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Globally significant nesting of the leatherback turtle (*Dermochelys coriacea*) on the Caribbean coast of Colombia and Panama

Juan Patino-Martinez[a,b], *Adolfo Marco*[a], *Liliana Quiñones*[a], *Brendan Godley*[b,*]

[a]*Doñana Biological Station, CSIC, Department for Biodiversity Conservation, Avda. María luisa S/n, 41013 Seville, Spain*

[b]*Marine Turtle Research Group, Centre for Ecology and Conservation, School of Biosciences, University of Exeter, Cornwall Campus, UK*

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ABSTRACT

We describe the results of extensive monitoring of leatherback turtle (*Dermochelys coriacea*) nesting in the Gulf of Uraba, Colombia and the Caribbean coast of southern Panama. On 100 km of coastline, we identified three important coastal stretches totalling 18.9 km that hold 98.5–98.7% of nesting activity. We estimated a total number of nesting activities at all sites of 6254 (2006) and 7509 (2007) and that 5689 (90.9%, 2006) and 6470 (86.2%, 2007) resulted in clutch deposition. Our data demonstrate that nesting levels in this region are much higher than had been previously been suggested. The Caribbean coast of Central America (Costa Rica, Panama, and Colombia) constitutes the fourth largest nesting aggregation for this species in the world after the Guianas (French Guiana and Suriname in South America), Gabon (West Africa) and Trinidad (Caribbean). Estimated nest survival showed strong inter-site differences, ranging from 23% to 75% and, if hatchling production is to be augmented, different management strategies will be needed at each site. Perhaps more importantly, our findings highlight that despite the intense conservation interest in this species for several decades, there are still major gaps in status information and there is a need for increased rigor in the extent of spatial coverage of baseline monitoring to effectively inform conservation assessments. We must guard against precise yet spatially limited estimates of small parts of populations leading to an inaccurate picture of overall status.

1. Introduction

The leatherback turtle (*Dermochelys coriacea*) is distributed globally, with breeding sites located between 40°N and 35°S (Eckert, 2001). In recent decades, drastic declines in stocks in the Indo-Pacific have been recorded (Chan and Liew, 1996; Spotila et al., 2000; Sarti et al., 2007). These are thought likely a result of anthropogenic impacts such as fisheries bycatch (Morreale et al., 1996; Eckert and Sarti, 1997; Alfaro-Shigueto et al., 2007; Lewison and Crowder, 2007), direct harvest off eggs and adults ((Chan and Liew, 1996; Spotila et al., 1996; Kaplan, 2005) compounded by climatic variability (Saba et al., 2007). In some cases, however, monitoring has not been consistent, particularly in the western Pacific (Hitipeuw et al., 2007), where little is known about the location, abundance and trends of some rookeries (Dutton et al., 2007).

The Wider Caribbean region holds some of the globally important nesting aggregations, such as French Guiana/

* *Corresponding author.*
E-mail addresses: juanpatino@ebd.csic.es (J. Patino-Martinez), amarco@ebd.csic.es (A. Marco), mliliana@ebd.csic.es (L. Quiñones), b.j.godley@exeter.ac.uk (B. Godley).
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Suriname (Girondot et al., 2002), Trinidad & Tobago (Eckert, 2001; Turtle Expert Working Group, 2007) and Costa Rica (Tröeng et al., 2004, 2007). The nesting colonies in French Guiana/Surinam, and Trinidad have been identified as a distinct stock, based on molecular data (mtDNA and nuclearDNA) (Dutton et al., 1999) although a clear stock delineation has not yet been possible as nesting levels and molecular profiles in Venezuela, Panama, and Colombia are still understudied (Dutton, personal communication).

Two decades ago, the western Atlantic nesting colonies from Costa Rica through Panama to Colombia were estimated as constituting some 4000 individuals (Pritchard et al., 1989). Recently the Caribbean coast of Costa Rica and northern Panama have been surveyed for leatherback nesting using aerial surveys (Tröeng et al., 2004) but until now, the majority of the Panamanian coastline has not been intensively surveyed. In Colombia, work in recent years has focussed on isolated beaches (Rueda et al., 1992; Duque et al., 2000) and the number of nesting leatherback turtles (also known as "tortuga Caná" in the study area), was considered as totalling between 100 and 250 nesting females per year (Meylan et al., 1985; Eckert, 2001). Here, we used a synoptic monitoring approach in order to generate a more comprehensive understanding of the spatial distribution of nesting and help inform status assessment in the region.

