Title

Turtle Tales: A closer look at the life history of green sea turtles in Urban Southern California Habitats

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Publication Date

2023-06-01

A Closer Look at the Life History of Green Sea Turtles in Urban Southern California Habitats

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Executive Summary

Information on habitat use among highly migratory green sea turtles is especially important for effective conservation – especially in urban habitats. However, long migration distances between sea turtle feeding grounds and nesting beaches make these long-lived marine reptiles difficult to study. Combining techniques, such as skeletochronology with stable isotope values from annual bone growth layers, can help determine life history traits and movement patterns of sea turtles. For one component of my capstone project, I helped members of the Marine Turtle Ecology and Assessment Program at the NOAA Southwest Fisheries Science Center take inventory of the East Pacific (EP) population of green turtles in San Diego Bay. Along with field work, I worked in NOAA's Marine Turtle Demography Laboratory prepping samples for stable isotope analysis. Finally, I analyzed data collected by NOAA to evaluate if trace elements found in bones, such as barium (Ba), magnesium (Mg), and strontium (Sr), could also be used to reconstruct transitions between oceanic and coastal life stages in sea turtles. For my capstone deliverable, I created a detailed, multi-year life history story of a few well-studied EP green sea turtles to increase awareness, and to further improve management and conservation efforts.

Introduction

Healthy oceans and seas are essential to human existence and life on earth. Scientists have identified sea turtles as bioindicators, animals that can be used to assess the overall health of the marine environment.[1] Much is still unknown about these long-lived, ocean travelers. They require air to breathe, and land to lay their eggs, but most of their lives are spent underwater. Which may be why many people don't know that sea turtles live in the waters around San Diego.

Sea turtles have been present in human cultural traditions and mythology for millennia and many cultures have revered these charismatic animals as celestial beings with supernatural powers.[2] One of seven turtle species found in the ocean today, the green turtle, *Chelonia mydas*, inhabits tropical and subtropical waters around the globe.[3] Wind-driven upwelling along coastal regions of the eastern Pacific Ocean creates highly productive waters that are used as foraging hotspots for green turtles and numerous other marine species. However, long

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[1] Savoca, M.S., Kuhn, S., Sun, C., Avery-Gomm, S., Choy, C.A., Dudas, S., Hong, S.H., Hyrenbach, K.D., Li, T., Ng, C.K., Provencher, J.F., Lynch, J.M. 2022 Towards a North Pacific Ocean long-term monitoring program for plastic pollution: A review and recommendations for plastic ingestion bioindicators, Environmental Pollution, Volume 310, 2022, 119861, ISSN 0269-7491, https://doi.org/10.1016/j.envpol.2022.119861.

[2] Frazier, J. 2003. Prehistoric and ancient historic interactions between humans and marine turtles, in Lutz, P., Musick, J. & Wyneaken, J. (ed.) The biology of sea turtles, Vol. 2: 1–38. Boca Raton (FL): CRC

[3] Seminoff, J.A., C.D. Allen, G.H. Balazs, P.H. Dutton, T. Eguchi, H.L. Haas, S.A. Hargrove, M.P. Jensen, D.L. Klemm, A.M. Lauritsen, S.L. MacPherson, P. Opay, E.E. Possardt, S.L. Pultz, E.E. Seney, K.S. Van Houtan, R.S. Waples. 2015. Status Review of the Green Turtle (Chelonia mydas) Under the U.S. Endangered Species Act. NOAA Technical Memorandum, NOAANMFS-SWFSC-539. 571pp.)

migration distances between feeding grounds and nesting beaches make these sea turtles difficult to study.

Green turtles have a complex life history, exploiting multiple habitats throughout their lives. After hatching, their life history begins with an omnivorous juvenile oceanic stage, feeding on pelagic invertebrates (e.g. jellies, pyrosomes, gastropods, cephalopods) and small fish.[4] As they age, green turtles exhibit a developmental shift and recruit to nearshore habitats where they often become resident foragers, consuming predominately seagrasses, algae, and benthic invertebrates.

