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Sea Turtle Conservation at Tortuguero: A Case on How to turn an Ecological Challenge into a Collaborative Opportunity for Research, Education Outreach, and Business Development

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Introduction

Sea turtles used to be abundant. It was common to see many of them appear on beaches along Central America and the Greater Caribbean. Every season, these turtles would come ashore to nest. Then, after the eggs hatched, baby sea turtles would crawl into the sea and embark on a journey to seek foraging grounds. Some might travel across thousands of miles on their journeys. Interestingly, at the proper time, they would follow different paths and make their way back to the original birth region to repeat the cycle. Such a natural process of sea turtles has taken place for many years. However, something has happened to disrupt this very cycle and threaten the survival of these amazing animals.

Sea turtle populations worldwide have declined significantly to an alarming level (Lyer, 2022). For instance, Costa Rica used to see a striking abundance of sea turtles coming to its coasts. It is a favorite place where female sea turtles would come and lay eggs. Specifically, within Costa Rica is the area called Tortuguero where females of 4 species of marine turtle: the green, the leatherback, the hawksbill, and occasionally the loggerhead would come to lay eggs and hatch for many years (Gutiérrez-Lince et al., 2021). Yet, now all four species are classified by the International Union for Conservation of Nature (IUCN) as either endangered or critically endangered (Seminoff, 2004; Wallace et al., 2013; Mortimer & Donnelly, 2008; Casale & Tucker, 2017).

The decline of sea turtles worldwide is a serious warning sign of an impending extinction of the various species if no action is taken to curb this trend. Sea turtles are not the only endangered, but there are others on the growing list of animals facing extinction. Is there an effort that an individual, a group, a community, a nation, or a group of nations can come together and meet a grave challenge to the sustainability of life on earth in general? Specifically, what has been done to save sea turtles? The answers to these questions are beyond the scope of this paper. However, what we present in this paper is a successful case of how an effort to save sea turtles has turned into a collaborative opportunity for research, education outreach, and business development. Our hope is that the lessons learned from this case can be applied to other ecological challenges and generate possible solutions to these complex environmental problems.

The paper is organized as follows. The first section provides a context of the case. Then, it briefly describes the threats that led to the work in conservation. The next section presents how the research, tracking, and monitoring were done in the conservation of sea turtles from the scientific and technological perspective. It is then followed with the highlight of Tour-de-Turtles that has brought together scientists, researchers, volunteers, officials, leaders from government, education, business to form a local and international community to save sea turtles. The final

section is a reflection on the collaborative efforts by all stakeholders and the role of information technology (IT) in supporting the efforts.

Background of Tortuguero

Tortuguero is a small village on the north-east Caribbean coast of Costa Rica. Tortuguero National Park is located to the south of the village of Tortuguero. Every year, between 17,400 and 37,290 female sea turtles are estimated to lay their eggs in Tortuguero, and their presence has provided a source of income for Tortuguero villagers for decades (Tortuguero National Park, n.d.). Income generation began with the extractive use of their meat and eggs. As sea turtles become endangered, the extractive use was prohibited. Following the creation of the Tortuguero National Park (TNP), turtles became central to ecotourism activities, which is now the base of the local economy (Gutiérrez-Lince et al., 2021).

Threats to sea turtles

Several nesting populations of the green, the leatherback, the hawksbill and the loggerhead in Central America and the Greater Caribbean are declining. There are many different factors contributing to this decline. Climate change, global warming, and increase in hunting pressure of sea turtles are among these factors. Directly related to human activities is the fishing and hunting of sea turtles. For many years, people caught and poached sea turtles for meat, shell, and raw materials for making products (Troëng and Rankin, 2005).

The threats from fishing, hunting, and poaching could be traced back to the growing demand of sea turtles in the marketplace since the arrival of Europeans to the New World. In recent years, efforts have been made to reduce such a demand. Furthermore, education about the decline of sea turtle populations and the risk of sea turtles extinction make people more aware of the need to protect these animals. Improvements in the economic life of local communities as well as government policies also help curbing the decline in sea turtle populations. However, the threats from environmental factors are harder to measure and mitigate. It requires more research and understanding to protect the livelihood of sea turtles and sustain and grow their populations.

There have been many initiatives aiming at protecting and recovering sea turtle populations around the world. Over the years, sea turtle conservation has gradually become one of the very active global initiatives with contributions from many different people in various regions. Specifically in Costa Rica, conservation relies on research to understand different aspects of sea turtle biology, life patterns, and movements being undertaken by governmental programs, universities, environmental organizations, as well as non-governmental organizations, such as the Sea Turtle Conservancy (STC) (Gutiérrez-Lince et al., 2021).

