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Citizen Science Contributions to the Conservation of Sea Turtles Facing Port City and Land Use Stressors in the Mexican Central Pacific

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Abstract: The unplanned development of a port city generates urban growth in its coastal zone that stresses the local biotic and abiotic resources, affecting the nesting beach areas of sea turtles. This work evaluated the impact of social collaboration on sea turtle conservation in response to coastal rigidization. Over the past twenty years, the Manzanillo Port (Colima), located in the Mexican Central Pacific, underwent vigorous development and urbanization. This growth has produced stressors including increasing levels of marine noise pollution due to the transit of merchant ships, the decrease in 4.3 ha in beach areas, and increased light pollution, which likely reduced the number of turtles that reached the nesting stage. Despite the above, the number of turtle nests has increased thanks to social collaboration through protection actions, education programs, and the participation of volunteers along with public and private organizations supported by the media and social networks. These actions are part of citizen science and contribute to the balance between urban development and the protection of sea turtles, reducing environmental vulnerability in the coastal zone. This success story can be reproduced in coastal cities for other wildlife species to achieve a social-ecological benefit through advocacy projects that involve the empowerment of local inhabitants and the appropriation of their landscapes and natural elements. These projects will contribute to alleviating the effects of coastal rigidization in the face of future challenges that will require solutions to different environmental aspects of imminent climate change.

Keywords: sea turtles; citizen science; rigidized coast; coastal urbanization

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1. Introduction

According to the United Nations, about 40% of the population around the world lives in coastal areas, boosting infrastructure development to meet the basic demands of the population [1]. This unplanned development has affected coastal ecosystems and natural populations of vulnerable species such as sea turtles [2–4]. In Manzanillo, a city in the state of Colima located on the west coast of Mexico, as in other regions of the world, sea turtle nesting has been disrupted by urban development fostered by port, tourist, urban, and residential growth [5]. All of these, together with the illegal consumption and trade of turtle eggs and meat, has resulted in the decline of the nesting populations of sea turtles in Mexico; it exceeded its maximum capture level in 1970, when the country contributed more than 70 % to the world's production of turtles, mainly olive ridley. As a result, it declared

the total closure of turtle fisheries in 1990 [6], aiming to protect the six species that reach the Mexican coasts [7]. Despite having a legal framework, regulations, and laws for sea turtle protection, illegal sea turtle captures are still prevalent as a result of the identification of nesting areas, the continued improvement of fishing gear, and other economic activities such as tourism [8], given the current limited surveillance or lack of command-and-control strategies in coastal management.

Tourism is one of the main economic sectors worldwide, especially the "sun, sand and sea" modality [9]. In Mexico, this industry generated profits amounting to US$209BN in 2018, with beach destinations like Manzanillo receiving more than 75% of tourists [10]. The main effects of tourism on the nesting process of sea turtles are related to the increase in the erosion of beaches and dunes since buildings prevent the natural transport of sediments, resulting in the reduction of the substrate and, therefore, of nesting areas [11]. Tourist urbanization produces visual and noise pollution from artificial lighting and beachfront activities which alter the nocturnal behavior of turtles and their nesting site selection [12,13]. As a result, turtles either do not nest or do so in sections of the beach that are subjected to direct wave action, also affecting the return to the sea of both females and hatchlings, which lead to the alteration of its population [14].

Moreover, the port industry plays a central role in the economic development of many countries, including Mexico, where Manzanillo is the largest port in the Mexican Pacific [15]. It has caused alterations in sea turtle nesting grounds and produces noise pollution from the transit of marine ships, disrupting the behavior of turtles and affecting their sea routes [16,17]. Additional stressors derived from port activities include the collision of vessels with turtles, hazards derived from pollutants (fuels and chemical wastes), incidental fishing of turtles entangled in fishing gear, and the risk of choking from swallowing plastic waste [18,19].

On the other hand, climate change is likely to bring major consequences for sea turtle populations. The rising sea level and the increasing number of severe storms have impacted beach erosion rates, reducing the availability of turtle nesting sites [20], ultimately impairing the sea turtle population dynamics [21,22]; besides, the rise in sand temperature affects egg development by skewing the sex ratio towards females and affecting the size and locomotion of hatchlings [23–25].

These alterations of the coastal zone in the face of climate change have prompted the adoption of urgent measures to meet the objectives of sustainable development [26], including the conservation and sustainable use of marine resources, as well as ensuring that cities and human settlements are inclusive, safe, resilient, and sustainable. Accordingly, mitigation actions have been proposed in various affected areas, including the collaboration of several actors, including government agencies, the tourism industry, private stakeholders, non-profit associations and groups, academic researchers, and the social sector [27]. There are numerous cases in which social awareness and participation have contributed to the successful conservation and management of different species of sea turtles [28–31] and other biodiversity topics. This type of action is known as *Citizen Science*, a participatory science initiative that implies a comprehensive way of connecting people with biodiversity and the challenges facing its conservation. It entails the interaction of volunteers from the general public with scientists and specialists for the development of plans for the conservation of species and the conduct of research in informal learning settings through observation and experimentation, using methods and techniques to generate knowledge and improve understanding. This approach allows society to engage with nature through collaboration, recreation, and various participatory projects whereby learning, environmental awareness, and education for sustainability are encouraged [32–35].