2. Methods

2.1. Study area

This study was carried out between Anachukuna (8°43′00″N, 77°32′50″W), in the Kunayala region, south-eastern Panama and Mulatos in Colombia (8°38′55.33″N, 76°43′09.25″W) including the Gulf of Uraba in Colombia (Fig. 1). The coastline presents a range of anthropogenic influence from urban to near wilderness state. Three sites (Armila = 2, Acandi-Chilingos = 4 and Playona = 5, Fig. 1) encompass the vast majority of the nesting activity along a total shoreline of 100 km. All three sites were high-energy shores, their orientation was (E–W) and they were open to the sea with little curvature and without visible obstacles in the sea (islands or reefs). However, some factors strongly varied among sites (slope: 8.0° in Armila, 18.7° in Acandi-Chilingos and 4.5° in Playona; sand colour: white in Armila, grey in Acandi-Chilingos and black in Playona; sand grain size, percentage weight coarse sand (0.2–2 mm): Armila: 97%; Acandí-Chilingos 59%; Playona 84%).

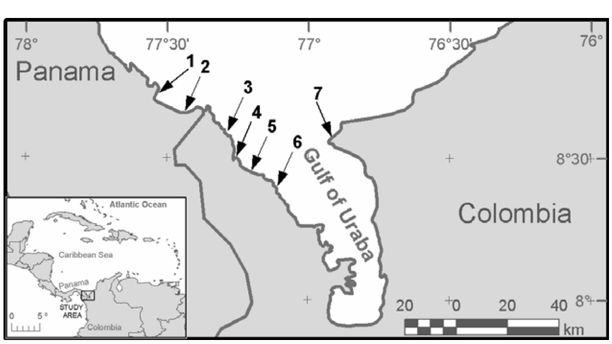

Fig. 1 – Study area location. The sites with nesting of leatherback turtle, identified during this study are: 1-Anachukuna (8°43′00″N, 77°32′50″W–8°43′25″N, 77°32′59″W), 2-Armila (8°39′40″N, 77°26′35″W–8°40′06″N, 77°27′59″W) in Panama and 3-Capitancito (8°35′03″N, 77°18′18″W–8°35′13″N, 77°18′33″W), 4-Acandí (8°29′26″N, 77°15′18″W–8°30′09″N, 77°16′26″W), 5- Playona (8°25′57″N, 77°09′59″W–8°28′16″N, 77°14′58″W), 6- Playeta (8°24′52″N, 77°08′13″W–8°25′06″N, 77°08′57″W) and 7- Pueblo Nuevo (8°36′01″N, 76°53′09″W–8°33′07″N, 76°56′16″W) in Colombia.

2.2. Nesting activity survey

We based our monitoring strategy upon that previously used for green turtles at Ascension Island (Godley et al., 2001). We utilised the fact that each time a female turtle emerges from the sea to attempt nesting (nesting activity) it creates a distinctive set of tracks on the sand: with a track ascending to any aborted digging attempts and/or successful nest, and a further track descending to the sea. We had a stratified monitoring protocol whereby two sites in Colombia with previously researched nesting (Duque et al., 2000), were chosen as intensive study sites. Here, we verified all nesting activities and nests with an early morning track count throughout the season (early February to mid July). These were Acandi-Chilingos (site 4) and Playona (site 5, 3 km of a total 12 km; Fig. 1). In order to survey the rest of the coastline, an extensive survey was made on April 15th 2006 by transiting the coast (100 m offshore) by boat. All sandy beaches were surveyed by foot, mapped and geo-referenced using GPS (Garmin e-trex summit) and classified as nesting or non-nesting beaches based on signs of previous nesting. Based on this initial classification, each indexed nesting beach (Fig. 1 $n = 7$; including the additional 9 km of site 5 that were not subject to daily monitoring) was subsequently surveyed on an additional 11 occasions before 17 June 2006. In 2007, each nesting beach was surveyed at least twice per week between March 9th and June 19th, except, because of its lesser importance and because of logistical reasons, site 7 (Pueblo Nuevo, Fig. 1) was not surveyed in 2007. In each survey, we recorded all nesting activities from the previous night and, in as many cases as possible, based upon track morphology we ascertained whether each activity had successfully resulted in clutch deposition.