Sea Turtle Conservation in Costa Rica

Efforts by the government

Specifically in Tortuguero, the work on sea turtle conservation began over six decades ago. It was apparent to Dr. Archie Carr, even back in the 1950s, that something had to be done to protect green turtles if they were to continue to survive in the Caribbean (Troëng and Rankin, 2005). What he did was to share his early research results with influential government officials, in an effort to increase their protection. The government took notice and implemented a series of measures to limit the over-harvest of turtles. Among them were a series of decrees to ban sea turtle hunting and exporting and the foundation of Tortuguero National Park in 1975.

Unfortunately, as in many countries, Costa Rica's Ministry of Environment and Energy is under-funded and understaffed. One of the STC's major priorities at the moment is lobbying for a change in legislation that would allow funds raised from tourist entrance fees to be used for management within the National Park instead of being sent to the central Government.

Conservation through research and field work: tagging, telemetry, data collection and analysis.

To be able to lobby the government effectively, STC needs to provide sound advice and propose viable policy recommendations. To be able to do so, STC in turn relies on research to better understand how sea turtles live, migrate, and reproduce. Carrying out such research requires mechanisms to track, monitor, and follow sea turtles. For many years, the core area of research has focused on how to identify individual turtles and find out where they go when they leave the nesting beach.

The invention of flipper tags was an important breakthrough that helped shed light into the seemingly mysterious movements of sea turtles (NOOA Fisheries, n.d.). Each tag carries a unique number on one side. Its main purpose is to identify individual sea turtles. On the other side of the tag is the contact information of a conservation organization or a research center. With these tags, anyone who encounters a tagged sea turtle may return the tag to the address provided along with information on where the turtle was found. This was how sea turtle movements were tracked in the early days. Currently, technology has advanced so much that researchers can gain much more accurate and timely data when tracing and tracking movements of sea turtles. One of the most commonly used technologies for tracking sea turtles is satellite telemetry (NOOA Fisheries, n.d.).

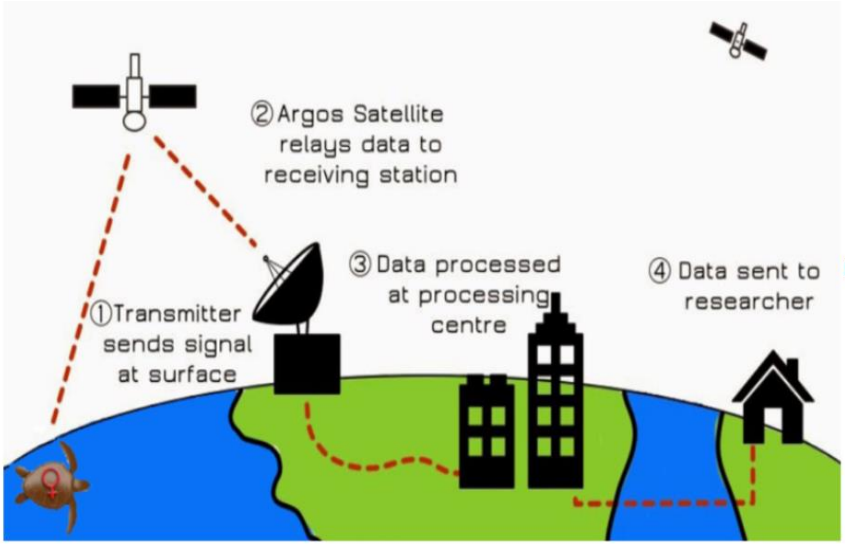

Figure 1: Illustration of how satellite telemetry works (Graphic adapted from OceansIQ.com)

Figure 1 shows how satellite telemetry works (Tracking marine animals, 2014). The system basically consists of four components: a transmitter mounted on a sea turtle, a satellite to receive and transmit data, a receiving station, and a data processing center. When a turtle surfaces to breathe, its transmitter sends data to the closest satellite. The receiving satellite then relays the data to a receiving station and from there, the data are transmitted to the processing center.

