

Status of Olive Ridley Sea Turtles (*Lepidochelys olivacea*) After 29 Years of Nesting Rookery Conservation in Nayarit and Bahía de Banderas, Mexico

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ABSTRACT. – Olive ridleys (*Lepidochelys olivacea*) are the most numerous sea turtle species worldwide and also locally along the Pacific coast of Mexico. Published data on their distribution and nesting abundance along the coast of Nayarit and northern Jalisco, Mexico are, however, scarce. Here we describe the current extent of conservation activities and the history of efforts to protect sea turtles along this 394-km stretch of coastline. We found that 110 km (of the total of 394 km) are monitored by 18 sea turtle conservation programs, which in 2015 accounted for 43.2% of the total shoreline. Olive ridley sea turtle nesting was encountered on all monitored beaches. Our use of hatchery-protected nests as a measure of nesting levels is undoubtedly an underestimate of overall nesting in the region; however, it nevertheless provides a baseline of current nesting intensity in sites under conservation. Bahía de Banderas presented the highest nesting levels in the study area with 46.4% (3742 ± 904 ; mean $\pm$ SD) of the total protected nests (8073 ± 547) while only representing 14.2% (15.4 ± 3.8 km) of the total area monitored (109.6 ± 4.5 km). The results provided here represent a valuable baseline upon which future research and assessments can be built when analyzing the sea turtle conservation progress in the region.

KEY WORDS. – *Lepidochelys olivacea*; hatchlings; nesting; community conservation; Jalisco; Mexico

Updated information on species distribution, as well as analyses of historical data (Balazs and Chaloupka 2006; Fonseca et al. 2009; Casale et al. 2012), is critical for governmental and nongovernmental status assessments of regional populations over time to implement effective conservation strategies. Such data rarely exist in sufficient detail, and this is particularly true for marine ecosystems (Sherman and Hempel 2008; Koslow and Couture 2015) where species may be so widely dispersed that multiple

resources are required to monitor population trends (Forney 2000; Taylor et al. 2007; Fujioka and Halpin 2014; Hart et al. 2015).

The gathering of turtles in front of nesting beaches, and subsequent nesting by females, allows the number of clutches to be used as an index of population size (Eckert et al. 1999). The collection of these data over extended periods of time is essential for monitoring of populations (Rees et al. 2016). This is especially true due to the

difficulty of tracking sea turtle population dynamics in foraging areas or during their pelagic migrations (Antworth et al. 2006).

For sea turtle species, this information is key to help mitigate threats such as fisheries (targeted and bycatch), climate change, and coastal development (Chaloupka et al. 2008; Hawkes et al. 2009; Witt et al. 2010; Fuentes et al. 2011, 2013; Rees et al. 2016), which have resulted in sea turtle species being categorized as globally at risk (Al Kindi et al. 2006; Harewood and Horrocks 2008). Coastal development is particularly problematic for breeding sea turtles, as the same beaches that support sea turtle nesting also attract tourism and have led to the development of important destinations worldwide.

Mexico's Pacific coast hosts nesting of 4 species of sea turtle: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*), with the latter being the most numerous. Since the country's total ban in 1990 of trade and consumption of turtle meat, eggs, and by-products (Diario Oficial de la Federación 1990), multiple conservation programs have been created to help sea turtle populations recover. These include the implementation of a national program for sea turtle conservation that constitutes both a nesting rookery and in-water conservation and monitoring projects at 46 different sites (Convencion Interamericana para la Proteccion y Conservacion de las Tortugas Marinas 2017). After legal protection was given to sea turtles, universities, local community groups, and nongovernmental organizations (NGOs) also began to work at other nesting sites not protected by government projects, responding to the need to protect sea turtles nesting on beaches in or near their communities (Marquez et al. 1998). Despite conservation efforts, all species of sea turtle remain listed as endangered on the "Mexican Red List" (Secretaría de Medio Ambiente y Recursos Naturales 2010), which catalogues the protection requirements for the country's flora and fauna.