In the city and port of Manzanillo, a sea turtle camp carries out activities aiming at the conservation of sea turtles that arrive at the local beaches, mainly through the rescue and release of turtle hatchlings. The objective of the present work was to evaluate the impact of social collaboration on the conservation of sea turtles in response to urban-port growth and

climate change as drivers of coastal rigidization as a success story in the Mexican Central Pacific that is potentially suitable for replication in other coastal regions of the world.

2. Materials and Methods

2.1. Study Area

Manzanillo Bay is located in the Colima state, Mexico, in the Mexican Central Pacific (19°07′12″–19°02′24″ N and 104°22′48″–104°18′00″ W). It includes Salagua Beach and Las Brisas Beach, which together comprise 6.7 km of coastline. These beaches have an intermediate morphodynamic profile resulting from the low wave impact associated with their geographic location within a protected area [36]. *Campamento Tortuguero Manzanillo*, a non-extractive sea turtle camp, is located at its western end (Figure 1).

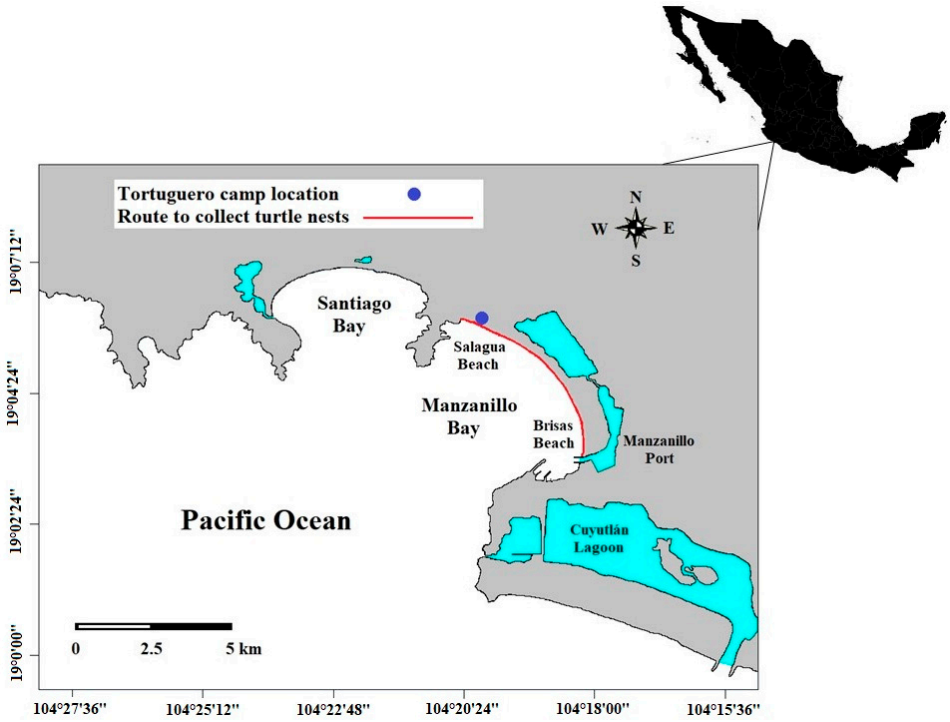

Figure 1. Study area. Location of the sea turtle camp in Manzanillo, Colima. The beach where the study was carried out is marked in red.

2.2. Port and Urban Growth

Port growth was determined based on the evolution of the arrival of commercial ships and the cargo transported between the years 2000 and 2020, as per the official information provided by the Integral Port Administration of Manzanillo [32].

Urban growth, from the perspective of coastal rigidization or loss of coastal plasticity and the changes in beach surface in the study area resulting from space occupation, was evaluated through an analysis of the spatiotemporal variability that modifies its amplitude, use, and functionality derived from oceanographic conditions and coastal settlement. To this end, we used Google Earth® satellite images in the Universal Transverse Mercator (UTM) coordinate system for the spring months (March to April) of 10 years: 2003, 2004, 2012, and 2014–2020 because clear images to quantify beach area were available only for these years. Subsequently, the polygons for the analysis of the beach area were delimited considering the wet zone as the seaward limit and urban infrastructure and areas devoid of dune vegetation as the landward limit. The estimated area (m^2) was compared between the individual years studied, as well as the overall change in surface area between the years 2003 and 2020. This allowed the identification of differences, changes, and trends in the beach area resulting from the construction of infrastructure and buildings, considered

as indicators of the rigidization of sandy and dune areas, with potential effects on sea turtle nesting.

