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Yaun, Kailey C. *Citizen Science Effectiveness among Sea Turtle Conservation Projects*

Abstract

Citizen science for herpetology is a growing area for research and conservation. Sea turtle conservation efforts are made vastly easier with citizen scientists or volunteerism focusing on education and population protection. Citizen science projects for sea turtles in the U.S. concentrate on the nesting and hatching seasons of sea turtle species that find suitable habitat on coastal beaches. Life history information, species identification, crawl identification, and threat identification are some aspects of conservation that are addressed with citizen scientists. I reviewed four sea turtle conservation and research projects which include the North Carolina Sea Turtle Project, South Carolina DNR Marine Turtle Program, SEE Turtles, and State of the Worlds' Sea Turtles. All projects involve volunteerism to some degree which include duties such as nest identification and monitoring, protection and relocation of nests or carcasses, and compiling and sharing data. Based on the projects evaluated, there is a calling for data, research, and conservation strategies to be shared among the global sea turtle conservation community. Volunteers provide extensive research projects with a variety of assistance.

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Chapter I: Introduction

Following a set of steps to answer a question is essentially what science is, and is a process truly open to anyone (Landgraf, 2013). Citizen scientists have long endeavored to understand the environment, although the term itself is fairly recent. A citizen scientist is essentially a volunteer from any background who collects data for use in organized research (Shirk & Phillips, 2015). Historically, hundreds of thousands of volunteers have donated their time to environmental and conservation programs. Citizen science can involve any group of people in research or conservation and provide the manpower to cover a great span of time or distance. However, volunteers may not have any formal training or interest beforehand and expressing the importance of the project may be a difficult task.

The conservation of marine turtles is crucial to coastline and oceanic ecosystems. The protection of these species is a shared global responsibility as many coastlines and beaches are used by female sea turtles to lay nests and much area is covered in migration for forage and reproduction. Having such an extended geographical region, it is not possible to monitor or protect the populations without the help of many willing individuals. This reason is just one of many reasons volunteers are encouraged to learn and help with conservation. These volunteers are then dubbed "citizen scientists" for their commitment to help biologists and conservationists with research projects. Citizen science can be employed in many forms, and a few are explored for this study.

Citizen Science

Citizen science has been shown to sometimes be the only practical way to cover sufficient geographic extent to address some ecological questions. A large range may be required to document ecological patterns and species range shifts, disease spread, migration patterns, broad-scale trends in population, effects of changes in national and state policy, and impacts of environmental processes such as climate change (Tulloch et al., 2013). For instance, a database of citizen science bird observations was used to evaluate spatiotemporal variation in avian migration across an unprecedented geographic region in North America to explain variation of phenologic responses to climate change (Hurlbert & Zhongfei, 2012). Hurlbert and Zhongfei found differences of mean arrival dates (from 0.8 days to 3-6 days per every ˚C of warming) across 18 common species and geographic regions from the database that would have been impossible to document without such an extensive dataset.

The drawback for such large scale measures when involving many citizen scientists is quality control of data collection and specificity. Training for such tremendous projects needs to be detail-oriented and consistent across similar projects. To address these concerns, an Incidence Function Model (IFM) can be applied, however there are problems of datasets not being at an appropriate scale in order to fit the model (Graham et al., 2015). Downscaling data by empirical models, spatial processes, and expert opinion are implored. The new patch level scale after these methods are used is helpful to eliminate false presences of species which would make parameter estimates biased (Graham et al., 2015). Using non-specialists has its risks, but some of these can be mitigated with quality control and appropriate analytical methods.

Citizen science is not a very new method but a greatly expanding one. The longest-running program of citizen science has been The National Audubon Society's Christmas Bird Count in the United States which started in 1905 and has accumulated over 110 years of data (Tulloch et al., 2013). This count was started by an ornithologist, Frank Chapman, who proposed an end to traditional Christmas side hunts and to count birds instead (Landgraf, 2013). Since the initial bird counting, a new wave of advanced equipment and methodology has ensued.

Networking technologies and distributed databases as well as geospatial analysis and imaging techniques have been brought to bear as levels of public involvement in citizen science efforts grow (Bonney et al., 2009). Historically citizen scientists have been embraced by ornithology, paleontology, astronomy, and atmospheric sciences (Bonney et. al., 2009), whereas herpetologists have only recently begun to develop citizen science programs and call upon volunteers.