There are several important technological evolutions related to tracking sea turtles (Hays & Hawkes, 2018). One of the earlier systems was the Argos tracking network introduced in 1978. The Argos satellite tags could relay up to 256 bits of data per 15 second uplink. In 2014, Fasloc-GPS was introduced with faster speed and more data transmission. With GPS, the location data was much more accurate. The advanced data compression was applied for uploading and downloading. As a result, remote biologging approaches to record aspects of an animal's behavior and movement, alongside the biophysical conditions could be collected. 3-D movement data became feasible with the use of accelerometry to reconstruct the likely movement of an animal. At the same time, tag technology continues to benefit from the advent of innovative information technology and more advanced materials. More robust tags are produced and deployed using long lasting battery duration. Currently, tags can operate much more efficiently. They can be deployed for a longer time and are subject to less interference with movements. Development of robust metrics, large databases, and open data for access have also contributed

to deeper and broader understanding of sea turtle movements (Hays & Hawkes, 2018).

Tracking green turtles

In recent years, STC has started to utilize more modern technologies to increase its knowledge of marine turtle behavior. To discover in more detail the routes that turtles take once they leave Tortuguero, researchers at STC have attached satellite transmitters to turtles. Figure 2 is the case in point.

Figure 2: A green turtle with a transmitter and the track of its movement as observed

The photo on Figure 2A shows a green turtle returning to the sea with her transmitter in place. It is attached to the carapace using a type of epoxy resin, and then held in place with layers of fiberglass. Each time the turtle surfaced to breathe a signal was sent to the satellite and her location was recorded. These location data were then used to plot a precise map of her movements as shown on the map at the right in Figure 2B. In this example, one green turtle had been followed by satellite telemetry after nesting at Tortuguero. Its tracks are shown on the map. Based on the data collected and analyzed, researchers at STC were able to follow and track this specific turtle as shown before its signal was lost.

Using flipper tags to follow movements of sea turtles

Before the advent of satellite transmitters over 47,000 green sea turtles and over 600 leatherback turtles were flipper-tagged at Tortuguero, and 4,469 green turtle flipper tags (or around 9.5%) have been recovered. These flipper tag returns have enabled researchers to determine where the turtles go when they finish the nesting for the season. With these available data, a visualization of their movements could be constructed. Figure 3 provides an illustration of the locations from where tags from green turtles have been returned.

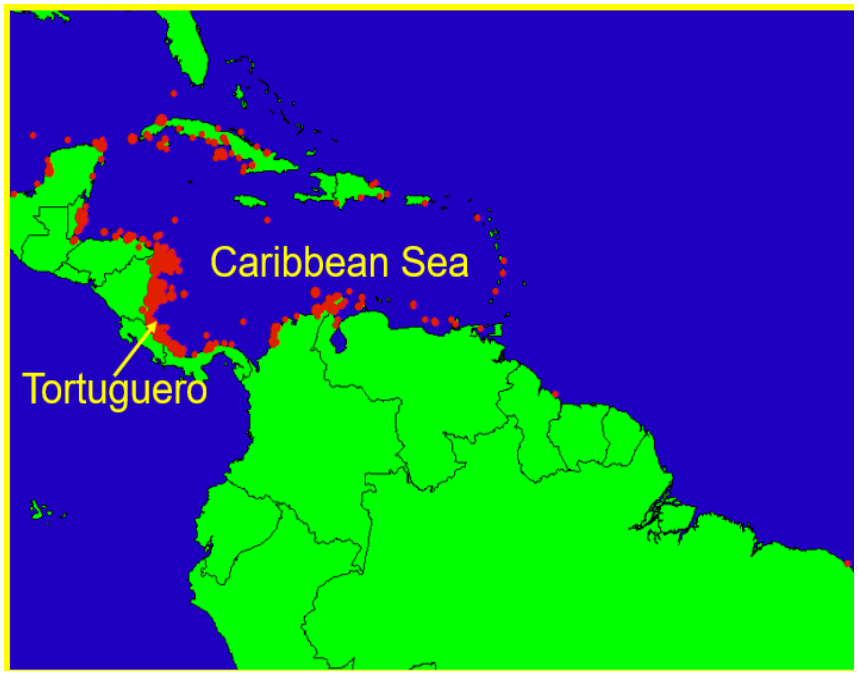

Figure 3: A simple tracking map of green turtles

There are some interesting observations to note about Figure 3.
_ Firstly, green turtles that nest in Tortuguero were migrating hundreds if not thousands of miles from the nesting beach to return to their feeding grounds. The distribution of the red dots shows that tags had been returned from many different countries around the Caribbean; 19 countries in total, including Nicaragua, Mexico, Cuba, Colombia, the eastern coast of Florida. The furthest point from which a green turtle tag had been returned was from a turtle tagged in Tortuguero in 1999 and her tags were recovered in 2001 in Brazil, a distance of around 5,200km!