2.3. Social Relevance

Indicators reveal and determine patterns of change and trends based on variables, records, or parameters; in the case of the social-ecological context, the selection of indicators considered data sources including social networks and newspaper publications, using a search engine and the keywords *turtle hatchling releases*, *egg rescue*, and *collaboration*, which returned several records. These were classified by year and analyzed according to content to identify temporal trends in the effect and local social awareness of the activities carried out by the Manzanillo Turtle Camp (*Campamento Tortuguero de Manzanillo*; CTMC, in Spanish). The results presented herein correspond to the period between the years 2012 and 2020 because no prior electronic records of the local newspapers are available that would support a representative search. We also consulted statistical data available on the Facebook page of the CTMC, analyzing data on the number of followers, scope of publications, and interactions with publications. Additional factors considered to determine the social impact on the operational activities of CTMC are the number of supporting organizations recorded, including in-kind contributions, monetary donations, the direct participation of students from primary to college levels, support from municipal and state authorities, as well as from companies linked to port operations, civil organizations, and the general public.

2.4. Protection of Sea Turtles

The CTMC started operations in the 2001 nesting season. Since its beginning, the routes for egg collection from sea turtle nests have remained unchanged over 6.7 km along the Salagua and Las Brisas beaches between July and December, but camp operations continue until February of the following year when the last hatchlings emerge, and turtle hatchlings are released to the sea. The variable considered to measure turtle protection efficiency was the number of nests monitored per season between 2011 and 2020 and also is considered an indicator of response and success recognize in the protection of sea turtles and biodiversity. These results are compared with those obtained in the same period by the other two camps, El Chupadero and Cuyutlán, which operated in the Colima state with the same purpose, protection. Data provided by the Department of Technical Supervision of the Secretary of the Environment and Natural Resources (SEMARNAT in Spanish), Colima state delegation.

To gather data on the potential impact of light pollution on sea turtles (although there are no data from previous nesting seasons), light pollution was estimated for December 2020 at 16 sections of the most intensely illuminated beaches in Manzanillo Bay, with one used as reference. To this end, an Extech Model 401036 Light-meter and a Garmin Map66S GPS were used, as well as a DJI Mavic Air2S DRONE to obtain aerial images as evidence of the luminosity at beach level. Two determinations were made in each section of the beach, one in the splash zone and another in the upper part near the urban limit, up to the level reached by sea turtles to lay a nest. Depending on the length of the beach, there were sections where several determinations were made.

3. Results

3.1. Port and Urban Growth

The total cargo in transit through the Manzanillo port between the years 2000 and 2020 shows a positive trend, increasing from 12,019,338 tons to 31,504,297 tons (Figure 2a). This trend was related to the number of commercial vessels, which increased over the same period from 1077 commercial vessels in the year 2000 to 1859 in 2020 (Figure 2b). In 2020, the port covered 437 ha, including storage areas and 19 docking positions (14 commercial sites, three sites dedicated to hydrocarbon trade, and two dock sites for cruise ships) [15].

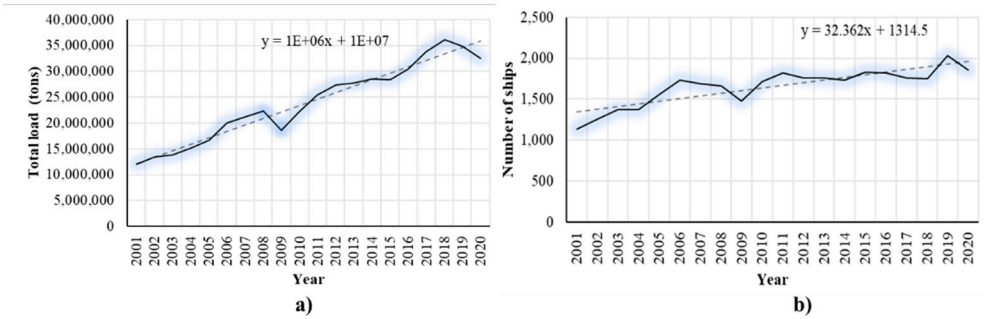

Figure 2. Evolution of the Manzanillo port between the years 2000 and 2020. (**a**) Total cargo transported; (**b**) Number of commercial vessels.

Urban growth was related to a reduction of the beach-front area (rigidization) of Manzanillo Bay where turtles arrive for nesting, resulting in a reduction in area from 22.5 ha to 18.2 ha between the years 2003 and 2020, respectively (Figure 3). This period shows variations in beach-front area, reaching a minimum size of only 15.2 ha in 2017. Contrasting the occupation zone in the year 2000 versus 2020 (Figure 3b,c), the Manzanillo port grew 105 ha associated with the increased operations and confinement of containers. This growth was related to the demand for port services, as well as urban development and growth, and was reflected in the population growth of the city of Manzanillo from 125,143 inhabitants in 2000 to 191,030 inhabitants in 2020 [37].

3.2. Social Relevance

Figure 4 shows a positive trend per year in the number of regional newspaper references related to sea turtle protection activities carried out by the Manzanillo Turtle Camp, Colima, between the years 2012 and 2020, with a peak of 17 references in 2017. The Facebook official Camp page (Tortugario Manzanillo, s. f.) recorded 15,971 followers in 2020, while the number of social media posts and shares increased from 8770 in 2012 to 17,778 in 2020.