Sea Turtle Conservation

Research on and conservation of the worlds' sea turtles is one area of study benefiting from the contributions of citizen scientists. Humans have been interacting with sea turtles since 5000 B.C.E. (Frazier, 2003), and within the last 50 years research and conservation communities have shown an increase in awareness of and focus on the many threats and hazards sea turtles are presented with (Donlan et al., 2010). Presently sea turtles at critical life stages are especially vulnerable to potentially lethal interaction with anthropogenic activities (National Research Council Staff, 1989). The egg, hatching, nesting stages in coastal waters, as well as the sub-adult and adult oceanic stages, are all susceptible to a great number of activities including predation and habitat modification, capture or entanglement in fishing gear, physical damage from dredging or channels, collisions with boats and ships, underwater explosions, and ingestion of debris (National Research Council Staff, 1989).

All sea turtles have a similar basic life history and temperature affects every life stage (Davenport, 1997). Of the seven species of sea turtle that swim the oceans, all were listed under the U.S. Endangered Species Act by the mid-1970s (Donlan et al., 2010). This includes loggerhead *(Caretta caretta)*, leatherback *(Dermochelys coriacea)*, hawksbill *(Eretmochelys imbricate)*, Kemp's ridley *(Lepidochelys kempii),* green *(Chelonia mydas),* and olive ridley

(Lepidochelys olivacea). These species must be protected, managed, and studied to ultimately increase population size and decrease anthropogenic deaths and population decline.

The loggerhead and leatherback sea turtles tend to be the focus of major sea turtle research and conservation programs. The global population of nesting loggerhead females is estimated to be 60,000 by the World Wildlife Fund. The global population of leatherbacks is estimated as 36,000 nesting females according to the Sea Turtle Conservancy (n.d.). Although these estimates give us a general idea of population sizes, they are imprecise and may not be completely accurate (*Information About Sea Turtles: Leatherback Sea Turtle,* n.d.*; Leatherback Sea Turtle (Dermochelys Coriacea),* n.d.*; Leatherback Sea Turtle*, n.d.*; Life Cycle of Leatherbacks,* n.d.) . It is possible that a population estimate for any sea turtle species can be generated with long-term trends or changes of individual population sizes (National Research Council Staff, 1989). Because females return to the same beaches to lay nests year after year, counting the number of nests laid or nesting females can provide a good indicator of population status (National Research Council Staff, 1989). Perhaps the best way to estimate population viability is by a stage-based model measuring reproductive output, probability of surviving and growing into the next stage, and the probability of surviving and remaining in the same stage (Crouse et al., 1987).

Loggerhead sea turtles undergo abrupt changes developmentally in their habitat, behavior, and resources (McClellan & Read, 2007). In the western North Atlantic, hatchlings disperse from their nests after six weeks to two months upon being laid, crowding the beaches as they have to overcome many obstacles to embark on their first swim (*Loggerhead Turtle (Caretta, Caretta),* n.d.*; Loggerhead Sea Turtle,* n.d.*; Loggerhead Turtle,* 2017). Once the hatchlings swim offshore, they become pelagic, living in the open ocean away from the sea floor or coastline. This time of the oceanic life stage was once thought of as the 'lost year' when their whereabouts were not known. Now we know that this 'lost year' is approximately a decade long of wandering the Atlantic (McClellan & Read, 2007).

After reaching sexual maturity, adult sea turtles return to coastal waters to reproduce. Female sea turtles expend a lot of energy to lay nests on coastal beaches. They migrate many miles to gather at nesting beach locations. Once the females are at nesting beaches, they emerge from the waters at night to excavate a hole in the sand for the egg chamber, deposit the eggs, fill and cover the nest to protect it, and return to the sea. They may repeat this process several times in a season, and they will continue to nest every other year or so throughout their lives while not breeding every year (Davenport, 1997).

