Herpetological Conservation and Biology 16(2):238–250.
Submitted: 6 June 2020; Accepted: 27 March 2021; Published: 31 August 2021.

Local Ecological Knowledge Supports Identification of Sea Turtle Nesting Beaches in Panama

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Abstract.—**We report on a study of previously un-surveyed sea turtle nesting beaches in an isolated region of the Azuero Peninsula in central Pacific Panama. The initial identification was based on information collected during semi-structured interviews (n = 21) in 12 communities. These engagements gauged local ecological knowledge (LEK) with emphasis on the critically endangered Leatherback Turtle (*Dermochelys coriacea*). Interview responses identified 22 beaches with sea turtle nesting activity. From these, we surveyed nine beaches: Cacajilloso, El Gato, Sandillal, Colorado 2, Sierra, Granada, Frijoles, Verde, and Horcones beaches. Nesting activity was documented by observing crawl tracks on the beach and/or directly encountering female turtles. In total, we observed 128 crawl tracks representing two species: Green Turtles (*Chelonia mydas*, n = 92) and Olive Ridley Turtles (*Lepidochelys olivacea*, n = 36). We also directly encountered Green Turtles (n = 16), Olive Ridley Turtles (n = 25), and Hawksbill Turtles (*Eretmochelys imbricata*, n = 2) during surveys. Olive Ridley Turtles had the most widespread nesting activity (six of nine beaches), followed by Green Turtles (four of nine beaches) and Hawksbills Turtles (two of nine beaches). We saw no evidence of Leatherback Turtle nesting, despite LEK suggesting the species had previously nested at several of the surveyed beaches; this lack of evidence is consistent with its critically low (and still declining) population size in the eastern Pacific. In addition to highlighting the value of LEK, our study provides novel information on the distribution and abundance of sea turtles in remote areas in Panama.**

Key Words.—Leatherback Turtle; Green Turtle; Olive Ridley Turtle; Hawksbill Turtle; LEK

Introduction

Sea turtles represent an important taxon in marine biodiversity conservation, as they play key roles in marine ecosystems and exhibit migratory patterns that traverse national boundaries of many countries (Marquez 1990; Bjorndal and Jackson 2003). In particular, sea turtle migrations between nesting beaches and foraging grounds make them susceptible to a variety of human threats, which present unique conservation challenges and require a variety of management actions (Shillinger et al. 2008; Gaos et al. 2012; Heidemeyer et al. 2014). Significant research during the last several decades has attempted to characterize the biology of sea turtles and their susceptibility to these impacts; however, basic questions relating to nesting distribution and abundance remain unanswered for many areas worldwide. The identification of previously unknown nesting sites, and periodic or long-term monitoring of these sites, are fundamental elements of sea turtle conservation and can provide important information about sea turtle population status and trends (Eckert et al. 1999; Wallace et al. 2011).

The eastern Pacific hosts four sea turtle species, including Leatherback Turtles (*Dermochelys coriacea*), Hawksbill Turtles (*Eretmochelys imbricata*), Olive Ridley Turtles (*Lepidochelys olivacea*) and Green Turtles (*Chelonia mydas*; Seminoff et al. 2012). For each of these species, Eastern Pacific populations have been described as independent regional management units (RMUs) due to their unique genetic and biological traits (Wallace et al. 2010). These RMUs often experience high levels of risk (i.e., low population viability and genetic diversity) and threats (i.e., direct and indirect anthropogenic factors) that may affect their survival (Wallace et al. 2011). As per conservation assessments presented by Wallace et al. (2011), Leatherback Turtles and Hawksbills Turtles in the region are under a high risk-high threat situation, whereas Olive Ridley Turtles and Green Turtles have a less critical scenario.

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Regardless of the species, however, local baseline data about where and when nesting occurs are required to support ongoing and future conservation status assessments for each RMU.

Local ecological knowledge (LEK) can provide insights about local natural resources and their value in the lives of local inhabitants and can yield important insights about local beliefs and practices relating to wildlife (Berkes et al. 2000). Understanding LEK and attitudes of local residents has become increasingly important when addressing issues related to natural resource use and conservation (Pierotti and Wildcat 2000; Charnley et al. 2007; Azzurro et al. 2011), especially considering the intimate links between humans and nature in remote and undeveloped areas (Campbell 2003). There are a variety of approaches to engaging local residents about topics related to natural resource management, such as inviting them to workshops, joining their daily activities, asking them to collect data, and/or conducting interviews to learn LEK. Indeed, these types of efforts have previously discovered important and novel insights about the biology of local wildlife species and ecosystem functioning (e.g., Wedemeyer-Strombel et al. 2019). For example, local consultation via formal interviews has been effective in obtaining reliable data for assessing the conservation status of a variety of sea turtle populations (Liles et al. 2015; Lucchetti et al. 2017; Palaniappan et al. 2018; Wedemeyer-Strombel et al. 2019). These interviews may help identify critical habitats and strongholds for threatened and endangered species, which is a first step in species conservation. Sea turtles are a taxon for which LEK may be particularly useful for revealing nesting sites and nesting activity not previously identified (e.g., Liles et al. 2015), and for guiding the implementation of field surveys in previously unstudied and/or remote areas (Carr and Carr 1991; Tapilatu et al. 2017).