A seasonal estimate of the total amount of nesting activities for each site was generated by interpolation of mean values between successive data points and presumed zeros at the start and the end of the season when considering all nesting at sites 4 and 5 (Start: February 10 and 7; End: June 25 and July 5 in the two years, respectively). Where possible, mean nesting success (proportion of nesting activities resulting in successful clutch deposition) was calculated for each site and used to generate an estimate of the number of clutches per season (total nesting activities * nesting success). As a result of the low number of activities on sites 1, 3, 6 and 7, it was not possible to effectively estimate nesting success and the lowest value from the most important sites (72%, site 5, 2006) was conservatively used (Table 1). Based on the estimated total values, we also calculated the density of nesting activity (Table 1) for each site.

Table 1 – Descriptive survey data per survey site (2006 and 2007)

Sites		1	2	3	4	5	6	7	Total
Length (m)		880	4500	700	2400	12,000	1500	8000	29,980
Total nesting activities (A)	2006	20	4302	30	1021	851	20	10	6254
	2007	18	4166	60	1121	2114	30	ns	7509
Nesting success (%) (*n*)	2006	72.0[a]	93.8 (*n* = 323)	72.0[a]	96.2 (*n* = 715)	72.0 (*n* = 522)	72.0[a]	72.0[a]	na
	2007	72.0[a]	86.4 (*n* = 1322)	72.0[a]	88.7 (*n* = 585)	85.1 (*n* = 1125)	72.0[a]	ns	na
Clutches	2006	14	4036	22	983	613	14	7	5689
	2007	13	3599	43	995	1798	22	ns	6470
A km^{-1}	2006	23	956	43	425	71	13	1	209
	2007	21	926	86	467	176	20	ns	250
Clutches km^{-1}	2006	16	897	31	409	51	10	1	190
	2007	15	800	62	414	150	14	ns	216
Nest mortality									
Clutches flooded or eroded (%)	2006	22.2	33.3	16.7	22.8	48.1	33.3	50	na
	2007	33.3	42.1	11.1	15.8	29.3	nd	ns	na
Clutches harvested (%)	2006	0.0	0.0	0.0	2.8	22.3	nd	nd	na
	2007	0.0	0.0	0.0	3.9	30.6	nd	ns	na
Clutches predated by dogs (%)	2006	nd	2.3	nd	4.9	6.6	nd	nd	na
	2007	nd	1.9	nd	5.4	5.2	nd	ns	na
Clutch survival (%) (*n*)	2006	77.8 (9)	64.4 (303)	83.3 (6)	69.5 (688)	22.9 (376)	66.7 (3)	50.0 (4)	na
	2007	66.7 (6)	56.0 (1142)	88.9 (9)	75.0 (519)	34.9 (957)	nd	ns	na
Hatching success									
Hatching success (%) (*n*)		nd	69.4 (*n* = 29)	nd	75.7 (*n* = 86)	43.8 (*n* = 17)	nd	nd	nd

Beach length, total estimated nesting activities (A), nesting success%, (*n* of activities used to generate estimate), total estimated clutches, density of nesting activity (A km^{-1}) and clutches (Clutches km^{-1}), estimated% loss and survival of clutches and hatching success% (*n* of clutches assessed).

a Estimated nesting success; a conservative minimum nesting success of the study (site 5, 2006); ns = not surveyed; nd = not determined, na = not applicable.

2.3. *Nest mortality*

Illegal take of eggs, nest predation, beach erosion, tidal inundation, driftwood accumulation and animal traffic were the main impacts identified in the study area. Nest mortality data were collected where possible for each site during all surveys. Data from the beach that we monitored most intensively (site 5) was used to ascertain the level of risk from beach erosion or tidal inundation. Mortality observed was 100% in the intertidal zone (*n* = 8 in 2006, *n* = 7 in 2007); therefore we assumed for all sites that nests in the tidal zone had no survival due to inundation or erosion. Further observations of eroded nests at other sites confirmed this. Human or animal predation of nests was recorded via observations of footprints/tracks around the nests, evidence of digging and broken eggshells at the surface (Tröeng et al., 2004).

2.4. *Hatching success*

During the 2006 hatching season (from 15 April), morning surveys (typically every 2 days in sites 4 and 5 and for a total of 10 surveys in site 2) were carried out to identify natural hatchling emergences from unmarked nests. Each hatched nest discovered was excavated and hatching success was estimated. Total number of eggs was calculated as a sum of full sized unhatched eggs and hatched egg fragments constituting more than 50% of the eggshell. The number of successful eggs was assumed to correspond to the shell fragment count. At site 5, 65 clutches were marked with GPS and their positions triangulated to markers behind the beach. These were randomly selected with the exception that clutches were not chosen should the nests be constructed in areas of the beach already subject to inundation.