Sea turtle conservation activities in the states of Nayarit and Jalisco, Mexico, have focused on sea turtle protection at rookeries through intensive beach management (García et al. 2003). These programs have concentrated on collecting nests for their incubation within beach hatcheries or polystyrene boxes until they hatch, and the resulting neonates are released into the ocean. Nest relocation occurs where in situ incubation is not possible due to coastal development, high anthropogenic activity on beaches, beach erosion, extreme temperatures, and where poaching and nest predation occur. This has proven to be an effective strategy to reduce both the loss of nests through human poaching as well as by erosion, high temperature, and predation (García et al. 2003; Cupul-Magaña and Aranda-Mena 2005).

In Nayarit, sea turtle rookery conservation activities officially began in 1971 on Chila beach, located on the central coast of Nayarit. This project was initiated by the

Oceanography Department of the Universidad Autónoma de Nayarit (UAN) and, since its founding, has been managed by multiple organizations (federal government, UAN, University of Guadalajara, Takutsi Asociación Civil [A.C.], and Playa Chila A.C.). Between 1979 and 1983, a conservation project was started on neighboring Platanitos beach. The Platanitos conservation program is notable for initiating training in sea turtle conservation practices for other communities, students, and individuals in Nayarit and has been run by the federal government since its founding. This project helped promote new projects within local communities and remains one of the only projects to have conducted research in the region (flipper tagging, incubation temperature registers, and incubation methods). Plantanitos is the longest-running continuous project, with data available between 1987 and 2011. The first community projects for sea turtle conservation were established in 1991 in San Francisco and 1993 in El Naranjo, Nayarit. In 1994, conservation activities began in Nuevo Vallarta, an 11-km, semideveloped beach in Bahía de Banderas, Nayarit. This beach was quickly identified as an area with high levels of nesting. From 1996 to 2006, 6 new projects were established, including those on the northern coast of Jalisco (Boca de Tomates, Puerto Vallarta, and Mayto). Since 2006, an additional 7 projects were established. Despite this, published data on distribution and abundance are still scarce in many areas. This may be due to a general lack of funding for research on olive ridley sea turtles compared with other sea turtle species.

This article aims to present what is known about the distribution and abundance of olive ridley sea turtles nesting along the coast of Nayarit and northern Jalisco, to provide information for the effective management of conservation programs, and to generate a starting point for new research initiatives and conservation in both states. To do this, we used the number of kilometers of beach patrolled and the total number of projects as an indicator of conservation effort over time, and we present mean nesting data from sea turtle rookery conservation programs (range, 1–18 projects) between 1986 and 2015.

METHODS

Study Area. — The state of Nayarit has 296 km of coastline between 22°32'N, 105°45'W and 20°40.308'N, 105°16.681'W, where it shares a border with the northern coast of Jalisco within the Bahía de Banderas. In this study, we consider the northern coast of Jalisco as that consisting of the 98-km municipal coast of Puerto Vallarta and Cabo Corrientes (southern boundary 20°5.718'N, 105°32.892'W) (Fig. 1). Sandy beaches are present along the majority of the coastal area and represent a suitable habitat for nesting olive ridley turtles. The region has well-defined climatic conditions, with a rainy season that normally lasts from June to November, and a dry season spanning December to May. Olive ridley nesting occurs