Inaccessible or difficult-to-access coastal areas may include important sea turtles nesting beaches and excluding these sites from population assessments can lead to underestimates in nest distribution and abundance (Khan et al. 2010). Nevertheless, there is a lack of published information for many beaches along the Pacific coast of Panama. Considering the Critically Endangered status of Leatherback Turtles and Hawksbill Turtles (International Union for Conservation of Nature 2020), and the fact that historical data suggest both species nested in the region, information on their present nesting distribution and status is essential for developing the most appropriate population recovery strategies. To date there have been few attempts to systematically survey nesting sites in the region, and rarely have local communities been involved in these efforts.

The objective of our study was to examine previously un-surveyed nesting beaches along the southwest coast of the Azuero Peninsula along the Pacific coast of Panama. This region is isolated, difficult to access, and has few towns and poor infrastructure; inhabitants of Azuero Peninsula are mainly farmers tending to agricultural fields and cattle. As a result, information on sea turtle nesting activity and abundance is sparse (Arauz et al. 2017 unpublished technical report); however, recent expeditions to the area have revealed range extensions for birds and amphibians (Hertz et al. 2013; Miller et al. 2015; Flores et al. 2017), suggesting the area may also be a source of untapped information about sea turtles.

Here we report on the results of several expeditions conducted to isolated areas in and near Cerro Hoya National Park located along the southwest coast of the Azuero Peninsula. We conducted semi-structured interviews with local inhabitants to assess LEK. Based on information derived from these discussions, we selected and explored several isolated beaches to evaluate the presence of sea turtle nesting activity. At beaches where no evidence of turtles was found, we recorded the physical and biological characteristics of the site to determine suitability for nesting during non-survey periods. We were particularly interested in learning about Leatherback Turtles because no clear information exists regarding nesting status on the Pacific coast of Panama, despite anecdotes about it nesting in the area (Arauz et al. 2017 unpublished technical report) and satellite tracking data that show this species traveling in nearby waters (Shillinger et al. 2008). Our results further establish the value of LEK for wildlife conservation and provide a first glimpse into the status of sea turtle nesting in one of the most remote areas of Panama.

Materials and Methods

Study site.—We conducted the study along the southwest coast of the Azuero Peninsula, which includes parts of Los Santos and Veraguas provinces in central Panama (7°14′3.57″N, 80°49′24.28″W; Fig. 1). There are various oceanic currents affecting this area, including the east-flowing North Equatorial Countercurrent (NECC) coming from the central Pacific, with greatest flow rates during August (Guzman and Breedy 2008). During the dry season (December to May), surface currents flow with more intensity towards the Azuero Peninsula, eventually reaching the Galapagos Islands (e.g., The Panama Flow; Glynn and Mate 1997; Guzman and Breedy 2008). These currents provide variable nutrient and oceanographic conditions through the year offering temporal and spatial habitats for different species of sea turtles in the area.

Local interviews.—During two field trips (March and December 2018), we conducted semi-structured