3. Results

3.1. *Magnitude of nesting*

Of 100 km surveyed, we identified 7 sites (Fig. 1) with nesting activity (A) totalling 30 km in length (1 = 0.9 km; 2 = 4.5 km; 3 = 0.7 km; 4 = 2.4 km; 5 = 12.0 km; 6 = 1.5 km; 7 = 8.0 km). We identified three important coastal stretches totalling 18.9 km that hold 98.5–98.7% of nesting activity in the region surveyed, in the two years, respectively, (Table 1). Although the nesting of the species in the current study area had previously been signalled (Pritchard et al., 1989) only sites 4 and 5 had previously been recorded as leatherback nesting sites (Duque et al., 2000; Ceballos-Fonseca, 2004). This is the first quantitative report on the status of nesting in this entire area. The first nests were recorded in early February and continued until early July (Fig. 2). The peak of nesting was in May in both years with a highly similar central 90% around the median nest in both study years (March 2–June 8 in 2006; March 9–June 9 in 2007).

In total, from 1604 and 3081 nesting activities that we directly observed, we estimated 6254 and 7509 nesting activities throughout the study site in 2006 and 2007, respectively, (Table 1). The nesting success varied among sites and years (72–96%; Table 1). Using site-specific nesting successes where possible, we estimate a minimum of 5689 and 6470 clutches

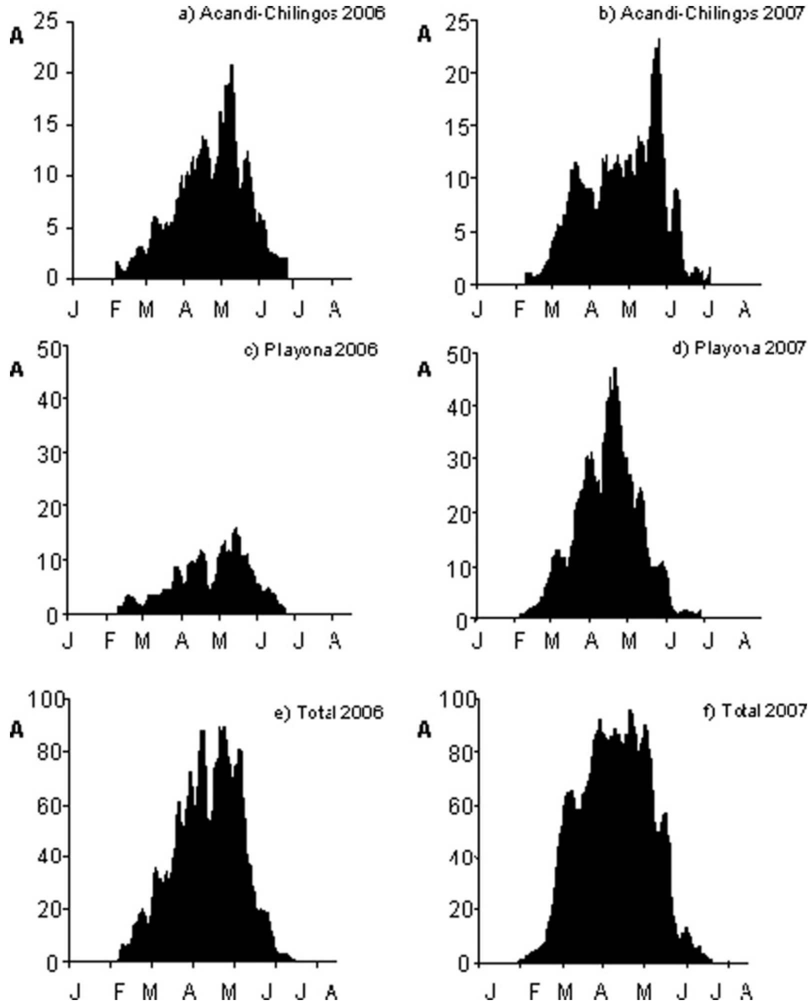

Fig. 2 – The temporal pattern of nesting at Acandi-Chilingos (site 4; a and b), at Playona (site 5; c and d) and in total at all sites (e and f). See Fig. 1 for locations.

were deposited throughout the study area in 2006 and 2007, respectively (Table 1). Armila (site 2 = 4.5 km), had the highest density of leatherback turtles nesting.

