International Journal of Biology; Vol. 16, No. 1; 2024
ISSN 1916-9671 E-ISSN 1916-968X
Published by Canadian Center of Science and Education

Citizen Science and Sea Turtles: Using iNaturalist as a Tool to Study Chelonian Conservation Biology

Shem D. Unger[1]

[1] Biology Department, Wingate University, Wingate, USA

Correspondence: Shem D. Unger, Biology Department, Wingate University, Wingate, N.C., USA. Tel: 1-704-233-6480
E-mail: s.unger@wingate.edu

Received: May 22, 2024 Accepted: November 18, 2024 Online Published: January 11, 2025

doi:10.5539/ijb.v16n1p13 URL: https://doi.org/10.5539/ijb.v16n1p13

Abstract

Sea turtles are among the most threatened group of marine animals, with all species at risk for an assortment of anthropogenic factors including pollution, over-fishing bycatch, and climate change. As the threats to these large aquatic reptiles continue to increase, populations may be facing declines in many areas of their native home ranges. Therefore, new techniques that allow for population monitoring alongside more traditional methods are needed to increase our understanding of these ocean-dwelling vertebrates. Due to their unique biology, sea turtles are often readily observed in near-shore waters and on beach habitats. I assessed the presence and general demography of sea turtles within the USA on the citizen science platform, iNaturalist and report on major findings related to mortalities, age classes, and states where observations are concentrated. iNaturalist observations in this publication represent 8,089 green, 1,171 loggerhead, 312 kemp's ridley, 129 leatherback, 128 hawksbill, and 17 olive ridley sea turtles. Observations consisted primarily of adult age classes (85.9%), with moralities representing only 10.2%, and the majority of images showing beach habitat (55%) versus open water (44.8%). The number of observations increased annually indicating the potential for this citizen science application to provide valuable population trend data for conservation managers and future study of their nesting and behavioral biology worldwide.

Keywords: Testudines, ocean science, sea turtles, conservation, marine biology, reptiles

1. Introduction

Sea turtles are severely threatened as large marine reptiles, with the majority of populations experiencing some level of current or historic decline (Tapilatu et al., 2013; Wibbels & Bevan, 2016) or classified as endangered. Subsequently, the number of nests is also on the decline for some species (Witherington et al., 2009), largely due in some part to loss or reduction of nesting sites (McCleachan et al., 2006). Declines in sea turtle species are also linked to anthropogenic factors including fisheries bycatch (capture via longline, gillnet, or trawling), coastal development, and nest harvesting (Donlan et al., 2010; Bolten et al., 2011), as well as natural habitat degradation, climate change, and infectious diseases (Caceres-Farias et al., 2022). Monitoring sea turtle populations often includes assessing the number of individual sea turtles coming to shore for nesting as they are easily observed during this time frame, which is often used as an estimate of abundance (Ceriani et al., 2019). In addition, these conservation efforts largely rely on volunteers alongside researchers to document population trends, or in the case of strandings, citizen scientists which report stranded turtles to local conservation agencies. However, supplemental methods for detecting presence and monitoring the heatlh of populations are needed for long-term conservation efforts.

Citizen science has emerged as one method to bridge gaps in data knowledge for conservation (Ellwood et al., 2017), and can be cost-effective for collecting biodiversity data across spatial and temporal scales (Wiggins & Crowston, 2011). Moreover, citizen science may serve as a potentially powerful avenue of research in marine environments (Kelly et al., 2020). Community citizen scientists have previously aided in state efforts to manage endangered sea turtles (Cornwall & Campbell, 2012), and provided data on the seasonality of leatherback sea turtles via weekly beach surveys (Nordstom et al., 2019). Citizen science data has been utilized previously to study the hawksbill sea turtle home range using smart-phone GIS tools from scuba divers (Baumbach et al., 2019), as well as images taken from kayakers and divers to conduct mark-recapture in green sea turtles (Hanna et al., 2021). Among the citizen science platforms available, iNaturalist has emerged as one of the more popular with over a million users or observers (Mesaglio & Callaghan, 2021). Therefore, it represents a means to monitor at-risk and rare species and marine biodiversity (Roberts et al., 2022). Previously, iNaturalist has been successfully used to quantify injury rates in freshwater turtles from motorboats (Seburn et al., 2023), and may prove useful in monitoring mortalities due to anthropogenic factors. iNaturalist has potential for citizen science monitoring, especially given the large geographic range and multiple species of sea turtles facing reductions in population size across the United States. However, at present, there appears to be limited study of the use of iNaturalist as a method for monitoring sea turtles.