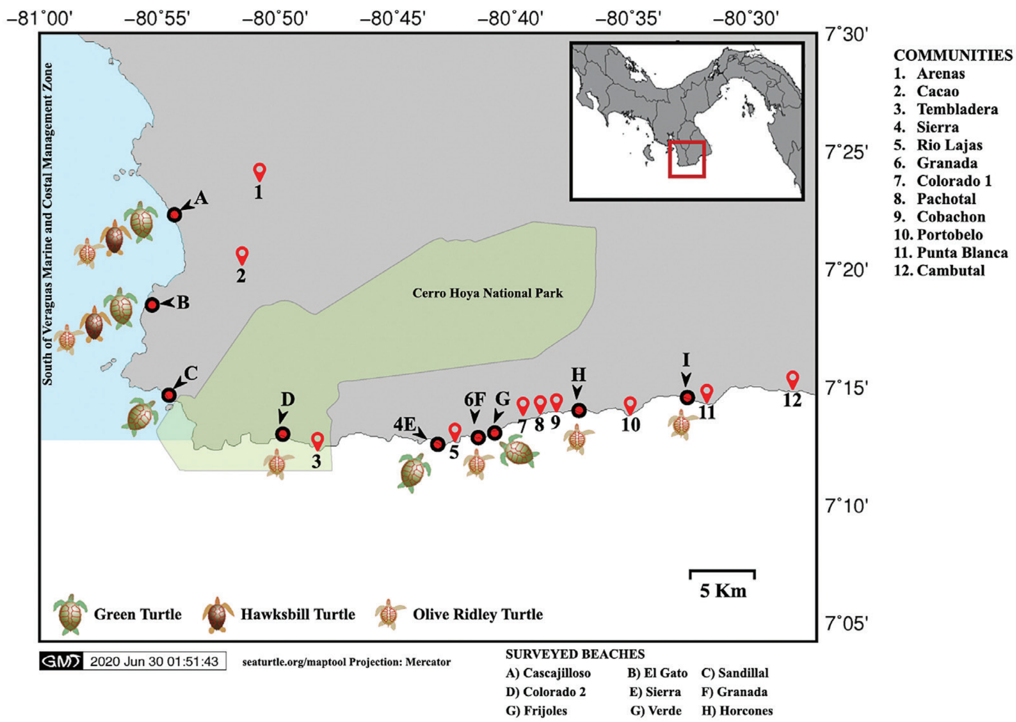

Figure 1. Location of the nine beaches (red and black circles) surveyed for sea turtle activity and the 12 communities where LEK interviews were conducted (red pins) along the southwest coast of the Azuero Peninsula, Panama. Light blue area is south of Veraguas Marine and Coastal Management Zone. Light green area is the Cerro Hoya National Park. (Base map source Maptool program for analysis and graphics a product of SEATURTLE.ORG, 2020; polygons of protected areas from Panama´s Protected National Parks Layers available at https://stridata-si.opendata.arcgis.com/datasets/8abb96387e6e4f39ad59159d932167c8_0)

interviews with local residents of communities along 30 km of coastline of the Azuero Peninsula, from the first roadside settlement to the last point accessible by car. During the first trip, we traveled 200 km by car from the city of Santiago to the town of Cambutal, an access point to remote areas along the southern coast of the Peninsula. During the second trip, we traveled 118 km from the city of Santiago to the town of Arenas to access the western-most settlements on the Peninsula (Fig. 1).

Prior to each interview, we defined the research objectives and displayed our scientific permits to each informant; the interview would commence once both parties clearly understood, and were comfortable with, the intended interview process. All interviews were confidential, and the identity of respondents was not recorded. We selected interviewees in an opportunistic way using casual encounters during visits to each community, including along roadsides, when arriving at communities, as well as at local bars, restaurants, and fish warehouses, which served as public gathering points. We emphasized selecting reliable and respected community members to maximize the quality of interview results. We chose this method of sampling due to the lack of telephone communication, low population density, and broad dispersion of homes and gathering points in our study area. Interviews consisted of open- and closed-questions, with sufficient time allocated to allow respondents to discuss issues related to sea turtles at will. Each interview lasted 15–20 min and comprised 17 questions, touching on the age, place of residence, and main source of income of the respondent; frequency and location of their sea turtle observation(s); date and location of their last observation; activity status of observed turtles (e.g., trapped in a fishing net, swimming, nesting); months of observed nesting events; and local names given to the Leatherback Turtles and other species (Supplemental Information Interview Form S1). We showed photos of beach crawl tracks and nesting females for each species in the region (included in the Sea Turtles of the Americas pocket guide produced by Conservation International; Rueda-Almonacid et al. 2007) to gauge the ability of the interviewee to correctly identify the species associated with observed beach crawl tracks and observed turtles. We grouped interviews by community and we summarized results by frequency of occurrence for categorical-variable responses and mean value (± 1 standard deviation) for continuous-variable responses.

Nesting beach surveys and data collection.—We conducted 14 expeditions by land and sea to survey selected beaches highlighted during the interviews.

These efforts occurred during the dry (January to April) and rainy (May to December) seasons in 2018 and part of the dry season (February to March) and beginning of rainy season (May) during 2019. Each expedition lasted 3–4 d, with nighttime beach patrols on foot to look for sea turtles and daytime checks for fresh turtle tracks and nests. Our patrol team was composed of two to four people, and we conducted 39 patrols in total. Patrol duration (hours) was calculated from the time a beach survey started until the time it ended. We also calculated the per-kilometer patrol duration for each beach (hours/km), defined as the patrol duration for each night divided by the length (km) of the beach. We summarized survey characteristics in terms of mean ± 1 standard deviation.

Because nesting activity and nest site selection may be the result of several factors (e.g., beach slope, width, and length [Garmestani et al. 2000], vegetation [Karavas et al. 2005], predators [Blamires and Guinea 1998], and human disturbance [Salmon et al. 1995]), we recorded a variety of physical and environmental attributes to describe the characteristics of each beach visited. These attributes included (1) beach length and beach width (both calculated with a GPS, with the later measured as the distance from the mean high tide line to woody vegetation behind the beach); (2) total area of the beach (calculated with the add polygon tool in Google Earth Pro; Google Earth version 7.3.2); (3) beach direction/orientation to the coast (determined using a compass); (4) description of common grasses and woody vegetation species following Condit et al. (2011), data from TROPICOS (www.tropicos.org), and the University of Panama Herbarium databases for species identification (http://herbario.up.ac.pa/Herbario/index.php); (5) presence of garbage and plastic debris (evaluated visually as common, fairly common, or none at the time of the visit), and (6) visual observation for the presence of predators (e.g., active or past evidence of egg and/or nest depredation by wild animals) and of human disturbance (e.g., illegal take of eggs, cattle intrusion on the beach, and deforestation).

