Analyzing Stranding and Sighting Data of Green Sea Turtles (Chelonia mydas) in the Southern California Region for Use in Conservation and Management

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Abstract

The southern California coast is well known for its surfing, beachfront towns, and high marine biodiversity. Humans share these coastal regions with species such as the green sea turtle (*Chelonia mydas*; hereafter referred to as "green turtle"). Over the last two decades, East Pacific (EP) green turtles have undergone substantial population recovery. As a result of improved protection efforts at nesting beaches and foraging areas in Michoacán, Mexico beginning in 1979 green turtles have been spotted in more areas and in greater numbers than before since 2014.[1] An analysis of existing stranding and sighting data is necessary to protect the growing EP green turtle population and ensure their continued population recovery in highly populated areas along the California coast. While the existing green turtle recovery plan (completed in 1998) addresses EP green turtles, it is dated and does not specifically address current known threats to this population, particularly in southern California.[2] Therefore, this report and accompanying StoryMap (link: https://arcg.is/0eX1zK) provide analyses on time-relevant and local scales. With the support of experts from the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) and the University of California San Diego, I review existing literature, analyze stranding and sighting data, and propose recommendations that could help reduce the human impacts on green turtles in the southern California region if implemented.

Initial Research Questions

1. How might green turtle stranding locations in southern California help identify areas where turtles are at higher risk for injury or death?
2. How might sighting locations of green turtles and human activities in southern California inform stakeholders about their current distribution and expansion to coastal areas further north?
3. What measures can be taken to minimize the human impact on the local green turtle population in southern California?

Background

Green turtles were first listed as "threatened" under the U.S. Endangered Species Act (ESA) in 1978, except for the Florida and Mexican Pacific coast breeding populations which were listed as "endangered."[3] However, listing a species as "threatened" or "endangered" under the ESA is only the first necessary step to begin the process that helps humans better protect it, and protections only apply within U.S. jurisdictions.[4] Based on a global status review, in 2016 the NMFS and the U.S. Fish and Wildlife Service (USFWS) reclassified and listed eleven distinct population segments (DPS) of green sea turtles under the ESA.[5] Six of these green turtle DPSs are in the Pacific, including the EP population, which NOAA categorizes as "threatened."[6] Officially, the biological range of EP green turtles extends from northern California (41° N)

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[1] Hanna, M. E., E. M. Chandler, B. X. Semmens, T. Eguchi, G. E. Lemmons and J. A. Seminoff. 2021. Citizen-sourced sightings and underwater photography reveal novel insights about green sea turtle distribution and ecology in southern California. Frontiers in Marine Science Vol. 8; Article 671061. https://doi.org/10.3389/fmars.2021.671061

[2] NMFS. 1998. Recovery Plan for US Pacific Populations of the East Pacific Green Turtle. https://repository.library.noaa.gov/view/noaa/15965

[3] 43 Federal Notice (FR) 32800 (July 28, 1978).

[4] NOAA Fisheries. N.d. Endangered Species Act. Accessed March 16, 2023. https://www.fisheries.noaa.gov/national/endangered-species-conservation/endangered-species-act

[5] 81 Federal Notice (FR) 20058 (April 6, 2016).

[6] Seminoff, J. A., C. D. Allen, G. H. Balazs, P. H. Dutton, T. Eguchi, H. Haas, S. A. Hargrove, M. Jensen, D. L. Klemm, A. M. Lauritsen, S. L. MacPherson, P. Opay, E. E. Possardt, S. Pultz, E. E. Seney, K. S. Van Houtan, and R.S. Waples. 2015. Status review of the green turtle (Chelonia mydas) under the Endangered Species Act. *NOAA Technical Memorandum, NOAA-NMFS-SWFSC-539. 571pp.* https://repository.library.noaa.gov/view/noaa/4922

southward along the Pacific coast of the Americas to central Chile (40° S) and westward to 142° W and 96° W, respectively.[7] The expansive biological range of green turtles requires local management plans to make conservation efforts most effective.