Anthropogenic threats to sea turtle populations throughout their lifetimes are aplenty. During the hatching stage artificial lighting can threaten their safety, as well as predation and harvest. During the juvenile and adult stage threats may include incidental capture in fishing gear, boat strikes, predation and harvest, or ingestion of floating debris. When females nest, artificial lighting can also affect the process as well as loss or degradation of nesting habitat, beach armoring, or non-native vegetation. Any change to their terrestrial or oceanic habitat can affect any and all stages (National Research Council Staff, 1989). Due to the extent of anthropogenic factors affecting these populations, as well as the highly migratory behavior of sea turtles, monitoring and conserving sea turtles should be viewed as a shared responsibility.

Study Objectives

Citizen scientists have proven to be great tools in scientific research and projects, and continue to play important roles regionally and globally in the conservation of sea turtle species. There are a number of forms of citizen science, and recognizing how citizen science is implemented is important to understanding its impact for conservation. Citizen science could be a valuable tool for conservationists concerned for the current situation and fate of the worlds' sea turtles. In this study I aim to identify, compare, and contrast different roles of citizen scientists in connection with sea turtle conservation, speculate the positive effectiveness of citizen scientists, and highlight the value of sea turtles conservation.

Chapter II: Methodology

Due to the nature of this study involving programs' website information, much "grey" area information was looked at. This notion has been taken into account in which website information be treated as delicate and to only use information available to the public, finalized information, or otherwise given consent to use. Many other websites, programs, and publications have been viewed in the search of the final information gathered and used.

Subject Selection and Description

I found literature about citizen science and/or sea turtle conservation using Google Scholar and the university library to search for the key words 'citizen science', 'sea turtle conservation programs', 'citizen scientists and sea turtles', and 'roles of citizen scientists'. Studies were then filtered further based on context to find those specifically related to sea turtles or to successful or historical programs wherein citizen scientists were involved. I visited each sea turtle conservation program's website, and the breadth of information provided was the criterion for which programs were included.

For each program, I recorded information about the program itself and the involvement of citizen science. I recorded when the program was initiated, the geographic scope of the program, the active time period, and its' funding streams. I categorized the mission of each program as pertaining to either or all categories of sea turtle conservation, sea turtle research, sea turtle population monitoring, and/or sea turtle education. I also recorded how many volunteers or volunteer hours had been documented, what roles were performed by volunteer citizen scientists, and if training was included and how.

Chapter III: Citizen Science Case Studies

I found sufficient information on the North Carolina Sea Turtle Project, South Carolina Marine Turtle Conservation Program, SEE Turtles, and State of the World's Sea Turtles. The oldest and longest running programs are the North and South Carolina programs initiated within the same decade, while the most recent is the program SEE Turtles. I found citizen scientists have been involved in many ways among these programs including species identification, nest monitoring, nest identification, nest relocation, responding to sea turtle strandings, and sharing and compiling data. Each program involves a number of volunteers ranging from 500 to 1,200 members.

North Carolina

The North Carolina Wildlife Resources Commission initiated monitoring sea turtle nesting activities in the late 1970s. Debbie Crouse began studying density, distribution, and chronology of nesting in the early 1980s, which established baseline data and led to the creation of the Sea Turtle Protection Program administered by the NCWRC's Nongame and Endangered Wildlife Program (now known as Wildlife Diversity Program). This prompted the development of the North Carolina Sea Turtle Project with the goal of "monitoring [North Carolina's] sea turtle population" (*Project Overview)*.

North Carolina has approximately 330 miles of coastline sandy beaches that provide suitable habitat for nesting, and monitoring would not be possible without the helping hands of hundreds of volunteers. Several private organizations and public agencies coordinate nest surveys and nest protection actions. In 2011, approximately 700 volunteers participated in sea turtle citizen science in North Carolina, accounting for the one of the largest networks of volunteers in sea turtle conservation of the U.S. Atlantic coast states among the Carolinas, Georgia, and Florida (Cornwell & Campbell, 2012). All subprojects submit their results to the NCWRC, which compiles the information for state and federal agencies.

The NC Sea Turtle Project (NCSTP) trains their volunteers on a number of essential monitoring measures. The hundreds of participants are trained how to identify crawl patterns of sea turtle species, identify nests, mark and monitor nests until hatching, and respond to sea turtle strandings. These trainings and a number of helpful resources are available on the project website. Thus, volunteers have easy access to materials such as the Handbook, Stranding and Salvage Network Report Form, Necropsy Report Form, Individual Crawl Record, Annual Sea Turtle Nest Report Form, and others that specify samples to collect, guides, and species identification. The participants monitor the beach coastlines from May until August, guard nests July until October, as well as respond to strandings through all these months and help biologists from the NCWRC tend to and transport injured sea turtles to rehabilitation centers.