3.3. Protection of Nets Sea Turtles

The activities carried out by the camp consist of tours along the beach for nest location and collection, transport, and planting of eggs in camp facilities. These tours are conducted from 22:00 h to 05:00 h from Monday to Sunday during each nesting season. Newly hatched turtles are released to the sea in the evening hours, at sunset. During the release of turtles, talks are delivered to the general public, informing them of the importance of the species, its ecological role, and conservation actions. Persons are advised that sea turtles should neither be disturbed during the egg-laying process nor consumed or traded, as these are illegal actions according to the environmental regulations currently in force in Mexico. The target audience includes students from primary level to senior high school, and these talks are delivered in public places and through different media (radio, television interviews), as well as in research and academic forums including the participation of students and college lecturers.

Figure 5a shows the evolution of protected nests by CTMC, with average hatching of 80%. The most abundant species during the study period was the olive ridley sea turtle (*Lepidochelys olivacea*), accounting for 99% of the protected organisms, followed by the Pacific green turtle (*Chelonia agassizii*) (or *Chelonia mydas agassizii*) with 0.7%, and finally the leatherback sea turtle (*Dermochelys coriacea*) with 0.3% of the protected turtles. There has been a positive evolution in the number of protected nests, which has remained on the rise, from 67 protected nests in 2001 to 1138 in 2020. Only 10 volunteers from two institutions (University of Colima and Manzanillo City Council) participated in the 2001–2002 season; by 2020, civil participation had increased to 110 volunteers from different schools and academic levels, institutions such as the City Council, civil associations, Tourist Police,

Secretariat of the Marine, and social organizations of Manzanillo (Figure 5a). Likewise, the support and participation of different institutions and port companies in the region through economic and in-kind donations to institutional interventions went from 2 to 18 over the study period (Figure 5b).

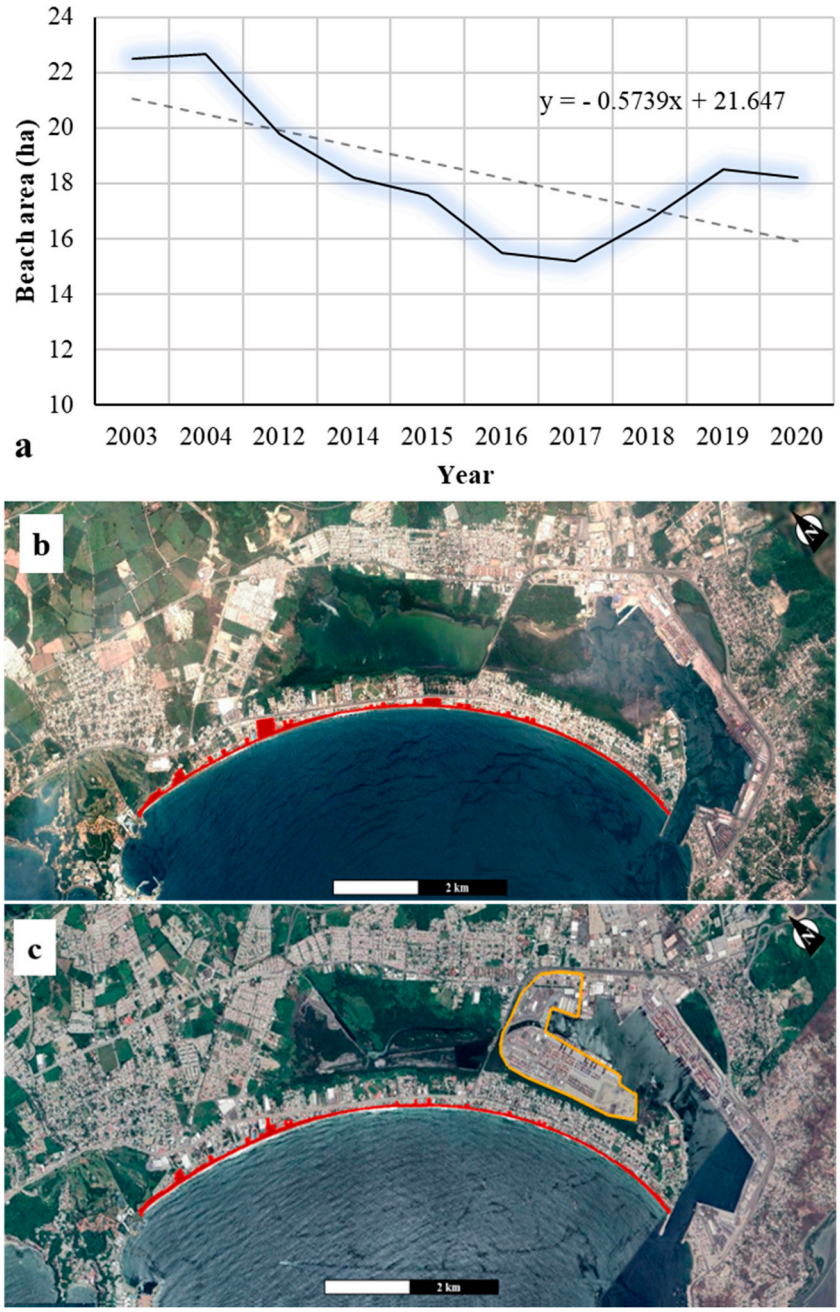

Figure 3. (**a**) Loss of beach area (rigidization) in Manzanillo Bay (ha) between 2003 and 2020. (**b**) In red, available beach area in 2003 (**c**) In red, available beach area; in yellow, the new area of the Manzanillo Port, in 2020.