Human Impacts

Diverse marine ecosystems in southern California attract a wide variety of marine life. However, roughly 90% of the natural wetlands and riparian habitats in California have been destroyed or altered in some way due to coastal development.[8] Along the Southern California Bight coast alone, which is the curved coastline of southern California between Point Conception and San Diego, there has been a loss of about 48% of historical estuarine habitat.[9] Adult EP green turtles inhabit much of these remaining coastal wetlands and estuaries to forage, while juveniles inhabit them for up to 20 years until they reach maturity at approximately 30 years of age.[10] Due to their life history traits (e.g., long-lived species, high mortality rates in the early life stages, and delayed sexual maturity) inhabiting coastal regions makes green turtles more vulnerable to human impacts and slow to recover.[11] In other words, it takes many years of development before a green turtle can reproduce and many die before they can do so. If green turtle mortality rates exceed that of reproduction, the species will continue to decline.

Of concern is the usage of much of the same coastal areas for recreation (e.g., fishing, jet skiing, motorized boating, etc.), energy generation (coastal power plants),[12] and military purposes.[13] The overlap of these activities in areas shared with green turtles increases the risk of harassment, injury, or death. Moreover, green turtles are more active during the daytime (when human activity is also at its peak) than at night.[14] Timing and shared usage of these areas puts green turtles at risk for fatal interactions. Other studies are still trying to discover how living in these coastal areas may affect green turtles chemically such as that of the bioaccumulation of pollutants, such as non-essential trace metals.[15] Their long-term residence in coastal inlets and proximity to pollution sources on land exposes them to more pollutants from coastal runoff than they might experience in their pelagic phases further from the shore.

Understanding the changes in environmental conditions and the anthropogenic effects that influence the behaviors of green turtles must be a conservation priority. For example, anthropogenically altered water temperatures (e.g., warm water discharges from coastal power plants) have the potential to affect the movement and distribution of green turtles by attracting

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[7] 81 Federal Notice (FR) 20076 (April 6, 2016).

[8] Dahl, T. E. 1990. Wetlands losses in the United States, 1780's to 1980's. Report to the Congress. https://www.fws.gov/wetlands/documents/wetlands-losses-in-the-united-states-1780s-to-1980s.pdf

[9] Stein, E. D., K. Cayce, M. Salomon, D. L. Bram, D. De Mello, R. Grossinger, and S. Dark. 2014. Wetlands of the Southern California Coast: Historical Extent and Change Over Time. Southern California Coastal Water Research Project. SCCWRP Technical Report 826: SFEI Report 720. http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/826_WetlandsHistory.pdf

[10] Turner Tomaszewicz, Calandra N., Larisa Avens, Erin L. LaCasella, Tomoharu Eguchi, Peter H. Dutton, Robin A. LeRoux, and Jeffrey A. Seminoff. 2022. Mixed-stock Aging Analysis Reveals Variable Sea Turtle Maturity Rates in a Recovering Population. The Journal of Wildlife Management 86 (4). https://doi.org/10.1002/jwmg.22217

[11] Eguchi, T., Seminoff, J.A., LeRoux, R.A. *et al.* Abundance and survival rates of green turtles in an urban environment: coexistence of humans and an endangered species. *Mar Biol* **157**, 1869–1877 (2010). https://doi.org/10.1007/s00227-010-1458-9

[12] Eguchi, T., J. Bredvik, S. Graham, R. ReRoux, B. Saunders and J.A. Seminoff. 2020. Effects of a power plant closure on home ranges of green turtles in an urban foraging area. Endangered Species Research. 41: 265-277.

[13] Office of Governor Gavin Newsome. 2023. California Military Installations and Operational Areas. Accessed March 20, 2023. https://militarycouncil.ca.gov/s_californiamilitarybases/

[14] Crear, D.P., D.D. Lawson, J.A. Seminoff, T. Eguchi, R.A. LeRoux, and C.G. Lowe. 2017. Habitat use and behavior of the east Pacific green turtle, Chelonia mydas in an urbanized system. Bulletin of the Southern California Academy of Sciences 116: Iss. 1.