We identified encountered turtle tracks and nests to species following Pritchard and Mortimer (1999) as well as prior knowledge about the types of beaches preferred by each of the four species potentially occurring in the area. For example, whereas Leatherback Turtles typically nest on open sandy beaches between the mean high tide line and the vegetation boundary (Eckert 1987; Kamel and Mrosovsky 2004), Green Turtles usually nest well above the mean high tide line, where beach topography is irregular and often near, but not in, beach vegetation (Whitmore and Dutton 1985; Hays et al. 1995). Meanwhile, Olive Ridley Turtles generally nest on beach slope areas of open sandy beaches (Huges and Richard 1974; Hinestroza and Páez 2001), and Hawksbill Turtles have the greatest tendency to nest within and under beach vegetation far from the mean high tide line (Horrocks and Scott 1991). Nesting activity was interpreted as any event where females conducted a beach crawl, regardless of whether eggs were deposited or not. When unsure, we confirmed nesting by careful nest excavation using a narrow probing stick into the body pit until the egg chamber was encountered.

For each encountered turtle, regardless of whether the turtle was nesting or not, we recorded species, and measured track width (cm) as well as curved carapace length (CCL; cm) and curved carapace width (CCW; cm) of the turtle using a flexible tape. We used Inconel flipper tags (Style 681, National Band and Tag Company, Newport, Kentucky, USA) to mark encountered Green Turtles and Hawksbill Turtles only; tagging programs for Olive Ridley Turtles already exist at adjacent beaches (i.e., La Marinera and Isla Cañas Wildlife Refuge; located to the southeast on the Azuero Peninsula; Arauz et al. 2017). We applied flipper tags to the left front flipper following Balazs (1999). We collected skin biopsies (0.5 × 1.0 cm) from the dorsal neck region following Dutton (1996), then transferred these to 1.5 ml Eppendorf tubes (Scientific Specialties Inc., Lodi, California, USA) and preserved them in 70% (v/v) ethanol for future genetic and stable isotopic analyses, which are part of a more extensive project. We summarized CCL and CCW measurements in terms of mean ± 1 standard deviation.

Results

Local interviews.—We visited 12 of 28 communities in the area (43%); 10 along the southern coast and two on the west coast of the Azuero Peninsula (Fig. 1). We interviewed 21 adults (Table 1). The mean age of the 17 interviewees that provided their age was 54 ± 14 y (range, 27–76 y); most (76%) were between 41 and 70 y old. The majority were male farmers devoted to agriculture and cattle ranching (71%), while two were male fishers and two female housekeepers (Table 1).

In total, 22 beaches were described during interviews as having sea turtle nesting activity. Interviewees reported Leatherback Turtles nesting at 13 sites (59%): Verde, Piro, Tembladera, Ventana, Colorado 2, Granada, Morro de Puerco, Naranjo, La Cuchilla, Pachotal, Frijoles, Cobachón, and Sierra. Of these, the most frequently mentioned nesting beaches for Leatherback Turtles were Verde, Granada, Colorado 2, and Sierra. Whereas 57% of respondents answered that nesting is more frequent during the rainy season, 28% indicated that it happens during the dry season.

Interviewees shared seven local names for the Leatherback Turtle: *Tres Filos*, *Siete Filos*, *Lobo Marino*, *Caguamo*, *Baula*, and *Canal*. *Tres Filos* was the most frequently mentioned common name for the species and

Table 1. Number and age range of informants interviewed in each of 12 communities along the southwest coast of the Azuero Peninsula, Panama. See Results section for more details about informants.

Province (District)	Community	Number of informants	Age range (years old)
Veraguas (Mariato)	Sierra	3	47–70
	Tembladera	3	46–72
	Cacao	1	65
	Rio Lajas	1	30
	Portobelo	1	—
	Colorado 1	3	49–64
	Cobachón	3	27–76
	Pachotal	1	—
	Granada	1	65
	Arenas	1	73
Los Santos (Tonosi)	Punta Blanca	1	51
	Cambutal	2	35–43

refers to the three ridges of the carapace that are visible when the animal is crawling on the beach. Almost all interviewees (90%, mean age = 56 ± 14 y, n = 19) said they had seen a Leatherback Turtle at least once in their life; on average 6 ± 8 y-prior (range, 0.25–30 y-prior, n = 19). Close to half (41%) of the interviewees (mean age = 55 ± 18 y), however, commented that Leatherback Turtles were seen less frequently during the more recent past. Most (71%) encounters took place while the animal was nesting, but 10% of the described observations were of Leatherback Turtles at sea (swimming or trapped in fishing nets). Older informants witnessed Leatherback Turtles nesting when they were teenagers; most agreed that currently it is more difficult to observe this species along the coast, although sporadic nesting events may still take place.