South Carolina

The South Carolina Marine Turtle Conservation Program (SCMTCP) is run by the South Carolina Department of Natural Resources (SCDNR). The program was established in 1977 with management research on beaches and tracking of post-nesting loggerheads in water. Nesting surveys and protective measures are carried out by a variety of public agencies, such as the SCDNR, as well as several private organizations. According to www.dnr.sc.gov/seaturtle (*SC Marine Turtle Conservation Program: Protecting Sea Turtles for Future Generations,* 2013), the program is committed to and responsible for “managing and protecting sea turtles in South Carolina”.

There are over 30 nest protection projects on the coastline of South Carolina that are under the umbrella of the South Carolina Marine Turtle Conservation Program. The program provides training and support to over 1,100 participants each year who protect nests and document sea turtles that wash ashore along the coast. The participants that help are a mix of paid federal and state employees, as well as many volunteers that run projects on their own, although the estimation of how many volunteers is not disclosed on their website.

The project requires all individuals participating in a nest protection program be trained by the SCDNR to acquire state permits in order to be able to manipulate any nests and handle stranded turtles or carcasses. There is an exception to this for federal personnel at Cape Romain National Wildlife Refuge in southeastern South Carolina. The training involves both classroom and field interaction and covers several topics. The activities include “beach patrol”, “nest relocation/inventory”, “nest protection”, “administration/organizational”, and “strandings”. Training aids in the form of printed materials, slides, and videos are used and protection project leaders and volunteers attend an annual spring workshop. Volunteer methodology and any questions are checked at each project beach twice per season with site visits. One site visit is made during nesting months and the other during hatching months.

The SCDNR offers a unique public support system to sea turtle conservation. The Endangered Species License Plate can be purchased from the South Carolina Department of Motor Vehicles for $30 in addition to registration fees every two years. This purchase shows the support for endangered and threatened species with a picture of a hatchling loggerhead. The hatchling is representative of the many months spent on nesting surveys and protection by the SCDNR and is dedicated to their volunteers. The funds acquired from the license plates go to the SCDNR and are used to help protect the endangered and threatened species of the state.

SEE Turtles

SEE Turtles is the first ever world effort to protect sea turtles through ecotourism. Launched in 2008 and originally supported by Oceanic Foundation, it has expanded to include educational programs which have reached over 10,000 students in the U.S. and Latin America, Billion Baby Turtles project, and the Too Rare To Wear and Travelers Against Plastic campaigns. SEE Turtles is now an independent non-profit organization based out of Beaverton, Oregon, although Oceanic Society continues to manage the tours.

Their mission is to “protect endangered sea turtles throughout Latin American and the world by supporting community-based conservation efforts through ecotourism, education, and 'Billion Baby Turtles’”. On the project website, www.seeturtles.org, they provide information on the role of volunteerism. More than 500 citizen scientists have completed approximately 3,500 work shifts at turtle projects since 2008. ‘Billion Baby Turtles’ has helped more than 800,000 hatchling turtles get to the sea across Latin America. Ecotourism plays a role in supporting SEE Turtles’ mission and over 1,000 tourists have visited projects that have supported local communities and conservation (*About SEE Turtles*).

SEE Turtles provides people with the opportunity to help conservation activities through travel and education. Interested individuals can volunteer with a project for short or long term (over a week) in many months of the year and a variety of locations, depending on the project. One example is working with leatherbacks in Costa Rica during nesting season. SEE Turtles partners with 15 organizations and 6 Latin American countries to accomplish connecting volunteers to community-based sea turtle projects. SEE Turtles also depends on support from “green businesses”, private foundations, and other individuals.