[15] Barraza, A.D., L.M. Komoroske, C. Allen, T. Eguchi, R. Gossett, E. Holland, D.D. Lawson, R.A. LeRoux, A. Long, J.A. Seminoff, & C.G. Lowe. 2019. Trace metals in green sea turtles (*Chelonia mydas*) inhabiting two southern California coastal estuaries Chemosphere 223:342–350.

them to those areas.[16] Warming trends in ocean temperatures due to climate change could also make the possibility of interacting with humans more likely as green turtles relocate and expand their ranges as far as their thermal tolerances permit.[17] Other changes in behavior such as modifying their diet could continue to occur as well. For example, green turtles will modify their diets to eat what is more readily available.[18] On the other hand, green turtle deaths and injuries from vessel strikes could also become more common. As ocean temperatures continue to rise, green turtle habitat ranges will possibly expand as well.[19]

Studies in Southern California

Some of the coastal areas that green turtles inhabit in southern California are the Ports of Los Angeles and Long Beach, San Gabriel River, Seal Beach National Wildlife Refuge,[20] and San Diego Bay.[21] Ongoing studies in the southern California region focus on green turtle genetics, movements, growth, toxicology, foraging ecology, and demography.[22]

At the San Gabriel River, the public assists with collecting "sighting" data by searching for green turtles, identifying their locations with geographic coordinates (latitude and longitude) and recording other details when they surface to breathe.[23] This type of public engagement is called "citizen science," "crowd science," or "community-based science" (CS) where volunteers from the public participate in scientific research.[24] CS helps fill the informational gap when traditional research techniques are ill-suited. Despite efforts to expand data collection through public engagement, existing sighting data is at best an underestimation because foraging green turtles spend most of their time underwater and out of sight from people.[25] There are coastal areas in southern California where green turtles have not been recently observed, but this does not necessarily mean they are not present.

Capture-mark-recapture data acquired from longitudinal (long-term) studies, such as that in San Diego Bay, has been integral to estimate the abundance and survival rates for green turtles that use the same foraging areas over multiple decades.[26] This research contributes to many years of compiled data that allows for various types of assessments and tracking over time within this population. Longitudinal studies are helpful for tracking local green turtle habitats and how the species' range changes over time with increased coastal urbanization, warming ocean

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[16] Crear, D.P., D.D. Lawson, J.A. Seminoff, T. Eguchi, R.A. LeRoux, and C.G. Lowe. 2016. Seasonal shifts in the movement and distribution of green turtles *Chelonia mydas* in response to anthropogenically altered water temperatures. Marine Ecology Progress Series. Vol. 548: 219-232.
[17] Madrak, S.V., R.L. Lewison, J.A. Seminoff, and T. Eguchi. Characterizing response of East Pacific green turtles to changing temperatures: using acoustic telemetry in a highly urbanized environment. Anim Biotelemetry 4, 22 (2016). https://doi.org/10.1186/s40317-016-0114-7
[18] Lemons, G., R. Lewison, L. Komoroske, A. Gaos, C. Lai, P. Dutton, T. Eguchi, R. LeRoux, and J.A. Seminoff. 2011. Trophic ecology of green sea turtles in a highly urbanized bay: Insights from stable isotopes and mixing models. Journal of Experimental Marine Biology and Ecology. Vol. 405, 1–2: 25-32. https://doi.org/10.1016/j.jembe.2011.05.012
[19] Eguchi, T., J. Bredvik, S. Graham, R. ReRoux, B. Saunders and J.A. Seminoff. 2020. Effects of a power plant closure on home ranges of green turtles in an urban foraging area. Endangered Species Research. 41: 265-277.
[20] Crear, D.P., D.D. Lawson, J.A. Seminoff, T. Eguchi, R.A. LeRoux, and C.G. Lowe. 2017. Habitat use and behavior of the east Pacific green turtle, Chelonia mydas in an urbanized system. Bulletin of the Southern California Academy of Sciences 116: Iss. 1.
[21] Barraza, A.D., L.M. Komoroske, C. Allen, T. Eguchi, R. Gossett, E. Holland, D.D. Lawson, R.A. LeRoux, A. Long, J.A. Seminoff, & C.G. Lowe. 2019. Trace metals in green sea turtles (*Chelonia mydas*) inhabiting two southern California coastal estuaries. Chemosphere 223:342–350.
[22] NOAA Fisheries. N.d. Green Turtle Research and Conservation in Southern California. Accessed May 1, 2023. https://www.fisheries.noaa.gov/west-coast/science-data/green-turtle-research-and-conservation-southern-california
[23] Massey, L.M., S. Penna, E. Zahn, D. Lawson, and C. M. Davis. 2023. Monitoring Green Sea Turtles in the San Gabriel River of Southern California. Animals 13, 434. https://doi.org/10.3390/ani13030434
[24] Ferran-Ferrer, N. 2015. Volunteer Participation in Citizen Science Projects. Prof. Inf. 24, 827. https://doi.org/10.3145/epi.2015.nov.15
[25] Gray, P., A. Fleishman, D. Klein, M. Mckown,V. Bézy, K. Lohmann, and D. Johnston. 2018. A Convolutional Neural Network for Detecting Sea Turtles in Drone Imagery. Methods in Ecology and Evolution. 10. https://doi.org/10.1111/2041-210X.13132
[26] Eguchi, T., J.A. Seminoff, R.A. LeRoux, P.H. Dutton and D.L. Dutton. 2010. Abundance and survival rates of green turtles in an urban environment: coexistence of humans and an endangered species. Marine Biology 157:1869-1877. doi 10.1007/s00227-010-1458-9.