Green Turtles were reported by 76% of interviewees (mean age = 48 ± 14 y, n = 16) at 13 (59%) of the 22 beaches mentioned by interviewees: Sierra, Colorado 2, Verde, Naranjo, Ventana, Cascajilloso, El Gato, Sandillal, Morro de Puerco, Playita, Punta Blanca, Horcones, and La Cuchilla. On average, Green Turtles were observed 1 ± 0.58 y-prior (range, 0.08–2 y-prior, n = 16). Local names for this species included: *Tortuga Blanca*, *Caguamo*, and *Tortuga Verde*. Olive Ridley Turtles were reported by 48% of interviewees (mean age = 51 ± 16 y, n = 10) at 12 beaches (54%): Colorado 2, Pachotal, Granada, Verde, Cambutal, El Gato, Sandillal, Cascajilloso, Playita, Frijoles, Horcones, and La Cuchilla. On average, Olive Ridley Turtles were observed 1 ± 0.57 y-prior (range, 0.16–2 y-prior, n = 10). Local names given to this species included *Lora* and *Caguamo*. Hawkbill Turtles, locally known as *Carey*, were reported by 14% of interviewees (mean age = 50 ± 13 y, n = 3) and were described as being very rare. Respondents described seeing Hawksbill Turtles at six (27%) of the 22 beaches: Naranjo, El Gato, Sandillal, Cascajilloso, Restingue, and Morro de Puerco. On average, Hawksbill Turtles were observed 1 ± 0.35 y-prior (range, 0.5–1 y-prior, n = 3).

Beach surveys.—Because our main goal was to identify nesting beaches for Leatherback Turtles, we surveyed the nine most-frequently mentioned beaches for this species; three located along the western side of the peninsula, and six located in the southern side (Fig. 1). Mean patrol time per night was 2.4 ± 1.4 h (range, 0.5–6.3 h, n = 39) and mean patrolling effort was 2.6 ± 1.9 h/km (range, 1–7.11 h/km, n = 39; Table 2). Both patrol time and patrolling effort were influenced by tides and weather conditions. Mean beach length was 1.7 ± 2.1 km, with Cascajilloso (6.7 km) being the longest and Frijoles (0.38 km) the shortest (Table 2). Mean beach width was 39.7 ± 6.9 m, with no substantial difference among beaches. Horcones and Cascajilloso presented relatively large beach areas, while Sandillal was the smallest. At the vast majority of beaches, we observed Coconut (*Cocos nucifera*) and Indian-almond (*Terminalia catappa*) trees, as well as creeping

Table 2. Temporal distribution and patrol effort of beach surveys for sea turtle activity along the southwest coast of the Azuero Peninsula, Panama as revealed by LEK.

	2018 (by month)												2019 (by month)					Mean patrol effort
Beach	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	(range)
Cacajilloso	•		•		•			•			•							0.4 (0.2–1.0)
El Gato	•	•	•	•										•	•	•	•	3.3 (0.6–7.1)
Sandillal														•				4.4 (4.0–4.8)
Colorado 2									•									1.5 (0.5–2.7)
Sierra												•						1.4 (1.2–1.7)
Granada											•							4.3 (3.2–5.4)
Frijoles			•															n/a
Verde										•								3.2 (1.6–3.9)
Horcones											•							1.0

Table 3. Summary of characteristics of beaches surveyed for sea turtle activity along the southwest coast of the Azuero Peninsula, Panama, as revealed by LEK. Garbage codes are • • • = common, • • = somewhat common, • = none; Threat codes*:* 1 = illegal take of eggs, 2 = deforestation, 3 = egg predation by Coyotes, 4 = egg predation by Coatis, 5 = disturbance by cattle, 6 = illegal take of eggs by humans; Species codes are Cm = Green Turtle (*Chelonia mydas*), Ei = Hawksbill Turtle (*Eretmochelys imbricata*), Lo = Olive Ridley Turtle (*Lepidochelys olivacea*).

Beach	Length (km)	Depth (m)	Total area (m^2)	Orientation	Garbage and plastic debris	Threats observed	Documented nesting activity
Cacajilloso	6.7	30	290,000	NW-SE	• • •	1	Cm, Ei, Lo
El Gato	0.82	45	39,616	N-S	• • •	2, 3	Cm, Ei, Lo
Sandillal	0.54	40	17,302	N-S	• •	3, 5	Cm
Colorado 2	0.96	44	27,440	NW-SE	• •	3, 4	Lo
Sierra	1.5	50	98,811	NW-SE	• •	2, 5	Cm
Granada	0.63	39	43,001	E-W	• •	3, 6	Lo
Frijoles	0.38	35	23,881	E-W	•	-	Cm
Verde	0.64	45	28,562	E-W	• •	-	Lo
Horcones	3.28	30	330,936	NW-SE	• • •	2, 6	Lo

supralittoral vegetation of different species; however, there were relatively few trees, grasses, or creeping vegetation at Cascajilloso, Horcones, El Gato, and Sierra (Supplemental Information Table S1).