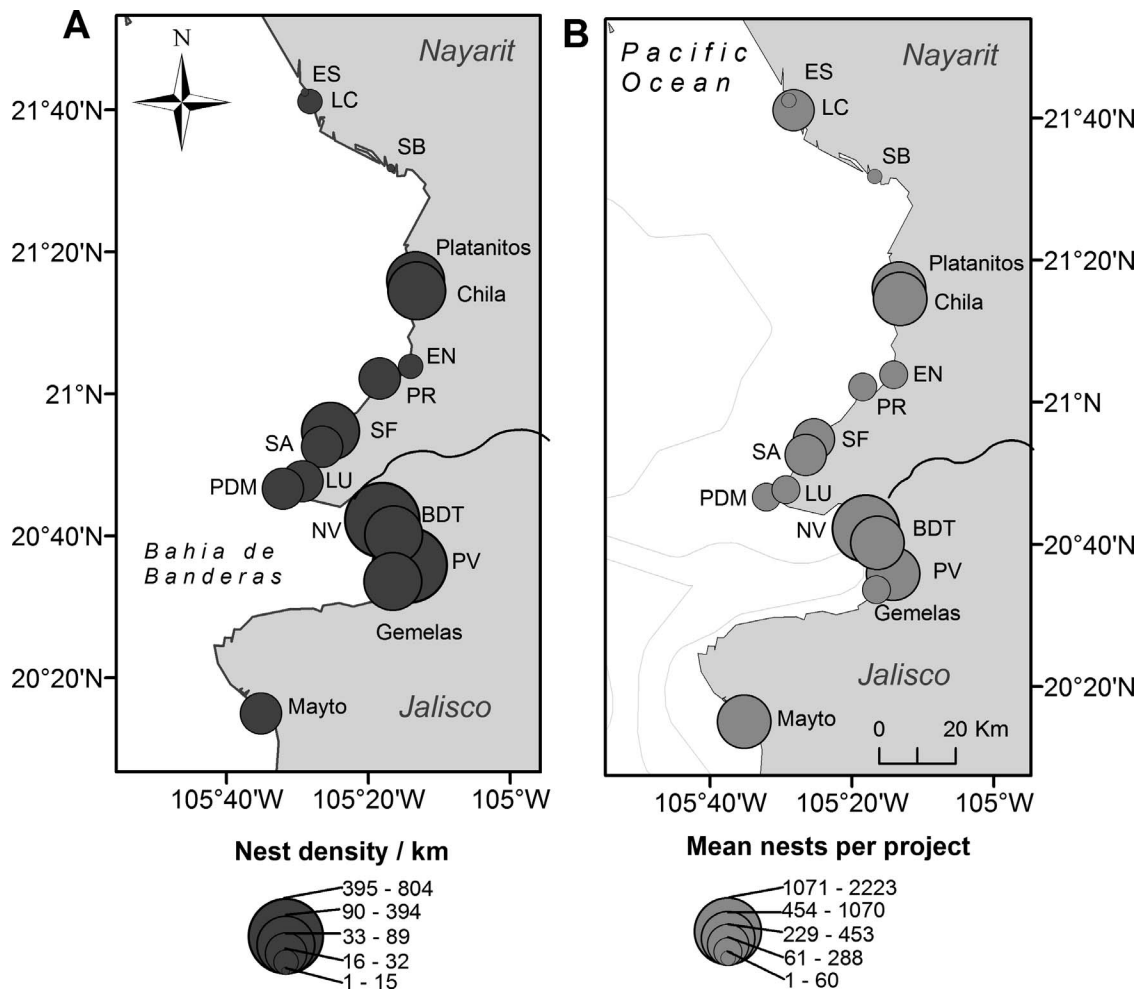


Figure 1. (A) Maximum nesting density during studied years of *Lepidochelys olivacea*, and (B) mean number of protected nests for 18 conservation projects in the study area. La Puntilla beach is not shown (6.4 nests/km). PV = Puerto Vallarta; BDT = Boca de Tomates; NV = Nuevo Vallarta; PDM = Punta de Mita; LU = Litibu; SA = Sayulita; SF = San Francisco; PR = Punta Raza; EN = El Naranjo; SB = San Blas; LC = Los Corchos; ES = El Sesteo.

year-round (Garcia et al. 2003), being significantly higher during the rainy season months of July to December (Hart et al. 2014).

Nesting Density. — As is common for conservation programs involving multiple institutions, temporal variations exist in monitoring efforts. However, most conservation groups monitored the beaches for which they had federal conservation permits during the peak nesting season. All projects reliably registered the number of protected nests, but not all projects registered false crawls, nests illegally taken by humans, and predated nests. Therefore, we used the number of protected nests per year as a measure of nesting density. Protected nests are an indicator of the annual minimum nesting, as some nests will not have been protected. We used the number of kilometers of beach patrolled and the total number of projects as an indicator of conservation effort over time. To compare nesting levels among beaches, we used nesting density (nests/kilometer/year) instead of total number of protected nests to partly compensate for

changes in conservation effort over time as well as beach length.

To calculate the involvement of different sectors (community groups, federal government, universities, and hotels), we assigned each conservation project to the sector that principally manages and contributes to the running of the project. We then calculated the total percentage of projects run by each sector.

Protected Nests. — These are nests that have been collected from their in situ position on the beach and moved to a protected hatchery to be incubated. Hatcheries use either seminatural (areas of fenced off beach) or artificial (aboveground rooms where polystyrene boxes are stored) methods.