temperatures from climate change, etc. By collecting blood and tissue samples scientists can compare data from green turtles in different locations to discover the similarities and differences of various populations within the DPS.

ArcGIS Analysis and StoryMap

On a larger spatial scale, understanding population structure and local human impacts on green turtles is critical for its conservation.[27] To infer trends in habitat use over time and identify high-risk areas with the most recent scientific data available, an analysis of existing stranding and sighting data is necessary. Using stranding data from 2010-2021 and sighting data from 2013-2022, I visualize the geographic locations of each data point on various maps to display where green turtle stranding locations are upon discovery and where people observe green turtles in the environment. These data were retrieved from a structured query language (SQL) database, transferred to Microsoft Excel spreadsheets, and then uploaded to ArcGIS Pro through the X-Y Data upload feature.

Stranding Data

Stranding events due to vessel strikes and fishery interactions are of greatest concern since they contribute to approximately half of all strandings in this data set. Out of a total of 138 stranding events, 41 (nearly 30%) were due to vessel strikes, 24 (about 17%) were due to some kind of fishing interaction (e.g., ingesting a hook or monofilament fishing line), and 3 (about 2%) were due to a combination of both vessel strikes and fishery interactions. None of the known stranding events involved a commercial fishery interaction (bycatch), so the stranding events from fishery interactions are assumed to be from recreational fishing.

Of the remaining stranding events, 45 (nearly 33%) are due to causes that "Cannot Be Determined." This category pertains to strandings with advanced carcass decomposition upon discovery, injuries that likely occurred after death, or the necropsy details are missing. The "None" category identifies 7 stranding events (about 5%) that have no internal or external signs of human interaction or trauma, and the turtle likely died of natural causes.

The remaining 18 stranding events are due to other human interactions. The "Power Plant" category contains 11 events (about 8%) from turtles getting stuck in intake and cooling water systems known as "entrainment." The "Entrapment" category identifies 3 stranding events (about 2%) from turtles getting stuck in the salt ponds channels of coastal salt processing facilities due to varying tides. The "Other" category identifies 2 stranding events (about 1.5%) that did not fit the other categories: one carcass had pellet gunshot wounds and the other died en route to Sea World for rehabilitation without further details. Lastly, the "Pollution" category contains 2 stranding events (about 1.5%) from the ingestion of plastic bags.

Some factors that may contribute to the discovered stranding locations are time since the initial stranding event occurred, weather, wind patterns, ocean currents, etc. Because of various reasons (e.g., recording errors, lack of equipment, human error, etc.,), some stranding locations are initially reported imprecisely. For example, the 7 data points labeled "Stranding Location Estimations" are the best guesses for the location of that stranding discovery. Relying on written

[27] Dutton, P.H., R.A. LeRoux, EL. LaCasella, J.A. Seminoff, T. Eguchi and D.L. Dutton. 2019. Genetic analysis and satellite tracking reveal origin of the green turtles in San Diego Bay. Marine Biology. 166:3. https://doi.org/10.1007/s00227-018-3446-4

descriptions of stranding locations is sometimes necessary when geographic coordinates are not recorded or missing. Therefore, each stranding location and estimation have "buffer zones" with a 1-mile (1.6-kilometer) radius to allow for error.