Garbage and plastic debris were present at nearly all surveyed beaches, with Cascajilloso and Horcones being the most impacted (Table 3). We observed evidence of active egg predation by Coyotes (*Canis latrans*) at Sandillal, El Gato, Colorado 2, and Granada, and predation by Coatis (*Nasua narica*) at Colorado 2. We identified deforestation at El Gato, Sierra, and Horcones, where we observed active expansion of pastureland and developed land. We witnessed active illegal take of eggs by local peoples during our surveys at Horcones and Cascajilloso (Table 3).

Nesting activity.—We did not detect any evidence of Leatherback Turtle nesting during our surveys; however, we found evidence of nesting by Green Turtles, Olive Ridley Turtles, and Hawksbill Turtles (Table 4, Fig. 1). Cascajilloso and El Gato were the only sites where all three latter species were encountered. For Green Turtles, 90% of tracks (83 of 92) and 62% of females (10 of 16) were observed at El Gato, with most observations occurring during the dry season (Supplemental Information Table S2). In addition, evidence of Green Turtle nesting was also observed at the beaches of Cacajilloso (one track), Sandillal (two tracks, one turtle), Sierra (six tracks, four turtles), and Frijoles (one turtle). Olive Ridley Turtles were more frequent during the rainy season (Supplemental Information Table S2), with most tracks and females observed at Colorado 2, El Gato, Granada, and Horcones (Table 4). We observed one female Hawksbill Turtle nesting at Cascajilloso and one and El Gato.

For Green Turtles, CCL was on average 89.9 ± 7.1 cm (range, 79–100 cm, n = 22), and CCL was most frequently in the 91–100 cm 10-cm size category (n = 10). For Olive Ridley Turtles, CCL was on average 64.9 ± 4.1 cm (range, 60–72 cm, n = 10), and CCL was most frequently in the 60–70 cm 10-cm size category (n = 9). The only Hawksbill Turtle that was measured was 82 cm CCL. General details on the size of nesting and non-nesting female turtles at each beach during the surveys are provided in Supplemental Information Table S2.

Discussion

We observed nesting activity of sea turtles at nine beaches as part of this survey effort, including Cacajilloso, El Gato, Sandillal, Colorado 2, Sierra, Granada, Frijoles, Verde, and Horcones. All sites, and especially those hosting substantial nesting activity such as El Gato, should be considered for inclusion in

Table 4. Sea turtle nesting activity documented during beach surveys along the southwest coast of the Azuero Peninsula, Panama, as revealed by LEK. Species codes are Cm = Green Turtle (*Chelonia mydas*), Ei = Hawksbill Turtle (*Eretmochelys imbricata*), Lo = Olive Ridley Turtle (*Lepidochelys olivacea*).

	Number of Crawl Tracks			Number of Females		
Beach	Cm	Ei	Lo	Cm	Ei	Lo
Cacajilloso	1	1	5		1	5
El Gato	83	1	7	10	1	2
Sandillal	2			1		
Colorado 2			8			6
Sierra	6			4		
Granada			6			5
Frijoles				1		
Verde			4			3
Horcones			6			4
Total	92	2	36	16	2	25

local and regional nesting beach monitoring programs to further promote the conservation and recovery of sea turtles in Pacific Panama. Of the nine beaches surveyed, we witnessed nesting events of Olive Ridley Turtles at six beaches, Green Turtles at four, and Hawksbill Turtles at two, but we did not find evidence of nesting activity by Leatherback Turtles. This information represents the first of its type for this remote region of the Azuero Peninsula and reflects the strong value of LEK for revealing the presence and distribution of endangered species in rural, difficult-to-access areas.

The use of LEK.—In Panama, studies involving the use of LEK have been primarily conducted in indigenous communities to understand patterns of traditional use and conservation of natural resources (e.g., Dalle and Potvin 2004; Sharma et al. 2015). As has been conducted in other areas of the Pacific (e.g., Vega et al. 2013; Guzman et al. 2015; Robles et al. 2015), studies such as this that solicit LEK via structured interviews can result in the collection of highly conservation-relevant information about resource use and management. We found the use of LEK to be effective in orienting our survey design as has been done in prior studies with sea turtles in remote, unexplored areas (Meylan et al. 1985; Carr and Carr 1991). Although the isolation of the area hindered our ability to collect more detailed data at all potential beaches, our study demonstrates the value of LEK in terms of the experiences and information shared by community members. Also, considering limitations in time and funding for our study, the use of LEK was hugely beneficial as we were able to concentrate our efforts on those beaches with higher probabilities of nesting for Leatherback Turtles and other species, thus maximizing the probability of encountering evidence of nesting activity.

During the interviews, local people were eager to communicate their knowledge, perhaps due to a novelty factor because many of them indicated that our team was the first to query them about sea turtles in the area. During informal conversations, we were told that most of the inhabitants of these communities normally stay for only short periods (3–4 mo) sporadically throughout the year to look after their cattle and crops. This information may help facilitate the involvement of local people in future conservation and monitoring initiatives (Senko et al. 2011).