Figure 6 shows the results of the other two turtle camps that operate in the Colima state, El Chupadero, and Cuyutlán. The data show the evolution of protected nests with respect to the main species of sea turtle that arrives to spawn, the olive ridley sea turtle. It is observed how, although the arrival of turtles is greater, their trend in terms of the number of protected nests is not homogeneous, and in recent years, they have shown a downward trend contrary to the results obtained in the CTMC in the same period.

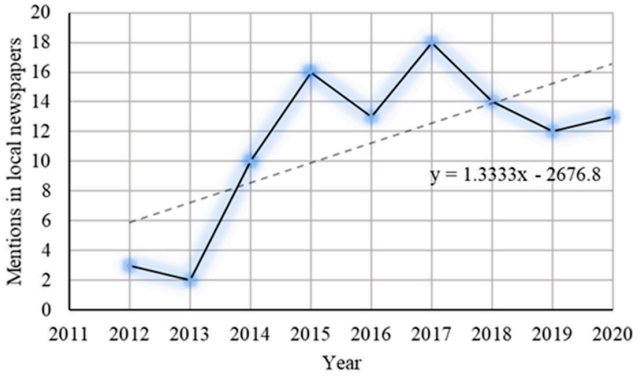

Figure 4. Evolution of the number of publications on sea turtle protection activities in regional newspapers.

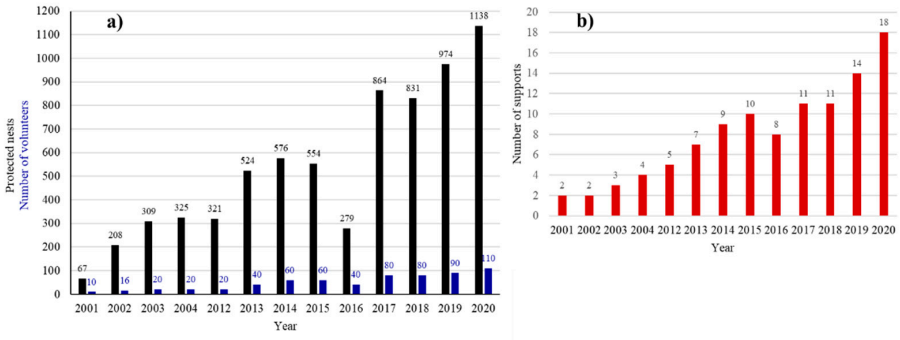

Figure 5. (**a**) Evolution of nests protected and number of volunteers, and (**b**) number of supports recorded by the Manzanillo Sea Turtle Camp, Colima, in the period 2001–2020.

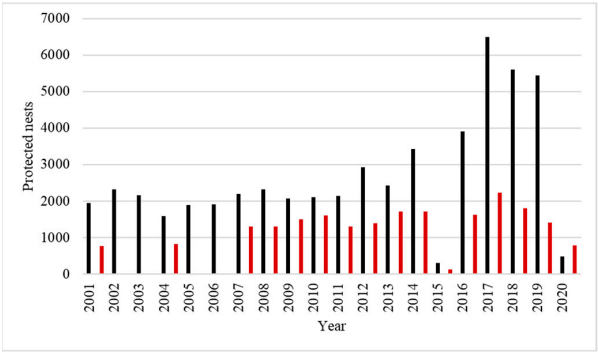

Figure 6. Evolution of nests protected of olive ridley sea turtle (*Lepidochelys olivacea* or *Chelonia mydas agassizii*) in Chupadero Camp (black) and Cuyutlán Camp (red) in the period 2001–2020. Unpublished official data provided by the Department of Technical Supervision of SEMARNAT, Colima delegation.

Table 1 shows how the amount of light perceived on the beach increases from the western region of the Bay of Manzanillo (Salagua Beach) to its eastern part (Las Brisas Beach) in front of Manzanillo Port, where urban nightlife and port activities have grown (Figure 7). Light records go from 1.45 Lux to 6.45 Lux in the splash zone, even reaching 216 Lux in the urban limit in this section; in contrast, the reference site records <0.05 Lux. To note, 1 Lux is equivalent to 1 Lumen·m^{-2}, which is the intensity of illumination (of visible light) on a surface. A reference standard technical about Lighting in Sea Turtle Nesting Areas (Environmental Technical Regulation for Lighting in Sea Turtle Nesting Areas of the Dominican Republic [38]), indicates that the intensity of the lighting lamps should not exceed 11 lux. That is, there is a factor of disturbance and potential disorientation for sea turtles.

Table 1. Amount of light recorded in different sections of the Manzanillo Bay beach. S = splash zone, UL = urban limit.