The green turtle has been subject to a long history of human exploitation.[5] Overharvesting, habitat loss, disease, pollution, and fishing have significantly reduced the numbers of green sea turtles over the past century. East Pacific (EP) green sea turtles, commonly found from southern California to Central America, are currently listed as threatened under the Endangered Species Act (ESA) (81 Federal Register 20058; April 16, 2016). NOAA Fisheries and the U.S. Fish and Wildlife Service share jurisdiction for the conservation and management of East Pacific green turtles under the ESA, and recent assessment show their numbers are increasing.[6] For the continued conservation of these animals, knowledge of basic life history parameters, including habitat use, reproduction, life span, and growth rates, is critical.[7]

Background/Problem Statement

Understanding habitat use among highly migratory green sea turtles is especially important for effective conservation but is challenging to determine. Originating from nesting beaches in Mexico, the East Pacific (EP) population of green turtles comes to California to take advantage of the productive coastal ecosystems, which are rich in seagrass, algae, and invertebrates.[8] Conservation efforts, especially those at nesting beaches, along with campaigns against the harvest and trade of turtle products, have helped some populations of green turtles gradually recover. Today, green turtles can be found in many of the bays, lagoons, and coastal inlets of

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[4] Arthur, K. E., M. C. Boyle, and C. J. Limpus. 2008. "Ontogenetic Changes in Diet and Habitat Use in Green Sea Turtle (Chelonia Mydas) Life History." Marine Ecology Progress Series. https://doi.org/10.3354/meps07440.
[5] Witzell, W. N. 1994. "The Origin, Evolution, and Demise of the U.S. Sea Turtle Fisheries." Marine Fisheries Review. https://aquadocs.org/handle/1834/26471.
[6] Seminoff, J.A., C.D. Allen, G.H. Balazs, P.H. Dutton, T. Eguchi, H.L. Haas, S.A. Hargrove, M.P. Jensen, D.L. Klemm, A.M. Lauritsen, S.L. MacPherson, P. Opay, E.E. Possardt, S.L. Pultz, E.E. Seney, K.S. Van Houtan, R.S. Waples. 2015. Status Review of the Green Turtle (Chelonia mydas) Under the U.S. Endangered Species Act. NOAA Technical Memorandum, NOAANMFS-SWFSC-539. 571pp.)
[7] NRC – National Research Council. Assessment of sea-turtle status and trends: integrating demography and abundance. National Academies Press. 2010. http://doi.org/10,17226/12889
[8] MacDonald, B. D., Lewison, R.L., Madrak, S.V., Seminoff, J.A., Eguchi, T.E. 2012. Home ranges of East Pacific green turtles, *Chelonia mydas*, in a highly urbanized temperate foraging ground. Marine Ecology Progress Series 461: 211-221.

Southern California. How do we learn more about these turtles to ensure their continued conservation?

Mark and recapture studies, satellite telemetry, and genetic tagging studies have been valuable, but they remain limited. New methods for determining habitat use and foraging patterns of long-lived marine species are shedding new light on the complex life history of green sea turtles.

Skeletochronology is the study of growth layers in bones. Like rings on a tree, sequential layers of bone are deposited over a turtle's lifetime. By analyzing the humerus bone taken from dead sea turtles found stranded or as by-catch, it is possible to determine age, growth, and maturity. Annual growth rings can also give clues about an animals' diet and habitat when the bone chemistry is explored further. The dense, cortical bone, portion of the humerus, does not have regular cellular turnover so stable isotope analysis of individual growth rings reflect the turtle's diet during the time period from when that bone layer was produced. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values provide insight into green turtle movement patterns as these values reflect the underlying nitrogen and carbon cycling processes that can be indicative of specific marine regions and prey.[9] This "skeleto+iso" data makes it is possible to detect the timing (age and size) of developmental and broad-scale patterns of habitat use in highly migratory sea turtles.[10]