Sea turtles present an ideal group of species to determine if citizen science is useful in monitoring, as they are readily visible and identifiable during nesting season, with females coming to shore to nest, and in the case of some species, to bask (i.e., green sea turtles in Hawaii; Whittow & Balazs, 1982). Moreover, several species, including kemp's ridley and loggerhead sea turtles experience "cold stunning" or severe hypothermia at low temperatures less than 10 °C, and can subsequently become stranded, washing ashore as they are unable to actively swim at lower temperatures (Burke et al., 1991). Even more problematic, many of the studies on sea turtles largely involve primarily adult age classes, with little information on juvenile age classes. Reliance on citizen science-based data can engage the public in endangered species monitoring, yet sea turtle observations may take months or years to accumulate sea turtle nesting documentation or characterization of foraging habitat (Hudgins et al., 2017). It is presently unknown the extent of sea turtle presence on citizen science platforms and whether these can be utilized as a monitoring method to detect population trends and document behavior across age classes, seasons, and geographic locations.

Herein, I present novel data on the presence, distribution, behavioral biology, and general demography of six species of sea turtles on the citizen science platform iNaturalist within the United States. I discuss the implications and future potential use of this powerful tool for monitoring sea turtle biology.

2. Method

Assessment of sea turtle observations by citizen scientists on the iNaturalist platform occurred via two primary methods, first, sorting observations across six species of sea turtles in the USA (i.e. full dataset), and second, manually examining a subset of images on iNaturalist to characterize basic life stage, habitat and behavior. Species assessed included *Chelonia mydas*, Linnaeus, 1758 (green), *Caretta caretta*, Linnaeus, 1758 (loggerhead), *Lepidochelys kempii*, Garman, 1880 (kemp's ridley), *Dermochelys coriacea*, Vandelli, 1761 (leatherback), *Eretmochelys imbricata*, Linnaeus, 1766 (hawksbill), and *Lepidochelys olivacea*, Eschscholtz, 1829 (olive ridley), hereby referenced by their common name. The Explorer tab on iNaturalist was searched with the following parameters for both methods: "Sea Turtles" "Superfamily Chelonioidea, Location= "USA", filters = "Wild", "Verifiable", and "Research Grade". The additional filter for the date observed range included only those observations up to Dec 31 2023, to allow investigation of the annual number of observations to assess if the use of iNaturalist increased over time for sea turtle species and not be biased for 2024, where there are fewer observations at the time of this publication.

2.1 Full iNaturalist Observations Database

I downloaded observations on 02/26/24 and subsequently sorted observations across species in Excel for the number of observations annually and location (state) for each species. Primarily descriptive statistics are presented for trends in the full dataset. A Spearman's Rank Correlation Analysis was performed on the year and number of observations for all sea turtle species, with 2000 as the beginning year as there were over 5 observations during this year.

2.2 Subset of iNaturalist Observations

Manual assessment of a subset of the full dataset, i.e. observation images, occurred between 02/26/2024 to 03/08/2024, using the same search parameters to ensure congruence between the downloaded dataset and the manual examination of observations on the iNaturalist website. For manual assessment of observation images, the following parameters were characterized, live or dead, age class of adult or juvenile, habitat of either beach or water. Additional notes were taken for any observation of behavior, or potential injury type, month of observation of nesting, human interactions, etc. All observation images available were assessed for species, except those for green and loggerhead sea turtles for which ~10% and ~20% were assessed respectively, due to the large number of observations for those two species. In the case of multiple hatchlings being present, for manual observations of images, these were recorded as a single observation. Observations where an individual female was actively nesting were recorded as a nest. In some cases, observations included tracks only or individuals likely returning from nesting or during the nesting season, but those were not recorded as nests. Primarily descriptive statistics are presented for the subset of iNaturalist observations.