Using the ArcGIS intersect tool, I performed visual analyses to identify fishing piers, jetties, and commercial fishing ports that exist within 1 mile of any stranding location or estimation. Fishing piers and jetties near stranding locations help identify where recreational fishing-related interactions may have occurred near the shore. Similarly, commercial fishing ports and navigational channels identify coastal destinations along routes that large shipping vessels travel regularly. However, a vessel strike of any kind can be harmful or fatal for marine animals. Being struck by a smaller motorized vessel (e.g., jet ski or motorized boat) could prove fatal to green turtles especially as they surface to breathe or bask near the surface. Following all intersection analyses, I exported each data layer as a "web layer" to ArcGIS Online and uploaded them to ArcGIS StoryMap.

Sighting Data

Sighting data help inform scientists about patterns of green turtle distribution, habitats, and how those change over time. Scientists acquire sighting data through capture-mark-recapture research or from members of the public through community-based science and online reporting.[28] Similar to stranding data, many sighting locations are approximate because they are reported by the public sometimes without GPS; it is possible that the public reports geographic locations inaccurately, too far inland to be realistic, or imprecisely. Moreover, relying on written descriptions of sighting locations is sometimes necessary when geographic coordinates are not reported. Therefore, each sighting location and estimation have "buffer zones" with a 1-mile (1.6-kilometer) radius to allow for error. Sighting data from 2013-2022 reports indicate a total of 151 sightings. Of these sightings, 7 data points (about 4.6%) labeled "Stranding Location Estimations" are best guesses for the locations of sightings based on descriptions since they do not have geographic coordinates reported. Analyzing sighting and stranding data together helps elucidate the picture of where green turtles inhabit, where people discover their carcasses, and the human activities that may contribute to known and future stranding locations.

StoryMap Data Layers

The accompanying ArcGIS StoryMap helps visualize the range of the EP green turtle DPS as a whole and some of the human activities that continue to affect its recovery along the southern California coast. It will assist stakeholders across multiple agencies such as individuals from NMFS, NOAA's Office of Law Enforcement, U.S. Navy, Army Corp of Engineers, California Ocean Protection Council, California Energy Commission, U.S. Fish and Wildlife Service, etc., to inform policy decisions while prioritizing conservation goals. Ideally, stakeholders will be able to understand existing threats to green turtles while considering their agency's requirements and goals.

The feature layers used in StoryMap come from various online sources. Firstly, I obtained the feature layer titled "CA Coastal Fishing Piers" from the UC Berkeley online GeoData Library. This point shapefile depicts piers and jetties regularly sampled by the California Recreational

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[28] West Coast Sea Turtle Sightings Submission Form. Accessed May 25, 2023. https://survey123.arcgis.com/share/ddb6e7a3f2f94d85b7391e4d537ca57b?portalUrl=https://maps.fisheries.noaa.gov/portal

Fisheries Survey and location sites are provided by the Pacific State Marine Fisheries Commission.[29]

Next, I obtained three data layers from the Marine Cadastre's data registry.[30] Firstly, the layer titled "Ocean Uses" originally shows ocean use patterns for ocean areas in New England, the West Coast, and Hawaii. However, I filtered the displayed layers on ArcGIS Online to only show the West Coast. "General Use" refers to areas where use is known to occur with some regularity regardless of its frequency or intensity, while "Dominant Use" areas are areas routinely used by most users most of the time for that use. Secondly, I obtained the layer titled "Coastal Maintained Channels" referred to as "navigation channels" in StoryMap from the Marine Cadastre website.[31] This layer refers to the coastal channels and waterways that are maintained and surveyed by the U.S. Army Corps of Engineers. These maintained channels are necessary to enable large vessels to pass through to a port as water becomes shallower closer to shore. Thirdly, I downloaded the polygon data layer titled "USA Inland Water Spatial Data" which represents the rivers, streams, and lakes across the entire United States.[32] I applied a filter to display only rivers and streams in the United States.