Understanding the life history traits and movement patterns of green sea turtles are top priorities for sea turtle population managers assessing recovery.[11] Combining skeletochronology with stable isotope values from annual bone growth layers in green sea turtles has shown new patterns of habitat use, specifically prolonged use of pelagic foraging areas in the EP population of green turtles.[12] Other elements that substitute for calcium (Ca) in sea turtle bones could give even greater spatial resolution for these migration patterns; and/or help corroborate the timing of suspected habitat shifts. Trace elements, such as barium (Ba), magnesium (Mg), and strontium (Sr), may also be helpful to reconstruct transitions between oceanic and coastal life stages in sea turtles. Previous studies have shown that unlike fish, air-breathing animals deposit trace elements into bone in relation to what is present in their diet. The potential value of trace element analysis for the reconstruction of habitat use and movement has shown potential in

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[9] Turner Tomaszewicz, C.N., Seminoff, J.A., Ramirez, M.D., Kurle, C.M. 2015. Effects of Demineralization on the Stable Isotope Analysis of Bone Samples. Rapid Communications in Mass Spectrometry: RCM 29 (20): 1879–88.

[10] Turner Tomaszewicz, C.N., Liles, M.J., Avens, L., Seminoff J.A. 2022. Tracking movements and growth of post-hatchling to adult hawksbill sea turtles using skeleto+iso . Front. Ecol. Evol., Volume 10, 2022. https://doi.org/10.3389/fevo.2022.983260

[11] NRC – National Research Council. Assessment of sea-turtle status and trends: integrating demography and abundance. National Academies Press. 2010. http://doi.org/10,17226/12889

[12] Turner Tomaszewicz, C. N., Seminoff, J. A., Avens, L., Goshe, L. R., Rguez-Baron, J. M., Hoyt Peckham, S., & Kurle, C. M. 2018. Expanding the coastal forager paradigm: long-term pelagic habitat use by green turtles Chelonia mydas in the eastern Pacific Ocean. Marine Ecology Progress Series, 587, 217–234

loggerhead and Kemp’s ridley sea turtles and a similar approach is being explored for EP green turtles.[13]

Capstone Work

Since 1990, research conducted by NOAA's Southwest Fisheries Science Center has been helping to paint a more complete picture of the life of a green sea turtle. This spring, I helped members of NOAA’s Marine Turtle Ecology and Assessment Program (MTEAP) take inventory of the East Pacific population of green turtles in San Diego Bay. By carefully capturing green turtles with a net at popular feeding grounds in Southern California, I helped the MTEAP team bring the turtles onto land for a complete physical examination. Each animal was weighed and measured, including curved carapace length (CCL) and body width. Notes were made about body condition and the presence of any injuries or barnacles was also recorded. Skin and blood samples were taken from each new turtle, and a digital Passive Integrated Transponder (PIT) tag and flipper tag were placed on the upper left flipper for easy reidentification. The data collected from yearly captures has created a long-term data set that is essential to future ecosystem and species management.

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Along with field work, I worked in NOAA’s Marine Turtle Demography Laboratory, prepping samples for analysis. I prepared skin samples for stable isotope analysis (SIA) and samples were then sent out to be analyzed by a third party with a mass spectrophotometer. In the future, results from SIA will be paired with mark and recapture data, satellite telemetry, and genetic

[13] Ramirez, M. D., Miller, J. A., Parks, E., Avens, L., Goshe, L. R., Seminoff, J. A., Snover, M. L., & Heppell, S. S. 2019. Reconstructing sea turtle ontogenetic habitat shifts through trace element analysis of bone tissue. Marine Ecology Progress Series, 608, 247–262.

tagging data to shed new light on the complex life history of green sea turtles in Southern California.

Finally, I analyzed data collected by NOAA to evaluate if trace elements (TE) found in bones, such as barium (Ba), magnesium (Mg), and strontium (Sr), could also be used to reconstruct transitions between oceanic and coastal life stages in sea turtles. In the 20 samples analyzed, the TE patterns appeared useful, mainly Ba, in confirming long-term habitat use, shown by constant patterns (Figure 1).