3. Results

3.1 Full iNaturalist Observations Dataset

The species with the most number of observations was the green sea turtle (8,089), followed by loggerhead sea turtle (1,171). The next four species had under 500 observations each, including the kemp's ridley (321), leatherback (129), hawksbill (128), and olive ridley (17). The states with the most number of observations were Hawaii (6,194), Florida (1,335) and Texas (1,094), for all sea turtle species (Table 1). The number of observations for all species increased annually except for 2020, likely due to the COVID-19 Pandemic (Figure 1). There was a strong correlation between the year and number of observations, Spearman's Rank Correlation, r_s (2) = 0.997, p = 0.001.

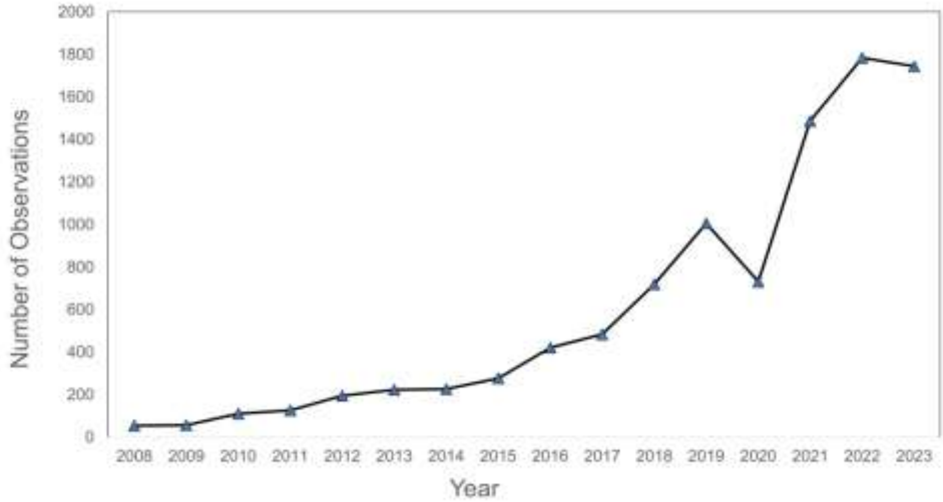

Figure 1. Annual increase in the number of observations for each year of sea turtles in the USA. Note only data from 2008 is shown, as iNaturalist platform was launched in 2008

3.2 Subset of iNaturalist Observations

A total of 1,656 observer images were manually assessed, including all available observer images for all species, except loggerhead and green sea turtles, for which I assessed, 250 and 811, respectively. Across all species, observations represented 89.6% live and 10.2% dead, with 0.2% unknown (unable to assess). Behaviors of interest across observations included breeding, feeding, and nesting behaviors (Figure 2). In total, there were 168 dead turtle mortalities in observations (Figure 3), and in some observations include accidental capture by fishermen using baited hooks or likely boat strike injuries. In addition, observations of hatchlings in at least one instance include a stranded hatchling caught in plastic (Figure 3). The largest number of dead turtle mortalities for all species were observed during April (17.3%), May (14.3%), and November (11.9%). Kemp ridley sea turtles were the most frequently observed mortality (44.6%), followed by loggerhead (28%) and leatherback sea turtles (16.1%). Qualitatively, for many observations of adults on the beach found in November to December, there was mention in observer notes of cold shock and local turtle rehabilitation association or aquarium contacted with turtles collected and rehabilitated.

The majority of mortalities were adults, except six juveniles (three kemp ridley, two hawksbill, and one olive ridley sea turtle). The majority of total observations were of adult sea turtles, 85.9%, with 14.1% juveniles, which consisted primarily of recent hatchling sea turtles. Across all species, 5.9% of observation images showed adult females actively nesting during months consistent for each species. The predominant habitat in observations across all species was beach (55%) followed by water (44.8%), and 0.2% unknown. Qualitatively, many of the green sea turtles's images in water represented underwater images taken by scuba divers or snorkelers, while the remaining images of all species of sea turtles in water were often of individual sea turtles swimming on the water's surface and still readily identifiable to species.