Nesting distribution and abundance.—Whereas we observed Olive Ridley Turtle nesting activity on the most beaches during this study, perhaps our most important result was the discovery of substantial nesting activity by Green Turtles at El Gato. Green Turtle nesting activity was observed most frequently at this and other surveyed beaches during the dry season (December-May), which is consistent with beaches in Pacific Costa Rica and Galápagos (Fonseca et al. 2018; Zárate 2012). Yet, while perhaps not as high nesting abundance at other areas within the region (e.g., Costa Rica, Fonseca et al. 2018; Galápagos Islands, Zárate 2012), the 83 tracks and 10 nesting females observed at El Gato during our study suggest that it could be an important nesting site in Pacific Panama and regionally. We recommend detailed, long-term monitoring efforts for Green Turtles nesting at El Gato, and perhaps Sierra and Sandillal, which were two other sites with observed Green Turtle presence. Our results indicate that such efforts should coincide with the dry season, when Green Turtle nesting appears to be most frequent in the region. We also encourage the assessment of potential threats at El Gato and adjacent areas.

In addition to our discovery of a potentially important Green Turtle nesting beach, our study confirmed that Olive Ridley Turtle nesting is widespread along the Azuero Peninsula with six surveyed beaches yielding evidence of nesting by this species. This result is consistent with observations at other sites along the Peninsula not included in this study (Arauz et al. 2017 unpublished technical report). For example, Olive Ridley Turtles *arribadas* (mass nesting events) occur at La Marinera Beach and in Isla Cañas Wildlife Refuge, both located on the south-central coast of the Azuero Peninsula and protected by the Ministry of Environment of Panama. In addition, community-based sea turtle programs that largely focus on Olive Ridley Turtles are present on the Peninsula at Malena and Mata Oscura beaches (the latest is being supported by Fundación Agua y Tierra), at Cambutal Beach (co-managed by Tortuagro and Fundacion Tortuguias), and at Pablo Arturo Barrios Wildlife Refuge, where the local non-governmental agency Tortugas Pedasi conducts beach monitoring and protection efforts focusing on Olive Ridleys and Green Turtles. A community-based monitoring program was also present at Morrillo Beach, although it has been abandoned in recent years.

The low numbers of Hawksbill Turtles that we observed may be in part the result of our surveys being mostly conducted out of the peak nesting months for the species in Central America (Gaos et al. 2017). Because most of our observations were of beach crawl tracks only, it is also possible that Hawksbill Turtle tracks were misidentified as Olive Ridley Turtle tracks because of the similarity between beach crawl patterns for the two species (Pritchard and Mortimer 1999; Gaos et al. 2006). This is unlikely, though, because the two species typically nest in very different locations on the beach (e.g., Olive Ridley Turtles in open sand, Hawksbill Turtles in beach vegetation). Unfortunately, Hawksbill Turtle populations in the Eastern Tropical Pacific remain substantially depleted relative to historic levels (Wallace et al. 2011) due to a combination of overexploitation of eggs and Hawksbill Turtle shell (tortoiseshell), fisheries bycatch mortality, and nesting habitat degradation (Mortimer and Donnelly 2008; Gaos et al. 2012; Arauz et al. 2017 unpublished technical report; Convention on International Trade in Endangered Species of Wild Fauna and Flora 2019). Although recent in-water observations revealed an important Hawksbill Turtle foraging ground at Coiba Island National Park (Llamas et al. 2017), located 90 km to the west in Panama, there is still uncertainty about the nesting distribution and abundance of the species along the Pacific coast of Panama.

Body size of observed turtles.—With respect to the size ranges of nesting turtles we observed, we note that both Green and Olive Ridley Turtles had CCLs that were generally consistent with data previously reported for nearby nesting rookeries for each species. For example, whereas here we report that nesting Green Turtles were generally between the 91–100 cm (CCL), females nesting in northwest Pacific Costa Rica were on average 85.4 ± 5.9 cm (Fonseca et al. 2018) and their counterparts in the Galapagos were on average 86.7 ± 6.2 cm (Zárate et al. 2003). Moreover, the size range of turtles reported for both Costa Rica and the Galapagos was 60.7–109.0 cm, which encompasses the size of all 10 Green Turtles encountered during the present study. For Olive Ridley Turtles, we found a CCL range of 60–70 cm ($n = 9$). This is largely consistent with the CCL range of nesting Olive Ridley Turtles in Costa Rica (66–69 cm; Robinson et al. 2019) and Mexico (65.5–70.7 cm; Hart et al. 2014), both of which are countries bordering the eastern Pacific with major Olive Ridley Turtle rookeries.