RESULTS

Development and Impact of Conservation Activities. — Sea turtle rookery conservation activities officially began in 1971 on Chila beach, located on the central coast of Nayarit (Fig. 1). Between 1979 and 1983 a conservation project was started on neighboring Platanitos beach.

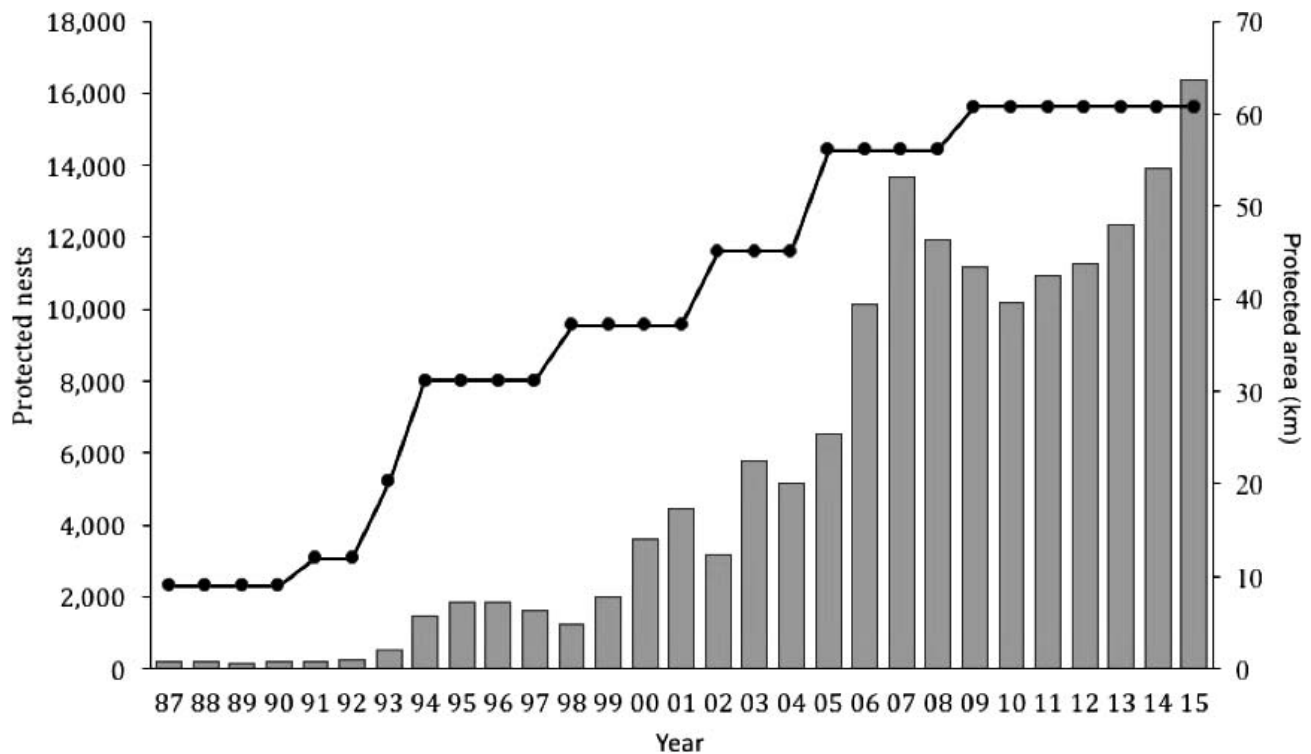


Figure 2. Number of protected *Lepidochelys olivacea* nests (bars) with the number of kilometers of protected nesting beach (points) between 1987 and 2015.

During the first 5 yrs after the ban on sea turtle consumption (1990–1995), 5 conservation projects patrolled 36.19 km of beaches (this does not include the Chila Project which had ceased operation during this period). During this 5-yr period, 4456 nests were protected which represented 432,080 eggs and the release of 274,595 hatchlings into the sea.

Nuevo Vallarta had a mean of 1379 ± 865 standard deviation (SD) protected nests (range, 559–3020) per season during the first decade (1994–2004) of monitoring. This increased to a mean of 5039 ± 1705 SD protected nests (range, 3202–7319) during the years 2005 to 2008. In 2008, Nuevo Vallarta was responsible for 38.9% of protected nests in the study area.