_ Secondly, the majority of the tag returns were coming from Nicaragua waters - 82% (3,638) of the recovered tags had come from feeding grounds off the Nicaraguan coast.
_ Thirdly, an important implication was that turtles were migrating across international boundaries during the course of their lifetime. This highlights the need for international cooperation in conservation efforts.

Ecotourism - Tour de Turtles (TdT)

With the advent of tourism in Tortuguero, there has been a shift in the way that the local community use sea turtles to generate income. Previously sea turtles were used in a purely extractive manner. Primarily, they were hunted and poached for their meat or shell. Nowadays, the key income generation comes from tourism. The use of sea turtles is predominantly non-extractive with a focus on conservation and sustainability.

STC came up with an innovative and entrepreneurial way to use the science and technology of satellite tracking sea turtles as an educational tool as well as a platform to raise funds. The previous program provided free tracking maps online and free educational resources, but was passive. The development of the Tour de Turtles started in 2008. This was a significant step up in expanding the sea turtle conservation effort beyond scientific research. It represented an initiative to reach out to broader communities and to bring in needed funds as well. One of the targeted communities is educational institutions from K-12 to higher-ed. Various kinds of tours with a focus on sea turtles were organized. For instance, at college and university levels there were opportunities for students to visit places such as Tortuguero to study, to do field work, to learn about ecology and environmental issues. There were also educational tours for high schoolers. These educational activities were offered on site and off site.

However, one of the very successful activities is Tour de Turtles (TdT). TdT organized by STC is an annual event. Its purposes are many-fold. One is to promote awareness of sea turtle conservation and research work. Another is to offer an educational opportunity for people to learn about sea turtles and its biology. At the same time, the event also provides a mechanism for economic and workforce development for the local community. Finally, it helps raise the needed funds to support conservation work.

Here is the basic concept and process behind TdT as described on the website of TdT at https://tourdeturtles.org/. At the core of TdT is a unique website designed specifically to support the program, which contains additional resources, animations, turtle characters, and introduces a discussion of different threats to sea turtles that are appealing to children and educators. The home page is set up as a "race" and shows the relative distance traveled since tagging, compared to the other turtles, each turtle swam since the start date of TdT. There are now 2 different TdT

races, one that features leatherbacks only, and the other one that features other sea turtle species. This is done since leatherbacks tend to travel longer distances.

The "winner" of each race would be the turtle that swims the farthest distance in a set amount of time. For leatherbacks, it is from June 26 to October 31, while for the other species it is August 1 to October 31. Each turtle has its own character and is given a name by their sponsor, usually a company that provides the funds for the satellite transmitter and other associated costs. Each turtle is assigned a threat to swim for and raise awareness about. This is based on the idea that marathon runners often run for a cause to raise awareness about that cause or issue. If a sponsor has a specific cause request, it can feature the cause on the webpage; otherwise, the organizer would assign a specific cause to a sea turtle to make sure different causes are included.

Figure 4: An example of a turtle biography page

Figure 4 shows an example of the biography page for each turtle including a photo, a created background and personality for the turtle, as well as the cause and sponsor.

The Map Page on Figure 5 shows each turtle's tracking map and has the distance traveled since the start of TdT. Most turtles are fitted and deployed with a satellite transmitter before the official TdT's start date, but only the distance from the start date is counted.

Figure 5: An example of a turtle map page

In addition to all these web pages above, there is also a leaderboard based on the real-time data. It is posted on the website for people to track and follow. The sponsor page lists all the causes (threats) associated with turtles in the current TdT. It provides a brief description of the threat and a link to the turtle, or turtles, associated with that cause. Additional information about each cause is provided on

the turtle's cause page with background information, species affected, possible solutions, a case study, and related links for more information. The people 's choice award tries to encourage people following the TdT to support, or cheer on, a turtle and raise awareness about their cause. Points are awarded to a turtle based on the number of times they are selected as part of STC's "Adopt-A-Turtle" program or each time they are tagged in a Tweet. There are some additional points through other social media platforms and contests.

Educational resources are provided to incorporate different aspects of satellite tracking into the classroom or programs. Topics include math, biology, conservation, and geography. Lesson plans are developed by teachers who have knowledge or experience with sea turtles. At the end of TdT, a winner is announced and the results are posted on the website. Figure 6 is an example of a recent winner of TdT.