Figure 2. Representative images from iNaturalist observations showing loggerhead breeding (top left), hawksbill feeding (top right), kemp ridley nesting (bottom left), and green hatchling moving toward ocean (bottom right). All images presented under creative commons

Figure 3. Representative images from iNaturalist observations showing mortalities of leatherback from propeller of large container ship (top left), kemp ridley dead from boat strike (top right), kemp ridley caught on baited hook and taken to rehabilitation center (bottom left), and kemp ridley stranded on beach wrapped in balloon ribbons and transported to rehabilitation center (bottom right). All images presented under creative commons

Table 1. Number of observations for all sea turtle species from full dataset within the USA

State	Number of Observations
Hawaii	6,194
Florida	1,335
Texas	1,094
California	291
South Carolina	208
North Carolina	191
Georgia	171
Virginia	64
Louisiana	51
Massachussetts	49
New York	40
New Jersey	38
Alabama	37
Mississippi	25
Rhode Island	19
Delaware	17
Maryland	12
Connecticut	10
Maine	3
Oregon	3
Washington	2
Alaska	1

For green sea turtle observations, several images showed clear signs of fribropapillomatosis, a tumor disease. In addition, within species, mortalities for green sea turtles were commonly observed from October to December, with hawksbill sea turtles experiencing mortalities across all months except February. Hawksbill sea turtles and olive ridley experienced the least amount of mortalities, three, and six, respectively. Leatherback sea turtle mortalities ranged from May to December, with almost all olive ridley mortalities occurring during November, except one that occurred during July.

Additional observations on iNaturalist included visible signs of tracks, and individuals either approaching or returning from likely nesting. Several observations for green sea turtles in Hawaii showed either locals or potential tourists on the beach visting nesting locations. In a few instances, satellite transmitters used in research were visible on individual sea turtle's carapaces. Moreover, several observations of mortalities included fragments of the skull or shell, yet were readily identifiable on iNaturalist. Most observations which included accidental capture by local fishermen did include some brief mention of being either released or taken to a local sea turtle rescue center or rehabilitation center, which was also the case for several of the live strandings across species. Interestingly, one observation for loggerhead sea turtles included a female nesting immediately next to beach chairs in Florida in July, while yet another observation showed a loggerhead nesting in the vicinity of other previous nests, which were blocked off and surrounded by local sea turtle monitoring efforts in Florida. One observation for a green sea turtle included a previous injury likely from a boat propeller, with the individual missing a portion of its rear right carapace and plastron, yet appeared to be swimming, and was alive, indicating the potential for at least some individuals to recover from boat interactions.

4. Discussion

Overall, the citizen science platform iNaturalist was successful in providing a method for documenting sea turtle distribution, behavior, mortality, age class, and presence. Interestingly, several observations for olive ridley sea turtles included stranding during November, likely due to cold shock. However, there were a limited number of observations for this species, likely due to its native geographic range extending beyond the small number of observations on iNaturalist within the USA, in California, Oregon, Washington, and Hawaii. However, I observed a majority of mortalities during spring and early summer, likely due to the proximity to shore during the breeding/nesting season. This is somewhat consistent with reports of strandings frequently in summer months (Tomas et al., 2008). Several mortalities in a subset of images were likely due to the boat propellers as injuries were consistent with anterior to mid-carapace sharp or blunt force injury, a vessel-strike injury (Foley et al., 2019). Loggerhead mortalities due to boat strikes have been linked to warmer seasons (Casale et al., 2010). Moreover, the death of both green and loggerhead sea turtles as evidenced by visible damage to the body and carapace has been linked to fishing activities (Bugoni et al., 2001).

For green sea turtles, there were many more observations taken underwater (not on the water's surface), likely by snorkelers or scuba divers. In addition, many observations of green sea turtles in Hawaii consisted of adults performing basking behavior, as they are frequently observed in Hawaii basking on several beaches (Lamb, 2021). Moreover, for green sea turtles, several observation images clearly showed evidence of fribropapillomatosis, indicating that researchers may be able to use this citizen science application to monitor the spread of this disease. Additional studies have incorporated observations from both tourism and fishing vessels for fine-scale distribution of loggerhead sea turtles (Casale et al., 2020). Therefore, iNaturalist may serve as a reliable, cost-effective supplemental monitoring method alongside larger state or regional conservation efforts for sea turtles. In addition, social networks used by citizens should also be potentially accessed to investigate if social networks can be further evaluated as a source of marine biodiversity data (Otero et al., 2024).