From 1996 to 2006, an additional length of 36.27 km of beach was protected by 6 new projects including those on the northern coast of Jalisco (Boca de Tomates, Puerto Vallarta, and Mayto). This extra effort resulted in a total of 10,121 nests being protected in 2006, resulting in incubation of 876,823 eggs and the subsequent release of 748,823 hatchlings. Since 2006, a further 7 projects were established, increasing the monitored area from 37.13 km to a total of 109.6 km by 2015. Although records of all projects until 2015 were not available, the trend (Fig. 2) is an increasing conservation effort represented by the number of kilometers and protected nests. No decreasing trend in nesting was recorded on any of the monitored beaches.

Current Monitoring Effort and Nesting. — In 2015, sea turtle conservation programs monitored 109.59 km of

the 394-km coastline, accounting for 43.2% of the total available nesting habitat. All monitored beaches (Table 1) registered olive ridley sea turtle nesting (Fig. 1). Overall, our multiple-year analysis showed that highest nesting levels occurred within Bahía de Banderas (Nayarit/Jalisco). Bahía de Banderas contained 46.4% (3742 ± 904) of the total protected nests (8072.5 ± 547) while only representing 14.2% (15.4 ± 3.8 km) of the total monitored area (109.59 ± 4.5 km) (Fig. 1A). Maximum nesting densities (nests/kilometer/year) on beaches varied between 3.4 and 805 nests/km/yr (mean, 197.7; Table 1; Fig. 1A). In northern Nayarit, La Puntilla and El Sesteo beaches recorded lower nesting densities (3.4–6.5 nests/km). In 2015, the estimated number of nesting females was 6549 for the 61 km of monitored beaches for which data were available.

Information recorded in 2015 showed protection was by a diverse group of actors: community groups (72% of monitored beaches), federal government (11%), Universidad de Guadalajara (11%), and private hotels (1%). Regarding the protected beaches, community groups protect 73% of the total area, federal government 19%, universities 7%, and hotels 1%.

DISCUSSION

Monitoring Effort and Nesting. — This study is the first of its kind that attempts to quantify the conservation effort for olive ridley turtles in Nayarit and northern Jalisco. We found that 110 km (of a total of 394 km) is

Table 1. Number of protected olive ridley sea turtle (*Lepidochelys olivacea*) nests at the 18 conservation projects along the Nayarit and northern Jalisco coast, Mexico, since 1986.

Site	Established ^a	Kilometers	Years in analysis	Protected nests			Max density	Reference
				Min	Max	Mean		
La Puntilla	2012	11	1	ND ^b	71	ND	6.5	Núñez-Ortiz, 2012
El Sesteo	2011	11	1	ND	37	ND	3.4	García-Tardeo, 2011; Inda-Ponce et al. 2011
Los Corchos	2001	9		147	283	283	31.4	Araiza-Montes et al. 2009; Araiza-Montes 2011
San Blas	1995	5		45	76	60.5	15.2	Vázquez and Robles-Arambul 1999, 2000; Michel 2002; Bojórquez-Martínez 2009, 2010; Palma-Hernández 2012
Platanitos	1986	9	29	175	2694	1070	299.3	Domínguez-Acosta 1993; Martínez-Rojas et al. 1995; Romero-Villarruel et al. 1995, 1996, 1997; Alvarez-López and Flores-Peregrina 1999; Alvarez-López et al. 2000; Flores-Peregrina et al. 2003, 2008; Flores-Peregrina 2004, 2006
Chila	2002	8	9	298	1604	749	200.5	Flores-Peregrina et al. 2003; Tena-Espinoza 2010, 2011
El Naranjo	1993	8.3	23	48	267	143	32.2	Hart et al. 2014
Punta Raza	2007	3.8	3	171	285	228	75.0	Hart 2013b
San Francisco	1992	2.89	25	98	1140	453	394.5	Smith et al. 2000, 2005; Smith and García-Palomera 2009
Sayulita	2013	3.8	3	276	276	276	72.6	Hart and Aguirre-Ayala 2014, 2015, 2016
Litibu-Careyeros	1999	4.4	16	28	302	142	68.6	Maldonado-Gasca 2006, 2007; Galindo-Castro 2010; Hart 2013c, 2014b, 2015b, 2016b
Punta de Mita	2012	4.7	4	142	266	145	56.6	Hart 2013c, 2014b, 2015b, 2016b
Nuevo Vallarta	1994	11	22	246	7319	2223	665.4	Peña 1995, 1996; Sánchez-González et al. 1996; Solís-Gil 2000; Romero-Villarruel 2005; Flores-Peregrina, <i>pers. comm.</i>
Boca de Tomates	1996	2.37		638	724	681	305.5	Hart 2014c, 2015c, 2016c
Puerto Vallarta	1998	1.5	18	122	1207	730	804.7	Aranda-Mena 2002, 2011a, 2011b; Hart
Playas Gemelas	2011	0.53		89	127	108	239.6	2013a, 2014a, 2015a, 2016a
Mayto	2005	11	10	445	985	689	89.5	Llamas-Gonzalez 2010, 2013, 2015, 2016

