations based on several recoveries of tagged turtles in the Atlantic coasts of Western Europe and Morocco (e.g., Manzella et al. 1988). There is even a report of *L. kempii* in the Mediterranean, off the island of Malta (central Mediterranean) (Brongersma and Carr 1983), which indicates that Kemp's ridleys may enter in the Western Mediterranean basin through the Strait of Gibraltar.

RESULTS

On October 15th 2001, fishermen brought a sea turtle to the Municipal Aquarium of the town of Santa Pola (38°12'N/0°34'W), Alicante (Spain). The turtle had been captured in a gill-net deployed from a small boat. The turtle was in good health condition. The fishermen did not provide the coordinates of capture, but said that it occurred in the coastal waters around Santa Pola, between the island of Tabarca (38°10'N/0°29'W) and the coastal village of Guardamar del Segura (38°06'N/0°39'W). We identified the turtle as L. *kempii* based on the presence of a small pore near the rear margin of the inframarginal scutes the coloration of the skin, the circular shape of the carapace, the presence of five pairs of coastal scutes, and the arrangement of head scales. Standard biometric variables are shown in Table 1. The age of the turtle was estimated to be 3-4 years based on carapace length (CL) measurements, following growth models derived from skeletochronological analysis (Chaloupka and Zug 1997, Zug et al. 1996). The specimen had only one pair of claws in its front flippers, instead of two as is typical for the species (Pritchard and Mortimer 1999). This reduction in the number of claws has also been observed in some adults, and has been interpreted as the result of a secondary loss (Pritchard and Mortimer 1999). Genetic analysis of mitochondrial (mt) DNA markers has been used within the context of phylogeographic studies of sea turtles worldwide. A small skin biopsy was taken from the dorsal side of the anterior left flipper and stored in 96% ethanol. DNA was subsequently extracted using a standard phenol:chloroform protocol (Sambrook et al. 1989) and preserved in TE buffer at -20°C. Polymerase Chain Reaction (PCR) was used to amplify a 460 base pair fragment of the mitochondrial (mt) DNA control region comparable to that analysed by Bowen et al. (1998), using primers LTCM2 (Encalada et al. 1996), HDCM1 (Allard et al. 1994), LTCM1.1 and HDCM1.1 (A. Formia unpubl. data). PCR products were double-sequenced with the ABI Prism Big Dye Terminator kit V.2 and analysed with an ABI 3100 sequencer (Applied Biosystems). Sequences were aligned and edited using Sequencher 3.1.2 (Gene Codes Corporation). The sequence obtained perfectly matched haplotype D previously observed in 5 individuals stranded on the Atlantic coast of the U. S. and Gulf of Mexico (Bowen et al. 1998) (GenBank accession number AF051777). However, since the control region haplotype distribution of Kemp's ridleys in nesting and oceanic habitats is still unknown, we cannot speculate on the origin of this individual, beyond the fact that its mt DNA was inherited from a female Kemp's ridley. Depending on its natal origin (Rancho Nuevo, South Texas or Florida), this specimen would have navigated a minimum distance of between 8,500 and 10,000 km. The actual distance

NOAA Technical Memorandum NMFS-SEFSC-503

PROCEEDINGS OF THE TWENTY-SECOND ANNUAL SYMPOSIUM ON SEA TURTLE BIOLOGY AND CONSERVATION

Miami . USA

4 to 7 April 2002
Miami, Florida, USA

Compiled by:
Jeffrey A. Seminoff

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
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August 2003