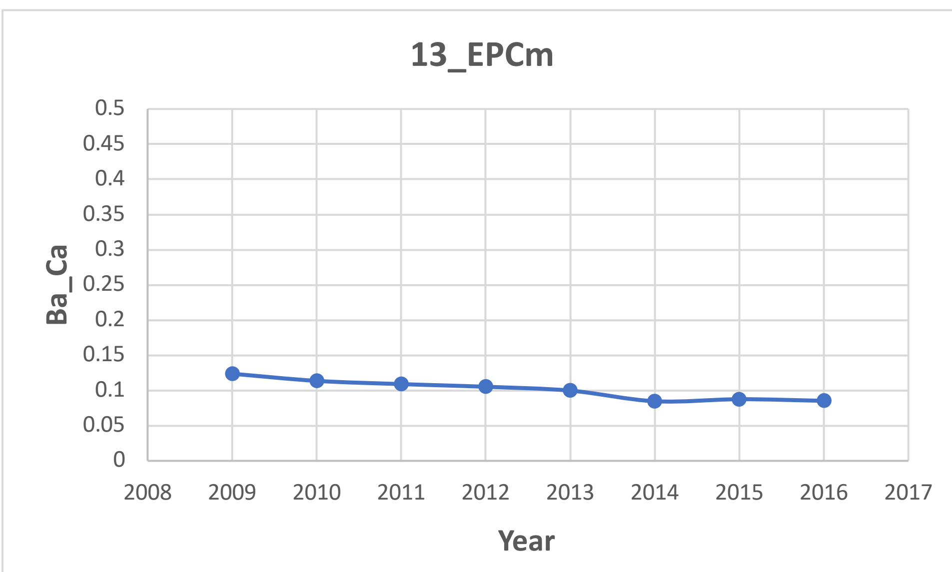

Figure 1

A couple of turtles showed potential habitats shifts from offshore to presumably near shore (Figure 2).

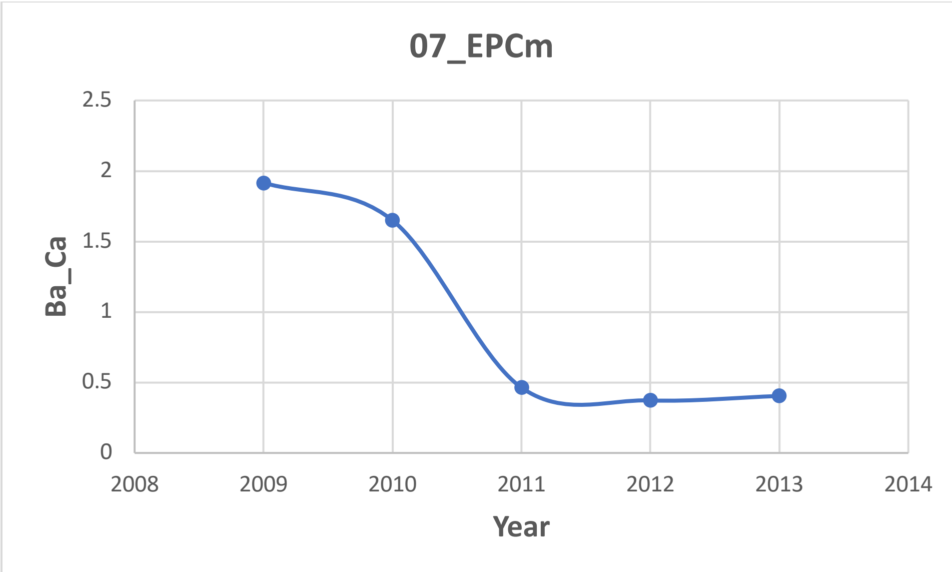

Figure 2

However, there were enough inconsistencies among all the samples that further research is needed before determining TE as a useful tool for assessing habtiat-use patterns for this group of EP turtles.

For my capstone deliverable, I combined geographic maps, satellite telemetry data, stable isotope data, skeletochronology data, narrative text, and multimedia content to share case studies of well-known EP green sea turtles in an interactive, dynamic, and meaningful way. The long-term data stored in the bones of sea turtles, along with the information gained from multiple captures over time, has helped reconstruct movement patterns of these highly migratory reptiles. Through my ArcGIS Storymap, I can share this conservation success story - to give people hope, to inspire action, and to ensure the protection and continued success of these turtles and their habitat. I hope the turtle stories bring curiosity, and a better understanding of the amazing science that is improving conservation efforts for sea turtles around the globe.