Next, I obtained three data layers from the Stanford Digital Repository. Using the water spatial data from the previous step, I created a data layer titled "Coastal Water Lines." I achieved this by first downloading the layer called "Coastal Counties" from the Stanford Digital Repository.[33] After, I applied the geoprocessing tool "intersect" to display only the rivers and streams in the coastal counties rather than the entire United States for this study. Another layer I downloaded from this source is the layer titled "Plant Entrainment Areas."[34] This coverage displays the estimated extent of area affected by power plant entrainment in the Southern California Bight. Entrainment is a process by which marine organisms are carried by the cooling water into the fore bay of a power plant.[35] Getting caught in these water intake systems can result in serious injury or death for green turtles. Lastly, I downloaded the layer titled "California Coastal Ports" which shows commercial fishing port locations according to the California Department of Fish and Game's Commercial Fishing Information System.[36]

I downloaded the layer titled "CDFW Districts" from The University of Texas at Austin GeoData Library.[37] This shapefile depicts all boundaries of the California Department of Fish and Wildlife (CDFW) Districts within the state. The waters off the California coast comprises a complex array of local, state, federal, and international jurisdictions. For example, the CDFW would likely be one of the regulatory agencies responsible for implementing a speed limit rule in

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[29] California Department of Fish and Game. 2005. California Coastal Fishing Piers. Accessed May 25, 2023. https://geodata.lib.berkeley.edu/catalog/stanford-pp467qx2820

[30] Marine Cadastre. n.d. Ocean Uses. Accessed May 25, 2023. https://marinecadastre.gov/data/

[31] Marine Cadastre. n.d. Coastal Maintained Channels. Accessed May 25, 2023. https://marinecadastre.gov/data/

[32] Marine Cadastre. n.d. USA Inland Water Spatial Data. Accessed May 25, 2023. https://marinecadastre.gov/data/

[33] Stanford Digital Repository. n.d. Coastal Counties, California, 2000. Accessed May 25, 2023. https://purl.stanford.edu/fb618rc6932

[34] Stanford Digital Repository. n.d. Power Plant Entrainment (Polygons): Southern California, 2008. Accessed May 25, 2023. https://purl.stanford.edu/yt699ry4370

[35] San Francisco Bay Keeper. 2010. Protecting Marine Life at California Power Plants. Accessed May 25, 2023. https://baykeeper.org/articles/protecting-marine-life-california-power-plants#:~:text=Larvae%20and%20small%20fish%20get,waters%20by%20once%2Dthrough%20cooling

[36] Stanford Digital Repository. n.d. California Coastal Ports: Commercial Fishing Information System, 2010. Accessed May 25, 2023. https://purl.stanford.edu/fm357jn1574

[37] The University of Texas at Austin GeoData University of Texas Libraries. n.d. Districts: California Department of Fish and Wildlife, 2008. Accessed May 25, 2023. https://geodata.lib.utexas.edu/catalog/stanford-vs537rq7663

state waters (up to three miles offshore).[38] I selected only relevant coastal counties and created a new layer retaining all original information prior to exporting to ArcGIS Online as a web layer.

Next, I added two imagery layers using the ArcGIS Online Living Atlas search tool. The first layer is called "West Coast USA Estuarine Biotic Habitat" which shows estuary habitats of the West Coast of the contiguous United States following the Coastal and Marine Ecological Classification Standard.[39] The map image layer is provided by the Pacific States Marine Fisheries Commission. Lastly, I added the imagery layer titled "HYCOM - Sea Water Temperature" which displays a 7-day forecast and 30-day hindcast from HYbrid Coordinate Ocean Model (HYCOM.)[40] I modified the layer in ArcGIS Online to display temperatures every 12 hours to quickly show temperature changes over the course of a day and month. Updates to the information in this layer occur close to real-time with the most recent data typically available within 48 hours. These two data layers may be unavailable to download without an active ArcGIS Online organizational subscription or an ArcGIS Developer account.

Displaying select informational layers in combination with stranding and sighting data allows the viewer to observe the environmental conditions and human activities that may affect green turtles. Analyzing the intersection between various layers and stranding or sighting data using ArcGIS Pro identifies specific locations where harmful interactions may occur.