^a Established means the first year for which we have found data for conservation activities at each site. Some projects have not been continuous since the year in which they were established.

^b ND = no available data.

monitored by 18 sea turtle conservation programs, which in 2015 accounted for 43.2% of the total shoreline. This region is of great importance for nesting of olive ridley turtles, with Bahía de Banderas presenting the highest nesting levels in the study area. Grassroots conservation undertaken by local communities, NGOs, and civil associations has been key to the increasing conservation efforts in the region. That said, the federal government still protects the largest number of nests compared with other groups in the area.

We used protected nests (see “Methods” section) as a measure of minimum population size. Because conservation projects use intensive beach monitoring (García et al. 2003), we believe that this is a good measure for comparing nesting levels between beaches, as all projects record protected nests yet not all report clutches illegally taken by humans and predated nests. From these data, we were able to estimate the minimum number of nesting females in the area (6549 females in 2015). We do, however, recommend that projects enhance their data collection methods to include nests illegally taken by humans and predated nests, as this will better inform measuring their ongoing success.

In this study, we lacked robust data from northern Nayarit, as these conservation projects are relatively new and therefore have limited funding to cover their 11-km-long beaches. We reported low nesting densities at El Sesteo and La Puntilla beaches in northern Nayarit; however, between 2012 and 2015, the adjoining beach of Teacapan in the state of Sinaloa protected a mean of 712.2 olive ridley nests per peak nesting season (June–December) (Briseño-Duenas, 2015), which suggests that as conservation activities increase and consolidate, so will the number of protected nests in northern Nayarit.

Conservation Activities. — Most of the monitored beaches and all the beaches of the Bahía de Banderas have high levels of coastal development. It is notable that the beaches with highest olive ridley nesting density are not those with little or no development but those with the highest levels of coastal development.

Nesting density is very high in Nuevo Vallarta and areas of Puerto Vallarta (El Salado and Boca de Tomates), with nightly nesting surpassing 100 nesting females/km/night during peak nesting season. However, it is common to find tourists walking on the nesting beaches at night, and light pollution is a problem. Detailed research is

needed into the characteristics or situations that result in high densities of solitary nesting in areas with large-scale coastal development. Southern Nayarit and Bahía de Banderas (Nayarit and Jalisco) present narrow beaches which suffer from erosion. This causes problems when protecting nests, as safe incubation areas are scarce due to the proximity of the high tide line to human-made structures or to the wetland areas backing the nesting beaches. Poorly managed human recreational use of beaches has the potential to reduce usable area for conservation activities.

Although it is recommended to leave nests in situ, illegal take of turtle eggs is still a problem on beaches monitored by conservation programs in this study. Levels on some unprotected beaches in the area are likely to be very high due to high levels of consumption and trade of sea turtle eggs in the area, despite 30 yrs of the total ban on consumption of sea turtles and their by-products. Those involved have been reported to interchange nests from less-abundant sea turtle species (hawksbill turtles, green turtles, leatherback) for olive ridley nests or try to sell these nests to conservation projects. This is a difficult situation for conservation programs, yet highlights an understanding of the differing conservation status among the species. Social studies are needed in the region to analyze the reasons why, after 3 decades of environmental education, the black market for sea turtle meat and eggs continues strong in some communities; and there is a need to establish more-effective environmental education for the adult population (as programs usually target children and youth) as well as alternative economic activities for marginalized communities.