State of the World's Sea Turtles

State of the World's Sea Turtles (SWOT) is a worldwide team that works to protect sea turtles and their habitats. SWOT is a network committed to compiling the most recent data across projects, regions, and countries to provide the global picture of sea turtle status. It was established in 2003 by Conservation International, the IUCN Marine Specialist Group, the International Sea Turtle Society, and Duke University. These institutions observed the lack of an up-to-date global picture of sea turtle status and wanted to take on this challenge. They sought out first to document the status of leatherback turtles in 2004 during the nesting season. Many researchers and conservationists at leatherback nesting sites were invited to join their 'SWOT effort', and the year 2006 marked the first ever publication addressing leatherback nesting with a global map (*SWOT History*). Their vision as described on their website, www.seaturtlestatus.org, is to "create a permanent global network of specialists working together to accelerate the conservation of sea turtles and their habitats, pooling and synthesizing data, and regularly sharing the information with audiences who can make a difference".

SWOT is a different kind of sea turtle conservation project in that their volunteerism strives to help advance work of those already involved in sea turtle conservation and bring information to new audiences. This is unique from NCSTP and SCDNR because the involvement is directed towards specialists willing to be transparent and trusting in sharing and compiling data. Instead of targeting the typical citizen scientist, who may have no background in science or conservation activities, SWOT targets those who are already established specialists and field-based sea turtle researchers.

Hundreds of individuals and institutions provide data to the network. An individual or institution can join online and can become 'Data Providers' to help track worldwide nesting patterns. Downloadable reports appear on their website and include much information on the sea turtle species, case studies in different countries or regions, challenges the sea turtles face, new state-of-the-art technology helpful for conservation activities, global nesting patterns, and much more. Over 1,200 SWOT team members, as well as authors, publishers, photographers, organizations, cartographers, designers, artists, and assistants have made it possible to recently publish their 11th report. New partners are recruited each year, and in 2012, Oceanic Society, a non-profit organization based in San Francisco Bay area, took over managing the SWOT Project.

Chapter IV: Results

The projects reviewed have goals ranging from monitoring to protection to education and scopes ranging from local and state levels to global conservation efforts. Each program involves a vast set of individuals, jobs, and duties involving between 500-1,200 individuals. We can begin to evaluate the success of each program by exploring the strategies used to carry out their missions and visions, such as nesting counts and protection measures, enumerating individuals participating as volunteers or reached by education, and assessing funds raised for projects.

Nest observations are a critical component of most sea turtle citizen science projects. Both SCMTP and SEE Turtles specify protection of sea turtles as a goal. SEE launched Billion Baby Turtles in 2013 specifically to protect hatchlings from poaching, getting caught in fishing gear, plastic pollution, or other obstacles that have caused endangerment. The primary activity used to address this goal is observation and physical protection of nesting sites. Monitoring is the primary goal of NCSTP, and they also rely on nest observations. In the season of 2016 for NCSTP, the record number of loggerhead nests was counted: 1,621 nests laid. No other projects have finalized to the public nest count numbers for 2016, but Billion Baby Turtles reports that they have helped more than 800,000 hatchlings since 2013 at 12 nesting beach sites in Mexico, Costa Rica, Cuba, Nicaragua, Guatemala, and El Salvador. However, only time will tell how many of these hatchlings will be recruited into the populations and survive until adulthood. Population modeling has shown that improving survival of hatchlings has limited impact on population viability for loggerhead sea turtles (Crouse et al., 1987), and the same is likely true for other species with similar life histories.

Success of projects such as these may be measured in other ways than how many nests or eggs a season brings. Volunteer involvement and training, education and outreach, and fundraising are all factors of success. Volunteerism is especially important to NCSTP, SCDNR, and SEE Turtles. Dr. Matthew Godfrey is the sea turtle biologist for the NCSTP and when asked via email about the assessment of using volunteers for the NCSTP his response was, "Overall, using volunteers is crucial to collecting data needed for assessing that status of recovery metrics for sea turtle populations. At the same time, volunteers play a role in protecting nests, monitoring for threats, and raising awareness with beach visitors. In this context, I would say it is successful. Of course, nothing is perfect and things could always improve." (Godfrey, M., personal communication, April 8, 2017). NCSTP and SCDNR sea turtle programs are trained volunteer based or run projects which are successful with the many individuals who help and support their efforts in protecting and monitoring sea turtles. More than 500 SEE Turtles volunteers have been connected to projects and have patrolled beaches, guarded hatcheries, or other important activities adding up to over 3,500 shifts. SEE Turtles has also trained more than 100 teachers and community leaders at 10 important projects in Costa Rica, Nicaragua, and El Salvador.