One caveat of this study, and the ever-increasing use of citizen science data in publications, is the need for data verification methods, which can the affect accuracy of observations. Therefore, research that utilizes citizen science should consider incorporating further expert verification or automated approaches (Baker et al., 2021). To overcome this weakness for iNaturalist data, previous studies have considered the target species and location of observation to further evaluate data (Koo et al., 2022). Subsequently, to avoid misidentifications in iNaturalist, recommendations to ensure proper identification include educating observers on using high quality, well-lit images, addition of notes for observations, and use of multiple images for observations to increase identification reliability, and thus data validation (McMullin & Allen, 2022). The reliance on citizen science data is likely to increase, especially as community and taxa data is used by ecologists, for conservation, and in the wake of global climate change (Prudic et al., 2023). Moreover, since citizen science data can enhance environmental stewardship and expand on scientific knowledge which can be implemented into marine conservation initiatives and policies (Kelly et al., 2020), it stands to reason that greater emphasis should be placed on assessing seasonal variations, migration patterns and in monitoring to detect long-term changes in species. For example, it is possible observations in the iNaturalist database can be used to monitor future changes in range shifts across sea turtle species. In conclusion, I recommend researchers consider this and only include observations with clear images showing morphology for species in areas of known distribution and during specific confirmed nesting seasons, strandings, or active periods as needed for research goals.

Future research could focus on noting both mortalities and nesting behavior in other parts of the world, as this research only includes observations within the United States as an exemplar. While this study focuses on observations within the United States, the methods presented here can be applied to sea turtles and other marine animals worldwide. Global datasets can be further utilized to increase the scope of citizen science and sea turtle presence, such as the State of the World's Sea Turtles Database (SWOT), or the Sea Turtle Nest Monitoring System (STNMS) and the Sea Turtle Rehabilitation and Necropsy Database (STRAND). The use of these additional databases could be used concomitantly with iNaturalist to further examine and validate results against traditional surveys for robustness of monitoring data. The use of this application may allow for comparison between historical and future observations as a proxy for population size, particularly since most sea turtle species have large geographic ranges and are readily identifiable to species in their local areas. Indeed, iNaturalist may prove a valuable monitoring methodology given not only the current large spatial scale but also the potential for sea turtles to expand their nesting range in response to climate change (Butt et al., 2016). Moreover, citizen science platforms like iNaturalist, when combined with community and research monitoring, have been utilized to estimate population size in freshwater turtles (Cross et al., 2021), indicating the potential for mark-recapture studies in sea turtle species using iNaturalist. Subsequently, it is likely this citizen science application will continue to increase in popularity and can likely be utilized for research in population trends of other marine species, such as jellyfish, fish, whales, etc. In conclusion, iNaturalist holds much promise as a monitoring tool for the future of sea turtle biology and conservation worldwide.

References

Baker, E., Drury, J. P., Judge, J., Roy, D. B., Smith, G. C., & Stephens, P. A. (2021). The verification of ecological citizen science data: current approaches and future possibilities. *Citizen Science: Theory and Practice*, *6*(1), 1-14. https://doi.org/10.5334/cstp.351

Baumbach, D. S., Anger, E. C., Collado, N. A., & Dunbar, S. G. (2019). Identifying sea turtle home ranges utilizing citizen science data from novel web-based and smartphone GIS applications. *Chelonian Conservation and Biology*, *18*, 133-144. https://doi.org/10.2744/CCB-1355.1

Bolten, A. B., Crowder, L. B., Dodd, M. G., MacPherson, S. L., Musick, J. A., Schroeder, B. A., Witherington, B. E., Long, K. J., & Snover, M. L. (2011). Quantifying multiple threats to endangered species: an example from loggerhead sea turtles. *Frontiers in Ecology and the Environment, 9*, 295-301. https://doi.org/10.1890/090126

Bugoni, L., Krause, L., & Petry, M. V. (2001). Marine debris and human impacts on sea turtles in southern Brazil. *Marine Pollution Bulletin, 42*, 1330-1334. https://doi.org/10.1016/S0025-326X(01)00147-3

Butt, N., Whiting, S., & Dethmers, K. (2016). Identifying future sea turtle conservation areas under climate change. *Biological Conservation, 204*, 189-196. https://doi.org/10.1016/j.biocon.2016.10.012

Burke, V. J., Standora, E. A., & Morreale, S. J. (1991). Factors affecting strandings of cold-stunned juvenile Kemp's Ridley and Loggerhead Sea turtles in Long Island, New York. *Copeia, 4*, 1136-1138.