The importance of community groups in conserving widely distributed species such as the olive ridley sea turtle should not be underestimated. These groups need to be promoted and supported and, where possible, aided by the local and federal governments because their closure not only causes the loss of thousands of nests per season but the end of the community engagement in conservation and educational impact. Senko et al. (2011) looked at the role of civil societies in sea turtle conservation at foraging grounds in the nearby state of Baja California Sur (BCS). They found residents of fishing communities had a high willingness (98%) to participate in sea turtle conservation programs. This was the case even without there being direct economic benefits from participation. Our observations are similar in this region, as reflected by the majority of sea turtle nesting conservation activities in our area being run by community groups. As in BCS (Senko et al. 2011), voluntourism is a source of income for turtle conservation projects, with many community projects relying on the donated labor and money to run their activities. Although key to projects, no studies on the contribution of voluntourism to sea turtle conservation (number of participants, etc.) have yet been carried out in our area.

Cooperation among community groups, the federal government, hotel, and university projects are essential for conservation in this region, with many interlinkages between institutions. Private hotels support both federal and community projects alike in Bahía de Banderas and Punta de Mita, e.g., the federal government and some community projects through the Resources Program for Conservation and Sustainable Development (PROCO-DES), and all partners are involved in some level of community education.

Of all institutions, community groups are less likely to register false crawls and illegally taken sea turtle clutches. This may be due to a sense of failure to those patrolling beaches and concern that conservation permits may be withdrawn if they report a large quantity of lost nests.

Involving community groups and local NGOs in sea turtle research programs could be used to improve data collection through creating an understanding of how such data can be used to understand populations and to create confidence in conservation practitioners' own abilities. To date, data often are seen only as a requirement for conservation permits and not as something that increases our understanding of population dynamics and helps us to improve our conservation efforts. Collation of data and reporting back to contributing groups is key here.

Regional Context. — The olive ridley sea turtle is known to be the most numerous sea turtle in the World. This abundance has resulted in the olive ridley management unit in the eastern Pacific being categorized as at low risk and low threat (Wallace et al. 2011). The increasing conservation efforts in Nayarit and the northern coast of Jalisco are an important part of this monitoring along the Pacific coast of Mexico. Although the number of females is not comparable to those seen in other areas of Mexico which host *arribadas* (mass nesting events), the solitary nesting characteristic of the females in our study represent the possibility for greater adaptability to change. Solitary olive ridley females are known to nest on multiple beaches (Morreale et al. 2007), and there exist high levels of connectivity between rookeries in the Mexican Pacific (Rodríguez-Zárte et al. 2013). Solitary olive ridleys, despite being from smaller rookeries than *arribada* females, have a high incidence of multiple paternity and therefore genetic variability within their clutches (Duran et al. 2015), and they significantly contribute to overall olive ridley populations (Dornfeld et al. 2015). These are important characteristics for adapting to environmental change, be it coastal development or climate change (Hawkes et al. 2009).

Nesting density in southern Nayarit and northern Jalisco are greater than that reported at Las Barracas beach, BCS, where low humidity affects nesting (Lopez-Castro et al. 2004). High humidity present in the Bahía de Banderas, and especially around the Ameca River mouth where Nuevo Vallarta, Boca de Tomates and Puerto Vallarta conservation projects are located, may be a contributing factor to the high nesting density on these beaches.

In the eastern tropical Pacific, it is estimated that there are 1.39 million adult and large juvenile olive ridley turtles (Eguchi et al. 2007). The contribution of the Nayarit/northern Jalisco region to this figure is a minimum estimate of 6549 breeding females. We recommend further studies that include all nesting data (protected, predated, eroded, and illegally taken clutches) because our results represent baseline data on the regional situation but should not be used as an estimation of global levels of nesting.

CONCLUSIONS

Olive ridley *arribada* beaches are clearly priority targets for the species on the Pacific coast of Mexico. Solitary nesting populations, however, should not be overlooked. These form the pillar of turtle ecotourism in the Mexican Pacific and an educational resource, with many school children learning about conservation from olive ridley conservation projects and subsequent releases of hatchlings.

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