Education and outreach of some media is seen in all programs I have reviewed. SCDNR sea turtle program has a very similar agenda as NCSTP wherein nest protection, education, data collection, and education are important factors to sea turtle status. SWOT produces reports for audiences to view and learn from in hopes of furthering support and knowledge. SWOT also has an initiative of providing up-to-data perspectives on sea turtle distribution and status. Knowledge of this type requires many collaborators and a transparent and trusting environment. Release of their first report was a major success having provided a global map of leatherback sea turtle nesting. The reports published are available and directed to all different audiences to understand the wide range of data of sea turtle conservation. The success of establishing a network this large says volumes of the outreach. SWOT is different from NCSTP, SCDNR sea turtle program, and SEE Turtles due to its nature of volunteerism from specialists.

SEE Turtles' education outreach promotes class presentations, scholarships for students to visit conservation projects, teacher training workshops, and bilingual lesson plans. The class presentations have been given to over 800 students in U.S. and Canada. Scholarship funding has been provided for over 2,000 Latin American students to visit nearby turtle projects. Also, through SEE Turtles' School Fundraisers, more than 1,200 students have had a part in helping more than 15,000 hatchlings.

Funding is also an important factor to success of sea turtle programs. SCDNR sea turtle program has the unique Endangered Species Specialty License Plate to help raise funds necessary for conservation activities. SEE Turtles measures conservation success by the $800,000 generated for conservation and local communities, turtle conservation tours and volunteer programs, Billion Baby Turtles, and sea turtle education. SEE Turtles claims they can save at least one baby sea turtle per every dollar raised with its partner organizations. Turtle conservation tours and volunteer programs contribute to success by helping local organizations sustain work and bringing alternative sources of income to the areas turtles are threatened.

In addition to bringing in funds, SEE Turtles awards small grants to partners to fund the removal of fishing gear and fund training guides in Baja California Sur. They have helped a women's cooperative expand an innovative recycled plastic bag program, and they have also supported a vast amount of sea turtle educational programs in Costa Rica, El Salvador, Nicaragua, and Mexico. Also, $45,000 has been raised for hawksbill sea turtle conservation through partners in the Eastern Pacific Hawksbill Initiative and is projected to help more than 90,000 hatchlings.

Between these four programs, thousands of individuals and organizations have succeeded in monitoring and protecting many nests, raising awareness, helping hundreds of thousands of hatchlings, raising a great amount of money for conservation activities, and collecting much needed data on sea turtle status. With a growing number of helpful hands and protection, especially from individuals upwards to the federal government, the number of sea turtle populations can be assessed, monitored, and ultimately with hope, saved from threats and endangerment.

Chapter V: Discussion, Conclusion and Conservation Implications

Citizen science may be an essential tool for conservation and research. Sea turtles cover a large geographical area throughout their life cycles. Due to this range, it is imperative research and conservation for these species are cooperative among regions. Citizen scientists help in many areas of activities for sea turtles as shown by case studies presented. How effective the helpfulness is to sea turtles can be dependent on factors such as protective measures, educational outreach, data collection, and threat monitoring. These factors are some among the roles volunteers play into the case studies of North Carolina, South Carolina, SEE Turtles, and State of the World Sea Turtles.

Discussion

Volunteerism is an alternative way to collect data for large projects. Sea turtles may depend greatly on individuals and organizations willing to volunteer their time for protection and monitoring. With a reduced survival and recruitment rate caused by human activity, conservation efforts are necessary. Whether these efforts are stemming from field-based research specialists, or the retired neighbor next door, they are key to sea turtle populations.

Successful monitoring and protection for programs such as NCSTP and SCDNR cannot be done without proper beach protection. The coasts of these states are indeed critical habitats for loggerheads and the government is starting to respond. A total of 739 miles of U.S. coastline was proposed in 2013 to be protected by the federal government upon many conservation lawsuits (Center for Biological Diversity, 2013). The proposal covered 84% of known loggerhead nesting areas and spans from North Carolina to Mississippi. In July of 2014 the government protected 685 of those 739 miles from North Carolina to Mississippi, and more than 300,000 square miles of ocean on the Atlantic and Gulf Coasts. Projects along these coasts, including NCSTP and

SCDNR sea turtle program, may now have more easement in the data collection of sea turtles as well as a crutch for protection.