Section of Beach		Lat	Long	Time	Lux
Salagua beach	S1	19° 6.2001′	104° 20.2364′	20:00	1.45
	UL	19° 6.2075′	104° 20.2254′		11.5
Family Condo 1	S2	19° 6.1579′	104° 20.0875′	20:20	1.79
	UL	19° 6.1644′	104° 20.0798′		5.76
Supermarket	S3	19° 6.1291′	104° 20.0408′	20:40	1.14
	UL	19° 6.1454′	104° 20.0360′		5.49
Bar 1	S4	19° 5.9783′	104° 19.6583′	20:50	0.72
	UL	19° 5.9700′	104° 19.666′		6.03
Mall	S5	19° 5.9214′	104° 19.5762′	21:05	1.07
	UL	19° 5.9258′	104° 19.5463′		3.3
Hotel 1	S6	19° 5.8645′	104° 19.4657′	21:16	1.33
	UL	19° 5.8757′	104° 19.4552′		10.02
Restaurant 1	S7	19° 5.8033′	104° 19.3619′	21:25	0.21
	UL	19° 5.8143′	104° 19.3519′		8.03
Hotel 2	S7	19° 5.7123′	104° 19.2334′	21:36	2.9
	UL	19° 5.7206′	104° 19.2272′		18.6
Restaurant 2	S8	19° 5.5261′	104° 19.0007′	21:47	0.84
	UL	19° 5.5159′	104° 18.9817′		9.17
Restaurant 3	S9	19° 5.2821′	104° 18.7519′	22:05	2.11
	UL	19° 5.2723′	104° 18.7412′		33.6
Mechanical	S10	19° 5.068′	104° 18.581′	22:20	0.1
workshop	UL	19° 5.070′	104° 18.591′		4.59
Restaurant 4	S11	19° 4.9859′	104° 18.5235′	22:39	0.7
	UL	19° 4.981′	104° 18.529′		9.86
Restaurant 5	S12	19° 4.7142′	104° 18.3647′	22:52	6.3
	UL	19° 4.7179′	104° 18.3736′		14
Hotel 3	S13	19° 4.4954′	104° 18.2869′	23:07	0.23
	UL	19° 4.4969′	104° 18.2803′		4.85
Brisas Beach	S14	19° 3.9473′	104° 18.1755′	23:30	1.3
In front of	UL	19° 3.9152′	104° 18.1669′		39.8
Manzanillo Port	S15	19° 3.8844′	104° 18.1779′	23:45	3
	UL	19° 3.8854′	104° 18.1676′		63
	S16	19° 3.8731′	104° 18.1778′	23:50	4.38
	UL	19° 3.8728′	104° 18.1690′		28
	S17	19° 3.8500′	104° 18.1775′	23:55	2.6
	UL	19° 3.8486′	104° 18.1661′		216
	S18	19° 3.7936′	104° 18.1867′	0:00	0.56
	UL	19° 3.7927′	104° 18.1775′		4.8
	S19	19° 3.7745′	104° 18.1854′	0:04	1.54
	UL	19° 3.7731′	104° 18.1779′		10.66

Table 1. *Cont.*

Section of Beach	Lat	Long	Time	Lux
S20	19° 3.7498′	104° 18.1881′	0:08	2.7
UL	19° 3.7493′	104° 18.1812′		21.6
Reference site	19° 7.1872′	104° 22.3591′	0:40	<0.05

Figure 7. Different nighttime views of the Las Brisas Beach section showing the impact of light on the sand. The machinery of Manzanillo Port can be identified in the background of the images.

4. Discussion

In Manzanillo, port facilities and infrastructure have undergone sustained growth over the past 20 years, reflected in the increase in tons of cargo transported and the arrival of ships (Figure 2a,b). As a result, Manzanillo is currently the largest cargo port in Mexico, with a 68% share in the Mexican Pacific and 48% at the national level, accounting for 67% of the country's GDP. Its influence zone covers the central and northeastern part of the country—the most industrialized zone that is home to 55% of the Mexican population. Internationally, it serves the Pacific Basin, the west coast of the American continent, Oceania, South Africa, and, to a lesser extent, the European Union [39]. It has been documented that the increase in national and international economic transactions and port growth are drivers of business and employment opportunities that boost the growth of port cities. In turn, these favor the creation of multimodal terminals and industries grouped by sector at the periphery, whose demands for services foster local development [40,41]. In the 2020 population census, Manzanillo was the city with the most vigorous population growth over the past decade and was the most populated city, even above the capital city of the state of Colima, evidencing the development boosted by port growth [37]. The images for years 2003 and 2020 illustrate this growth, which amounts to 105 ha (Figure 3c), linked to urban development, which has led to the rigidization of the coastal zone of Manzanillo Bay. The expansive and fragmented patterns of urban growth that characterize most human settlements imply several unresolved challenges in their relationship with the natural environment. The accelerated urbanization rates have promoted changes in land use that, although difficult to delimit and evaluate, generate impacts well beyond the landscape level that become social-ecosystem functioning issues [42].