Recommendations

Raising public awareness is at the forefront of management actions that may reduce harmful interactions for green turtles. Since recreational fishing and vessel strikes are the human activities confirmed to have caused nearly half of all strandings since 2010, areas with higher concentrations of these human activities and strandings identify where stakeholders may wish to focus management efforts. Educational campaigns such as tabling events, handing out flyers, or tackle box stickers can inform beachgoers, boaters, and fishers about the vulnerability of local green turtles and the actions they can take to minimize harm. Further, signage and a recommended or mandatory reduction in vessel speeds close to areas with the highest concentrations of strandings could be beneficial.

Educational signs are effective in discouraging unwanted behaviors and encouraging desired ones.[41] Signs are also a relatively quick and cost-effective method to educate the public on local environmental issues they might not be aware of otherwise. By educating the public on fishing activities that may have direct impacts on marine animals (or what to do in case of unintentionally hooking a turtle or other marine animal) fishers may directly help reduce the risk to green turtles and ultimately reduce stranding frequency.

A speed limit rule for areas within 1 mile of commercial shipping ports, navigation channels, or green turtle critical habitat (anticipated to be proposed by NMFS and USFWS in June 2023) that would apply to all motorized vessels could help reduce the frequency of fatal vessel strikes of

[38] California Ocean Protection Council. n.d. Overview of California Ocean and Coastal Laws with Reference to the Marine Environment: pg. 11. Accessed May 25, 2023. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/Documents_Page/Noteworthy/Overview_Ocean_Coastal_Laws.pdf
[39] Lanier, A., T. Haddad, L. Mattison, L. and Brophy. 2014. CORE CMECS GIS PROCESSING METHODS OREGON ESTUARY PROJECT OF SPECIAL MERIT. Accessed May 25, 2023. https://www.coastalatlas.net/documents/cmecs/PhaseI/EPSM_CoreGISMethods.pdf
[40] HYCOM. n.d. Consortium for Data Assimilative Modeling. Accessed May 25, 2023. https://www.hycom.org/
[41] Meis, J. and Y. Kashima. 2017. Signage as a tool for behavioral change: Direct and indirect routes to understanding the meaning of a sign. PloS one, 12(8), e0182975. https://doi.org/10.1371/journal.pone.0182975

green turtles. Currently, a speed limit rule exists along the east coast aimed at protecting endangered North Atlantic right whales from collisions with boats.[42] However, implementing a speed limit rule off California's coast to protect green turtles would likely take multiple years of public engagement and interagency cooperation. Specifically, section 102(2)(C) of the National Environmental Policy Act (NEPA) requires Federal agencies such as NOAA to prepare "detailed statements," otherwise known as environmental impact statements, for "every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment" and provide opportunities for public participation to help inform agency decision making.[43] The implementation of a speed limit rule similar to that on the east coast would be a lengthy legal process that could benefit marine turtles and other protected species on the west coast.

Conclusion

Future considerations with the best available science and data will be necessary to monitor the status of EP green turtles. Increased traffic in and out of major southern California ports to support international trade is ongoing. Specifically, the Port of Los Angeles and Port of Long Beach handle more containers per ship call than any other port complex in the world.[44] Large vessel traffic will continue and will follow established navigational channels. Similarly, motorized boating activities will continue in bays and estuaries green turtles are known to inhabit. Recreational fishing will continue, but there are ways to help reduce its impacts. Ongoing analyses of stranding and sighting data is necessary as the ranges of green turtles may expand occupying more coastal areas further north in the future. Overall, understanding current green turtle distributions, what affects their behaviors, and the overlap of areas that humans and green turtles use is crucial to help this recovering species flourish and promote the coexistence between humans and green turtles.

[42] NOAA Fisheries. n.d. Reducing Vessel Strikes to North Atlantic Right Whales. Accessed May 2, 2023. https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales
[43] NOAA Fisheries. N.d. National Environmental Policy Act.https://www.noaa.gov/nepa
[44] The Port of Los Angeles. 2023. Facts and Figures. Accessed March 16, 2023. https://www.portoflosangeles.org/business/statistics/facts-and-figures