The North Carolina Sea Turtle Project, South Carolina DNR Marine Turtle Conservation project, and SEE Turtles use volunteers from any background to collect data for use in organized research. State of the World's Sea Turtles is a special case where most individuals are specialists with varying backgrounds related to sea turtle research and conservation, and these individuals volunteer their data and research. All cases are eager to educate others and spread the word of sea turtle facts, history, data, and conservation tips. Although ornithology programs are the classic examples for citizen science, it is evident by these case studies that there are valuable herpetology research and conservation citizen science programs within the U.S. and other regions.

Due to the nature of this study being a literature review, there were limits to acquiring information. As stated previously, herpetology citizen science projects are fairly recent in development and therefore more study is needed on these programs and projects. Given the extent of information available on the case studies their effectiveness can really only be speculated, to a point. Not all projects have specific quantitative measures to make formal assessments on whether citizen scientists have an appreciable influence on sea turtle status.

Whether or not the nest and egg numbers that are protected shows success quantitatively warrants further investigation due to the growing amount of nest protection projects. The simulations developed by Crouse, Crowder, and Caswell (1987) suggests that the key to improving the outlook of populations lies in reducing mortality in the later stages, particularly the large juveniles of the populations. Putting forth a model to project numbers and assessing the model with the real number of additional hatchlings protected by these projects may be a way of measurement. This may be a challenging task, however, because estimating the required parameters could mean following the thousands of new sea turtles through their life cycle. This would take an astronomical amount of time, effort, technology, and finances. This is perhaps why tagging and monitoring of adult sea turtles has been a big area of research and holds the key to improving the outlook (Crouse et al., 1987).

Educational outreach to the public is a great tool to gather support for programs and projects towards sea turtles and conservation. A questionnaire or study of how many people visit nesting sites and talk amongst those working at nesting sites may be helpful to see what people ask about and learn. SEE Turtles was able to identify the number of people that have visited beaches of their projects. This number can show how many are at least curious about what the projects' mission is. Further evaluation of these numbers and the insights those visitors are taking away can be a great aide for conservation.

Conservation Implications

Success of citizen science programs can be achieved by public outreach, increased protective and conservation measures, and the assistance with strandings or rehabilitation. The more information the public has, the more likely others can be involved in monitoring and protection or help in other ways such as beach cleanup or turning off artificial lights during hatching season. The more that these projects are written and talked about, the more the public can know about the importance of sea turtles and conservation.

Sea turtles have quite an interesting life history that involves migration of many miles for different stages. Conservation efforts of sea turtles in the U.S. reflect nesting season due to the suitable beaches on the coasts. Other areas of the world may make efforts such as tagging and distribution research through visualization (Willams et al., 2015) or GIS in which adult turtles can be monitored. The combination of nesting and adulthood studies captures the sea turtle journey from both sides and teaches us valuable information. Budgets for studies such as these may not be readily available, and this is one reason why volunteerism provides tremendous assistance. Raising money and awareness for these projects makes it easier for better training, technology, rehabilitation facilities, equipment, and more. The specialty license plate in South Carolina and Billon Baby Turtles by SEE Turtles are two creative ways conservationists have raised awareness and money.

Matthew H. Godfrey, PhD, sea turtle biologist of the NCSTP, stated towards the mortality rate of sea turtles, “In terms of the 1 in 1000 saying, I have also heard 1 in 5,000, 1 in 10,000, etc. Nobody knows for sure, although there is consensus that the general idea that hatchlings have a high rate of mortality is true.” (Godfrey, M., personal communication, April 8, 2017). Diminishing the amount of human activity that negatively affects the survival rate of sea turtles can be addressed using citizen scientists. All seven species of sea turtles are captivating audiences around the globe, and ecotourism is an adventurous way to involve participants that do not live near the populations. Taking a stroll on a beach to identify crawls and nests, tracking threats, monitoring nests, assisting stranded carcasses, and educating others are all activities that citizen scientists undertake to contribute to projects presented in this study. In conclusion, NCSTP, SCDNR, SEE Turtles, and SWOT show the different ways volunteerism is helpful to sea turtles species.

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