The changes in the physical features and processes of the local environment (rigidization) in the coastal zone resulting from anthropogenic activities are linked to a warmer world at a higher risk of disasters. As a result, nature as we know it is currently a socio-cultural fabric where the boundaries between the human and the natural have become

blurred; today, nature is a space emerging from the coupling and interplay between human societies and natural systems. There is talk of human nature, with minimal wild nature, if any; currently, ecosystems show different degrees of human interaction, which differ in their degree of naturalness or humanity [43,44]. This transformation of natural processes has reached such a magnitude that it is identified with the ability of human beings as a global transforming force [45], which has led to a reduction in biodiversity from the fragmentation and destruction of ecosystems worldwide, and has led to a 100- to 1000-fold increase in the extinction rate of species, higher than the geological standard, and may cause the disappearance of 20% of the total animal and plant species by 2030, particularly in the coastal zone. This entails the loss of protection against erosion, and the lack of regulation of the quality and volume of water available in environments that are essential for higher species such as sea turtles.

The anthropogenic pressure due to the commercial growth of the port has produced increased levels of underwater noise that may cause hearing loss in birds, sea turtles, and marine mammals [46]. For Manzanillo Bay, it has been reported that the noise produced by ships transiting to and from the port ranges between 130 and 170 dB and occurs 81.8% of the time throughout the year, on average; it should be considered as a potential source of impact for wildlife living in the area [47]. Likewise, it has been reported that light pollution linked to coastal settlements affects the nesting of sea turtles by disrupting turtle nesting attempts, contributing to hatchling disorientation and failure to return to the ocean, and leading to higher egg predation rates [48,49]. Although no light pollution data were available for years prior to 2020, it is evident that urban growth along the coast has also generated increased light intensity levels, which translate into another human stressor with considerable repercussions on the arrival. of sea turtles.

The beach, as a heterogeneous coastal environment where the atmosphere, mainland, water, organisms, and microorganisms co-occur with intense ecological interactions, together with biological and cultural diversity, is extremely important for social and economic development at all latitudes [50]. Today, climate change stands out among the major abiotic variables affecting this environment. It is now certain that human greenhouse gas emissions have caused a 1.2 °C increase in air temperature compared with pre-industrial levels; this increase will impact the rise in mean sea level, even in intertropical latitudes, due to continental ice melting [51,52]. In Mexico, 17 sites were studied across the Gulf and Pacific coasts to assess the impact of climate change on mean sea level since 2000. For the Manzanillo Port, a dataset from 1954 to 1994 was reviewed, finding a rising trend of 3.28 mm per year [53]; this could mean an estimated rise of 65.6 mm for the year 2020. On the Mexican Pacific coast, many coastal areas currently host urban and industrial settlements where the effects of climate change will result in unavoidable systemic disruption and high disaster costs. This will lead to progressive environmental degradation of coastal habitats that exacerbate these ecological and economic effects [54]. Environmental health seeks to understand the physical, chemical, biological, and anthropogenic factors that affect their interactions or alter the ecological balances that are essential for the preservation and maintenance of a healthy environment [42]. These include climate change that specifically affects aquatic ecosystems in inland and marine environments, supplying multiple environmental goods and services to society [55]. As a result, the coastal zone is undergoing changes in its development and utilization, with socioeconomic and environmental effects that will increase in the coming years and will be reflected in different patterns of land use and urban structure, leading to higher population densities compared to non-coastal areas in Latin American countries [56,57].

Knowledge of social-ecosystemic services, as well as the understanding thereof by the local inhabitants, has shown that it can affect the behavior of society toward conservation practices. In the face of a scenario of limited success or indifference by governments and corporations to seriously commit themselves to address environmental risks, organized communities at different geographic and socio-political scales offer prospects for simpler, more participatory, and ecologically less destructive lifestyles by facilitating the creation of cooperative networks to support and exchange knowledge between communities and

academia aiming to preserve natural elements [58,59]. Such is the success story of the conservation of sea turtles in Bahía Magdalena, Baja California, Mexico, where fishers were empowered to visualize themselves as key players of conservation, providing valuable knowledge to scientists and participating in planning and management processes [60]. On the other hand, emotional bonds with the environment can also benefit conservation activities from the perspectives of connectivity, empathy, and natural attachment to the site because the connectivity of individuals with nature and its inclusion in daily life implies a sense of belonging that translates into attitudes and intentions in favor of the environment.

Volunteer participation in the CTMC has resulted in an increased number of protected nests (Figure 5a). Likewise, the frequency of references in regional newspapers regarding topics related to sea turtle conservation in the camp shows this rising trend (Figure 4); when this topic was surveyed on social networks like Facebook (Tortuguario Manzanillo, s.f.), we found that it currently has over 15 thousand followers. These social media are important tools to raise public awareness and support the conservation of sea turtles in the region, which in this case have yielded positive results and could be related to the concept of citizen science, currently referred to as a new science and research concept related to datasets and the possibilities of mobilizing people outside of science to assists with observations and classifications of natural phenomena [61].