3.2. *Mortality factors*

The general pattern of survival of the nests varied, among the three major nesting sites (Table 1), with loss of nest by erosion and inundation accounting for 33–42% at Armila (site 2), 16–23% at Acandi-Chilingos (site 4) and 29–48% at Playona (site 5). Anthropogenic impacts also varied among sites. At Armila, inhabited by people of the Kuna indigenous community; there was no demonstrable consumption of eggs. At Playona, nest survival was low resulting from illegal take of eggs by local people which accounted for 22–31% of clutches and an additional 6.6% of clutches were destroyed by domestic/feral dogs (Table 1). At Acandi-Chilingos, although egg take was at a very low level (3–4%) losses to dogs were around 5% in each year. There is a small but demonstrable take of adult females; local fishermen accidentally kill 5–20 leatherback nesting females per year in multifilament gill nets at each of sites 4 and 5. These turtles are not consumed for meat.

Surveys conducted during the 2006 hatching season identified the hatch and natural emergence of nests on site 2 (hatching success 69.4% SE = 3.3, 95%CL = 62.8–79.5, $N = 29$) and site 4 (hatching success 75.7%, SE = 1.9, 95%CL = 71.9–79.5, $N = 86$). The analysis of 65 natural nests identified and monitored on Playona (5), showed that compacted sand prevented the emergence of all hatchlings in 7 nests (10.8%), 20 nests showed total lack of embryonic development, 4 were consumed by dogs (6.2%), 11 were consumed by people (17%) and the mean of the hatching success in the rest of nests (32.3%) was of 43.8% (Table 1).

4. Discussion

The study region is clearly a stronghold for the leatherback turtle and is important for the regional conservation of the species. Previous estimates of the number of nesting females using beaches in the study region ranged between 100 and 250. (Meylan et al., 1985; Eckert, 2001). Our data demonstrate that the nesting population in Colombia and south-eastern Panama is of a considerably greater size, with an estimated 6254–7509 nesting activities, 5689–6470 nests and based on five clutches per individual (Dutton et al., 2007; Hilterman

Table 2 – A summary of the magnitude of nesting at major leatherback turtle rookeries across the world

Ocean	Location	Estimated per year	References
Atlantic	Costa Rica&N Panama	5759–12,893 nests	Tröeng et al. (2004)
	Colombia&SE Panama	5689–6470 nests	This study
	Central America Total	11,448–19,363 nests	
	French Guiana&Suriname	13,291–63,294 nests	Girondot et al. (2007)
	Gabon	30,000 nests	Billes et al. (2003)
	Trinidad & Tobago	6000 females	Turtle Expert Working Group (2007)
Indo-Pacific	Papua	3000 nests	Dutton et al. (2007)
	India	1690 nests	Andrews and Shanker (2002)
	Western Pacific Total (28 beaches)	5067–9176 nests	Dutton et al. (2007)
	Playa Grande, Costa Rica	1250 nests	Santidrian et al. (2007)
	Pacific coast, Mexico	<1250 nests	Sarti et al. (2007)

and Goverse, 2007) of the order of 1138–1294 nesting females per year. Moreover, Armila (site 2), has shown the highest abundance and density of nesting (897 nests km^{-1}), in the Central American Caribbean, compared to Chiriqui (128 nests km^{-1}) (Ordonez et al., 2007), Gandoca (75.7 nests km^{-1}) (Chacon-Chaverri and Eckert, 2007), Pacuare (91.6 nests km^{-1}) and Tortuguero (14 nest km^{-1}) (Tröeng et al., 2004). Based on these and other published data, the Caribbean coastline of Central America (Costa Rica, Panama, and Colombia) is probably the fourth largest nesting aggregation for this species in the world (Table 2), after French Guiana & Suriname (Girondot et al., 2007), Gabon (Fretey et al., 2007) and Trinidad & Tobago (Turtle Expert Working Group, 2007).

Decades of investigations in marine turtles have generated a great deal of knowledge of the status of this species (Tucker and Hall, 1984; Meylan et al., 1985; Pritchard et al., 1989; Spotila et al., 2000; Price et al., 2004; Eckert, 2006; Thome et al., 2007). Nevertheless, the discovery of these important leatherback turtle nesting sites is important in filling the gaps in known range distributions of a species of high conservation interest (Turtle Expert Working Group, 2007). In some cases we only have qualitative data on the distribution and range of nesting sites in different countries, particularly in the eastern Atlantic (Fretey et al., 2007) but it is perhaps somewhat surprising that we should discover such a major nesting aggregation in the western Atlantic, given the attention this species has had in the region for several decades (Pritchard et al., 1989).