Caceres-Farias, L., Resendiz, E., Espinoza, J., Fernandez-Sanz, H., & Alfaro-Nunez, A. (2022). Threats and vulnerabilities for the globally distributed Olive Ridley (Lepidochelys olivacea) Sea Turtle: a historical and current status evaluation. *Animals, 12*, 1837. https://doi.org/10.3390/ani12141837

Casale, P., Affronte, M., Insacco, G., Freggi, D., Vallini, C., D'Astore, P. P., Basso, R., Paolillo, G., Abbate, G., & Argano, R. (2010). Sea turtle strandings reveal high anthropogenic mortality in Italian waters. *Aquatic Conservation: Marine and Freshwater Ecosystems, 20*, 611-620.

Casale, P., Ciccocioppo, A., Vagnoli, G., Rigoli, A., Freggi, D., Tolve, L., & Luschi, P. (2020). Citizen science helps assessing spatio-temporal distribution of sea turtles in foraging areas. *Aquatic Conservation: Marine and Freshwater Ecosystems, 30*, 123-130. https://doi.org/10.1002/aqc.3228

Ceriani, S. A., Brost, P. C., Leone, E. H., & Witherington, B. E. (2019). Conservation implications of sea turtle nesting trends: elusive recovery of a globally important loggerhead population. *Ecosphere, 10*, e02936. https://doi.org/10.1002/ecs2.2936

Cornwall, M. L., & Campbell, L. (2012). Co-producing conservation and knowledge: citizen-based sea turtle monitoring in North Carolina, USA. *Social Studies of Science, 42*, 101-120. https://doi.org/10.1177/0306312711430440

Cross, M. D., Mayer, J., Breymaier, Chiotti, J. A., & Bekker, K. (2021). Estimating population size of a threatened turtle using community and citizen science. *Chelonian Conservation and Biology, 20*, 43-49. https://doi.org/10.2744/CCB-1384.1

Donlan, C. J., Wingfield, D. K., Crowder, L. B., & Wilcox, C. (2010). Using expert opinion surveys to rank threats to endangered species: a case study with sea turtles. *Conservation Biology, 24*, 1586–1595. https://doi.org/10.1111/j.1523-1739.2010.01541.x

Ellwood, E. R., Crimmins, T. M., & Miller-Rushing, A. J. (2017). Citizen science and conservation: recommendations for a rapidly moving field. *Biological Conservation, 208*, 1-4. https://doi.org/10.1016/j.biocon.2016.10.014

Foley, A. M., Stacy, B. A., Hardy, R. F., Shea, C. P., Minch, K. E., & Schroeder, B. A. (2019). Characterizing watercraft-related mortality of sea turtles in Florida. *The Journal of Wildlife Management, 83*, 1057-1072. https://doi.org/10.1002/jwmg.21665

Hanna, M. E., Chandler, E. M., Semmens, B. X., Eguchi, T., Lemons, G. E., & Seminoff, J. A. (2021). Citizen-sourced sightings and underwater photography reveal novel insights about green sea turtle distribution and ecology in southern California. *Frontiers in Marine Science, 8*, 671061. https://doi.org/10.3389/fmars.2021.670161

Hudgins, J. A., Hudgins, E. J., Ali, K., & Mancini, A. (2017). Citizen science surveys elucidate key foraging and nesting habitat for two endangered marine turtle species within the Republic of Maldives. *Herpetology Notes, 10*, 463-471.

Kelly, R., Fleming, A., Pecl, G. T., von Gonner, J., & Bonn, A. (2020). Citizen science and marine conservation: a global review. *Philosophical Transactions of the Royal Society, 375*, 1814. https://doi.org/10.1098/rstb.2019.0461

Koo, K., Oh, J., Park, S., & Im, J. (2022). Assessing the accuracy of citizen science data based on iNaturalist data. *Diversity, 14*(5), 316. https://doi.org/10.3390/d14050316

Lamb, G. (2021). Sea turtle tourism and conservation. In *Communicating Endangered Species* (pp. 87-100).