Participation in citizen science can also enhance the connection of people with nature, thereby broadening the knowledge, perception, observational skills, and outdoor experience of citizens regarding environmental topics. Indeed, those who feel more connected with the natural world are more likely to achieve greater psychological wellbeing and a pro-environmental behavior, which can be defined as a behavior that consciously seeks to minimize the adverse environmental impacts of anthropogenic actions on natural and social environments. With more citizens connected with their local urban environment, the adverse human impact on wildlife (e.g., coyotes, pollinators, invasive species, sea turtles, sharks) may be reduced, and government decisions may be influenced or modified towards proactive positive environmental policies. Knowledge of processes that threaten wildlife and of general conservation issues can stimulate pro-environmental attitudes, behaviors, and engagement with biodiversity conservation (sea turtles) on urban environments in coastal areas [32–35].

A similar phenomenon can be appreciated in the case of CTMC, where the number of protected nests has increased over the study period despite the stressors detected. It could be thought that the work of this camp is minor or insignificant compared to the other two established in the state, but unlike these, despite the anthropogenic disturbances already described, the protection of nests is increasing, without considering that the other camps are located on the coast in the open ocean where urbanization is almost nil, and the extension of the beach in which they operate is greater than that of the CTMC, in both cases, they exceed 8 km. In addition, this camp is already a reference in the Central-West area of Mexico, according to the followers who routinely participate in social media posts such as Facebook and Instagram or according to regional newspapers (Figure 4), and since it operates within an urban area, it has more contact with citizens, which may be generating greater participation and social awareness. An average hatching of 80% as a result of an increase in nests protection is an indicator of response and success recognized in the protection of sea turtles and biodiversity in the Basic Set of Environmental Performance of the National System of Environmental Information and Natural Resources of the Secretary of the Environment and Natural Resources (SEMARNAT) [62], which reflects the contribution of the CTM to the conservation of sea turtles despite urban stressors.

The transdisciplinary protection and research actions of this camp have contributed significantly to addressing strategic sustainability issues. Collaboration between members of different institutions and sectors is relevant to understanding complex social-ecological systems through the co-generation of knowledge, creating alternatives to contribute to more relevant and effective decisions and actions [63,64]. Without these actions, it is impossible to link scientific and social work in the search and implementation of sustainable alternatives

through advocacy. Currently, transdisciplinary work is not common practice, and the institutional adoption of policies and practices leading to transdisciplinary collaboration is still limited in Mexico.

In its early stages, the CTMC worked with the participation of staff from the University of Colima (lecturers and students) and the City Council; then it grew and sought links with various local and regional social actors including businesses, NGOs, local authorities, and schools, media, and the public (Figure 5b). Although the area under the monitoring of protected species is small and is currently shrinking due to the rigidization of its coastline associated with urban port growth (Figure 3a–c), the results regarding nest care and release of sea turtle hatchlings are positive and have led to the steady recovery of the sea turtle population nesting in the Manzanillo area over time (Figure 5a). This fact is an outcome of the links established between different actors of the society and public and private institutions, where their economic and in-kind support has been pivotal for the success of the sea turtle protection initiative. Additionally, this continued effort has led to the co-generation of knowledge and experience, training of professionals, environmental education initiatives, optimization of resources and infrastructure, awareness-raising, social participation, sense of belonging, and care of natural resources. It can certainly be stated that this transformation promoting sustained actions to protect and restore the environment through social awareness and empowerment has been successful.

The rigidization of the coastal zone that involves the reduction of beach surface area (Figure 3) for sea turtle nesting, was expected to result in a lower number of nests; however, the analysis of records indicates a sustained increase. One possible explanation is the adaptation and resilience capacity of sea turtles; another is the activities on sea turtle protection, environmental monitoring, and environmental education carried out during the same period by the CTMC. This study illustrates a social-environmental work carried out by a part of Manzanillo inhabitants that has laid the foundation for the development of public policies and strategies changing the social paradigm in terms of the set of actions aimed at sustainable environmental use, including social, economic, cultural, and environmental aspects [65]. This work exemplifies a social advocacy project by the CTMC, whose continuity over time has fostered resilience as well as assets, benefits, and services supplied by coastal natural resources for society through community intervention initiatives that have been carried out for decades in different places and environments worldwide [66,67]. Humankind is acting as an ever-increasing stressor of natural systems, projecting an unsustainable future for all forms of life, so understanding how this process occurs is crucial to generating protection and responsibility for the planet [68]. Citizen or participatory science initiatives involve a comprehensive way of connecting people with biodiversity and its current conservation challenges [69]. The interaction between volunteers, scientists, or specialists in relation to species conservation planning, in addition to conducting research through observation and experimentation, has created new methods and techniques to produce knowledge and understanding in informal learning environments. This has allowed engaging society through collaboration [70], recreation, and incentives to interact with nature beyond urban environments, in addition to fostering learning, environmental awareness, and education for sustainability [71,72]. The activities of the CTMC are a clear example of the valuable benefits of citizen science.

5. Conclusions

We can conclude that citizen science as social collaboration contributes to the balance between social development and the protection of wildlife species such as sea turtles, hence reducing the vulnerability of marine resources that have been left most exposed by direct or indirect actions of human activities and the potential effects of climate change. This success case can be replicated in other cities and latitudes, and even for other coastal species or environments, to gain socio-ecosystem benefits through social advocacy projects involving empowerment and social appropriation of threatened coastal spaces and their natural elements by the local population.

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