Leatherback Turtles, then and now.—Interviews revealed nesting events by Leatherback Turtles were more frequent in the past at our surveyed beaches, with one informant suggesting that their last encounter with a nesting female was around 30 y ago (approximately 1988). One intriguing aspect is that 41% of respondents mentioned they had seen Leatherback Turtles in recent times, which could be an artifact of misidentification because, according to our results, some local people confuse Leatherback Turtles with Green Turtles. More than half of the respondents, however, answered that Leatherback Turtles were most frequently observed during the rainy season, which is consistent with the nesting season of the species in nearby Costa Rica (Reina et al. 2002). While currently it appears that Leatherback Turtle nesting occurs rarely if ever on the surveyed beaches, the interview results indicate that the species was at least more common during past decades. It is unclear if Leatherback Turtles were ever more than a sporadic nester in the region.

Human and natural impacts at surveyed beaches.—Garbage, and plastic in particular, continues to be one of the most ubiquitous forms of marine debris in marine environments around the world, including beaches (Storrier et al. 2007; Addler et al. 2009). In general, plastic debris on beaches may originate from two main sources: direct human disposal inland or debris washing back from the ocean (Corcoran et al. 2009). Although the exact source of the garbage at the surveyed beaches is unknown, it was clear that the sites near populated settlements were more affected (e.g., Cascajilloso and Horcones). For example, during beach cleanup activities at Cascajilloso in 2018 and 2019, organized by Panama Wildlife Conservation Charity and the Ministry of Environment of Panama, 160 kg and 338 kg of garbage were collected, respectively, the vast majority of which was plastic collected in just two hours (Eric E. Flores, pers. obs.). Considering the extreme amounts of plastic collected during our efforts, we encourage future research into the origins, rate of deposition, and direct effects of this material on the local marine biota, including sea turtles.

We found Coyotes and Coatis predating sea turtle eggs at nearly half of the beaches we surveyed. These species are among the main predators of sea turtle eggs that have been reported at many nesting beaches throughout the Americas (e.g., Atencio 1994; Drake et al. 2001). Considering that Coyotes are expanding their range in Panama, using deforested areas and areas of cattle ranching (Méndez-Carvajal and Moreno 2014), it is possible that egg depredation may increase in the future. We recommend that ongoing and future nesting beach monitoring and protection programs work to mitigate this threat through the use of protected beach hatcheries and/or some form of predator exclusion.

Conservation implications.—Our study reveals several apparently important nesting beaches for sea turtles in the Azuero Peninsula in Panama that were previously unknown, and this marks the first effort in the region to use LEK to orient local survey efforts. Although we demonstrate the value of LEK for identifying areas that need to be protected, the reality is that continuous *in situ* efforts to protect the beach habitats as well as nests and hatchlings will perhaps be hindered by the isolation of these sites. One promising course of action may be the implementation of a citizen science project, where local communities gain and share knowledge about sea turtles and conservation activities. Our study opens the doors to conduct more systematic and hypothesis-driven studies to feed future management strategies in which local people are active participants, especially considering they are at the frontline of conservation in these isolated areas of Panama. In addition to enlisting local inhabitants in beach monitoring and protection initiatives, it would also be beneficial to engage with other community efforts and those of Non-Governmental Organizations in the area, such as the Panatortugas Network, to help expand local beach monitoring capabilities. Indeed, most of the beaches mentioned by interviewees lack any monitoring program or protection.

Building synergies with existing protected areas would also be beneficial. Most of the beaches surveyed during this study are either within the core area or buffer zone of the Cerro Hoya National Park (CHNP; Fig. 1) or just south of the Veraguas Marine and Coastal Management Zone, which affords special protection status. While CHNP has a management plan that was implemented in the mid-2000s (Autoridad Nacional del Ambiente 2004), this park is insufficiently staffed to provide adequate surveillance and law enforcement. Nevertheless, a sea turtle monitoring program was initiated by the Ministry of Environment of Panama at Cascajilloso Beach in 2018 to stop predation and illegal collection of eggs and, after our survey, a sea turtle egg hatchery was established in 2019, which protected 80 Olive Ridley Turtle nests and produced 5,953 hatchlings. This was an encouraging advancement and will hopefully serve as an impetus for the implementation of additional nesting beach conservation programs along the Azuero Peninsula. While these programs develop, however, perhaps one of the positive realities about the area is its remoteness, which so far has kept human presence and egg harvest impacts relatively low compared to more populated areas in Pacific Panama.

Acknowledgments.—We thank Daniel Rivas, Marcos Caballero, Bernardo Peña, Dineylis Aparicio, Amarilis Ramos, Juan Ayala, and Diego Amorocho for help with fieldwork. Special thanks to Marcelo Rodriguez and his wife in Granada Beach, and the Moreno family for allowing special access to El Gato Beach. Amanda Branford, Edgardo Díaz-Ferguson, and Omar Lopez made useful comments to the early version of the manuscript. Field work was conducted under the Scientific Permits No. SE/A-21-18, and SE/A-86-18 issued by the Ministry of Environment of Panama. This project was funded by Panama Wildlife Conservation Charity, complemented with a bursary to Dr. Eric E. Flores from Sistema Nacional de Investigación (SNI) in Panama.

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Supplemental Information: http://www.herpconbio.org/Volume_16/Issue_2/Flores_etal_2021_Suppl.

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