McClenachan, L., Jackson, J. B. C., & Newman, M. J. H. (2006). Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment, 4*, 290-296. https://doi.org/10.1890/1540-9295(2006)4[290:CIOHST]2.0.CO;2

McMullin, R. T., & Allen, J. L. (2022). An assessment of data accuracy and best practice recommendations for observations of lichens and other taxonomically difficult taxa on iNaturalist. *Botany*, *100*, 491–497. https://doi.org/10.1139/cjb-2021-0160

Mesaglio, T., & Callaghan, C. T. (2021). An overview of the history, current contributions and future outlook of iNaturalist in Australia. *Wildlife Research, 48*, 289-303. https://doi.org/10.1071/WR20154

Nordstrom, B., James, M. C., Martin, J., & Worm, B. (2019). Tracking jellyfish and leatherback sea turtle seasonality through citizen science observers. *Inter-Research: Marine Ecology Progress Series*, *620*, 15-32. https://doi.org/10.3354/meps12978

Otero, P., Velasco, E., & Valeiras, J. (2024). Surveillance of coastal biodiversity through social network monitoring. *Ecological Informatics, 80*, 102515. https://doi.org/10.1016/j.ecoinf.2024.102515

Prudic, K. L., Zylstra, E. R., Melkonoff, N. A., Laura, R. E., & Hutchinson, R. A. (2023). Community scientists produce open data for understanding insects and climate change. *Current Opinion in Insect Science, 59*, 101081. https://doi.org/10.1016/j.cois.2023.101081

Roberts, C. J., Verges, A., Callaghan, C. T., & Poore, A. G. B. (2022). Many cameras make light work: opportunistic photographs of rare species in iNaturalist complement structured surveys of reef fish to better understand species richness. *Biodiversity and Conservation*, *31*, 1407-1425.

Seburn, D. C., Burns, M., Akinrinola, I., McIntyre, P., & Page, J. (2023). Assessing injury rates in Northern Map turtles (Graptemys geographica) from motorboats using iNaturalist Canada. *Herpetological Conservation and Biology, 18*, 244-253.

Tapilatu, R. F., Dutton, P. H., Tiwari, M., Wibbels, T., Ferdinandus, H. V., Iwanggin, W. G., & Nugroho, B. H. (2013). Long-term decline of the western Pacific leatherback, Dermochelys coriacea: a globally important sea turtle population. *Ecosphere, 4*, 1-15. https://doi.org/10.1890/ES12-00348.1

Tomas, J., Gozalbes, P., Raga, J. A., & Godley, B. J. (2008). Bycatch of loggerhead sea turtles: insights from 14 years of stranding data. *Endangered Species Research, 5*, 161-169. https://doi.org/10.3354/esr00116

Whittow, G. C., & Balazs, G. H. (1982). Basking behavior of the Hawaiian Green Turtle (Chelonia mydas). *Pacific Science*, *36*, 129-139.

Wibbels, T., & Bevan, E. (2016). A historical perspective of the biology and conservation of the Kemp's Ridley sea turtle. *Gulf of Mexico Science, 33*, 1–9. https://doi.org/10.18785/goms.3302.02

Wiggins, A., & Crowston, K. (2011). From conservation to crowdsourcing: a typology of citizen science. *44th Hawaii International Conference on Systematic Sciences*, *Kauai*, *HI*, 1–10.

Witherington, B., Kubilius, P., Brost, B., & Meylan, A. (2009). Decreasing annual nest counts in a globally important loggerhead sea turtle population. *Ecological Applications*, *19*, 30-54. https://doi.org/10.1890/08-0434.1

Acknowledgments

SDU is thankful to both Wingate University and the Biology Department for conducting this research. No permits were needed as this manuscript summarizes data on the freely available citizen science platform iNaturalist, shared via creative commons.

Authors contributions

SU was responsible for all aspects of study design, revising, data collection, and manuscript preparation.

Funding

Not applicable

Competing interests

The authors declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.