4.1. *Spatial and temporal variability*

The sporadic recapture of turtles tagged in Colombia, in Panama or Costa Rica and vice versa (Chacon-Chaverri and Eckert, 2007; Ordonez et al., 2007; Tröeng et al., 2007) strongly suggests that turtles nesting throughout Central America may be part of the same regional metapopulation. It is of high priority that vouchers must be analysed from Panama and Colombia to help resolve the degree of genetic substructuring in Atlantic leatherback turtle stocks. Leatherback rookeries are, however, dynamic and can demonstrate significant shifts in space (Dutton, 2005; Hilterman and Goverse, 2007; Kelle et al., 2007) and can vary markedly in magnitude between seasons (Broderick et al., 2001; Reina et al., in press). Kelle et al. (2007) have recently shown that depending on beach accretion or erosion, the relative importance of any single beach fluctuates considerably at a regional scale. Tröeng et al. (2007) concluded that the nesting trend at the three most important beaches in Costa Rica may have undergone a decline since 1995. Part of the explanation of any negative trend may be that a proportion of the metapopulation has shifted south. It may be, also, that numbers nesting in Colombia and Panama are increasing in line with other regional rookeries of this (Dutton et al., 2005; McGowan et al., 2008) and other species (Troëng and Rankin, 2005; Beggs et al., 2007). Although, the combined data during both years of this study do not indicate a great temporal variability, if single sites are analysed (e.g., site 2) variability can be high (Fig. 2). Interannual fluctuation in the number of nests deposited within any given survey unit, including those in this study, mandates ongoing monitoring to allow a full elaboration of the true status of the nesting aggregation. We suggest that the full coastline of Panama be surveyed for nesting to ensure that no major pockets of nesting remain unquantified.

4.2. *Nest mortality and management strategies*

There are three sites that encompass the vast majority of the nesting in the study area that should, in principle, make it easier to focus any conservation efforts. These sites, however, differ in threat levels to reproductive success of leatherback turtles. Each one has different environmental and mortality conditions that may require different management strategies.

Armila (site 2) has demonstrating high levels of nest survival and hatching success, it presents exceptional conditions for the conservation of leatherbacks. Currently, in this beach there is no coastal construction, egg consumption or capture of adult females. The Kuna society (inhabitants of the area) has approved a regulation that prohibits the capture of the marine turtles and the consumption or commercialisation of any of its parts as well as the destruction or alteration of nesting habitats. The combination of the legal protection and the attitude of respect of the local inhabitants, provides excellent conditions for conservation and maintenance of the species in the region. It may be, therefore, that no direct action, other than continued monitoring, is needed at this site.

At Acandi-Chilingos (site 4), although hatching success is high, nest survival is impacted by domestic/feral dogs; a potentially tractable problem. Egg consumption by local people is low; likely a result of the difficult access to the beach and by the presence of a local organisation that incorporates the care of the beach within its activities.

Playona (site 5) has the lowest nest survival of nests due to anthropogenic and natural impacts. Playona suffers from organic waste accumulation, deforestation, compacted sand, erosion, traffic of cattle, egg harvest and predation by dogs. A decade long effort to improve hatchling recruitment using open-sand hatcheries has had only modest success with very variable hatching success and number of protected nest each year (Patino per. obs). Given the site's importance, there is a need to involve the community more deeply in the fate of the turtles nesting there.

In summary, our observations elevate the global importance of the Caribbean coast of Central America for leatherback turtle conservation suggesting it is the fourth largest nesting aggregation, after Gabon, French Guiana/Suriname and Trinidad. Armila appears to have the largest level of nesting and density for leatherback turtles in Central America. The long duration of work in Costa Rica and Panama and the novelty of our findings underscore the need for more coordinated studies among researchers in Central America. This collaborative approach should be extended to the study of other species, particularly hawksbill turtles (*Eretmochelys imbricata*) that are relatively understudied. We reiterate the need to have a broader, more integrated view of population assessment (possibly involving more extensive boat or aerial surveys e.g.: Tröeng et al., 2004) in these species. How many other globally important populations are as yet unknown or under-estimated because efforts are overly focused on excessively detailed work at a few key sites with little attention paid to the wider view? We must guard against precise yet spatially limited estimates of small parts of populations leading to an inaccurate picture of overall status.

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