Figure 6: Feature one of the 2022 TdT winners

Since its start in 2008, TdT has evolved to become a fun, educational journey through the science, research and geography of sea turtle migration using satellite telemetry. The business model of TdT was based on the scientific work at STC. With a vision to reach out to others beyond the scientific community, STC

has worked with sponsors, volunteers, and partners to create an interesting event that follows the marathon migration of sea turtles, representing four different species, from their nesting beaches to their foraging grounds. TdT tracks individual sea turtles, for approximately three months, as they leave their respective nesting beaches and race to complete a "turtle" marathon. Turtle competitors set out to swim with the goal of becoming the one that swims the furthest distance during the migration marathon.

Reflection

Before his death, Dr. Archie Carr urged young researchers to dedicate more time to studying how and where sea turtles migrate and what mechanisms they use to return from thousands of miles away to the same tiny stretch of beach. In particular, Dr. Carr lamented that the use of satellite telemetry to track turtles in the open ocean had not yet reached the required level of sophistication. Well, Dr. Carr would be pleased to see what is being done with satellite technology today to study and protect sea turtles. Anyone can get involved in a conservation effort such as TdT at STC by helping raise awareness about their cause. Specifically in the TdT at SCT, while one may not know the outcome of the race, one thing is certain: saving sea turtles is a marathon, not a sprint! (Tour de Turtles, n.d.)

The case started with the awareness of an emerging ecological challenge. Specifically, the threat of endangered species was triggered by the significant decline of sea turtle populations. The impact was real and visible in places like Tortuguero, Costa Rica. What used to be abundant along the coast began to disappear and became an endangered species. The risk of the potential extinction of sea turtles alarmed many people. Something needed to be done to protect the sea turtles in places where they feed, breed, nest, and hatch.

Costa Rica had responded. The case at Tortuguero National Park is a good model for how to face and deal with an ecological threat through concerted conservation efforts. As described in the case, it took leadership, proactive response, collaboration, and innovative ideas to bring together various stakeholders including researchers, volunteers, educators, entrepreneurs, and local communities for a good cause. An ecological problem such as the risk of sea turtle extinction is complex. Taking appropriate actions to mitigate is not a small task. Yet, through concerted efforts over six decades, the case at Tortuguero demonstrates a good model of how to turn a challenge into an opportunity to advance research, protect endangered sea turtles, build up local communities through ecotourism, engage educators, students, and volunteers in the conservation work, and raise money and awareness for the cause.

One of the interesting aspects in this case is the role of IT. First, IT has played a critical role in making it possible for researchers to track and monitor sea turtle movements. Tagging was used and then satellite telemetry was deployed.

Data was collected and analyzed. Then came the use of the internet and computers to capture, store, process data into information. Through the web and social media, information was disseminated. Innovative and entrepreneurial thinking as demonstrated in the case not only expands the initiative beyond the scientific community but also sustains and enhances it with newer technology, more resources, and wider support from various stakeholders. Now, what presented in the case is a successful working model including features of scientific research, conservation effort, educational outreach, fundraising mechanisms through events such as annual sea turtle research conference, ecotourism like TdT, workforce and economic development with conservation-related initiatives. The approach from this case can be adopted and applied in other contexts. Through working together with the capabilities offered by technologies, a challenge can be turned into an opportunity. The result is a win-win for all.

Conclusion

The case as presented in this paper starts with a brief introduction of the STC's conservation efforts in Tortuguero, Costa Rica over the last six decades. The efforts have involved many stakeholders including research scientists, government officials, volunteers, partners from universities, business leaders, and experts in applied technology. In the beginning, the focus was on making people aware of the severe decline in sea turtle populations. The government had to intervene by passing decrees to ban sea turtle hunting and poaching. At the same time, educational campaigns were launched to help people change from being sea turtle predators to protectors. Business investments were made to create opportunities to generate revenue not from killing sea turtles but from ecotourism. While the threat to sea turtles is far from over, the efforts to save them, constitute a remarkable story. More and more people are part of the efforts. The conservation work is now world-wide. An event such as TdT is the case in point. It represents an innovative and entrepreneural way to combine science, technology, and business together to face an ecological challenge. It connects together needs and resources and is able to draw people year after year to respond to a common cause through education and engagement. The success of TdT can serve as a working model to guide how a community of concerned people should respond to a common issue. As in the case of sea turtles, the approach is simply to turn a challenge into an opportunity for interdisciplinary research, education outreach, and business development.

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