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CHARACTERIZATION OF ATTACK EVENTS ON SEA TURTLES (CHELONIA MYDAS AND LEPIDOCHELYS OLIVACEA) BY JAGUAR (PANTHERA ONCA) IN NARANJO SECTOR, SANTA ROSA NATIONAL PARK, COSTA RICA

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Abstract

In this study, we examined sea turtles consumption by jaguars and their temporal and spatial distribution at Naranjo beach, Santa Rosa National Park Costa Rica. We include information about sea turtle consumption rate by jaguars and whether this represents a threat to the population on the study area. We monitor jaguar predatory behavior on the sea turtles Lepidochelys olivacea and Chelonia mydas between August 2012 and September 2013. We located predation events and measured all turtles preyed carapace width (ACC) and length (LCC). Mean ACC of killed turtles was lower than the ACC population mean. Killed turtles LCC mean and population mean were the same. The beach was not used uniformly as sea turtle hunting area and it was shared by at least three jaguars. Jaguar hunting impact on sea turtle populations is very small in comparison to fishing by-catch. C. mydas and L. olivacea are important jaguar food source because they are easy to hunt and they have a high biomass. Sea turtles can be key preys when other prey availability is low and/or the period when female jaguars are feeding their cubs.

Keywords: *Carnivore; Predatory behavior; Seasonal resources.*

Introduction

Jaguar (*Panthera onca*) predates on two sea turtle species (*Chelonia mydas* and *Lepidochelys olivacea*) at the Pacific coast of Costa Rica. As a result, this relationship involves three species threatened by human impacts. Jaguar populations are threatened by hunting, habitat destruction and declining of prey populations [1-3]. Sea turtles major threats are fishing by-catch, illegal fishing, and egg poaching at nesting sites [4, 5]. Knowledge of some ecological aspects of jaguar-sea turtle relationships may contribute to their conservation.

Prey populations may exist at low densities due to predator pressure, or at high density regulated by competition for food or other resources [6]. Jaguars and sea turtles coexist in coastal ecosystems, basically in sea turtle nesting areas. Although there are no data on the effect of jaguar predation on sea turtle populations, its impact is likely to be low due to their habitat differentiation. However in coastal areas where they coincide, predation pressure may be high

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and affects the success of sea turtles reproduction with its consequent population regulatory effect [6].

Among carnivores, prey variation depend less on nutritional quality differences than differences in prey biomass, visibility, capture success and injury risks from the hunting activity [7, 8]. Although jaguar predation on marine turtles has been described only three times in the Neotropics, specifically in Costa Rica [1, 9-10] it can be inferred that capture effort and risk is significantly lower comparing with other preys' capture [11]. Additionally, large carnivores such as jaguars, seek to consume heavier preys to optimize energy expenditure [12]. Food for carnivores is a determining factor for their territoriality [13, 14], and felids have an exclusionary behavior, aggressiveness and territory defense [15]. The jaguars have a similar behavior pattern, but at lower intensity [12]. Jaguars tolerate, to some degree, the presence of other individuals within their home ranges; however, they maintain exclusive areas mainly for hunting [12].

In this study, we examined marine turtles hunting by jaguars and its temporal and spatial distribution in Naranjo beach, Santa Rosa National Park Costa Rica. We established the following predictions: 1) Jaguars will predate on sea turtles of both species by selecting individuals larger than the population mean and 2) Each individual jaguar will have an exclusive sea turtle hunting area. We include information about sea turtle consumption rate by jaguars and whether this represents a threat to turtle population on the study area. The results of this research can be used by the national park authorities as an input for regulating access to the area to protect these species.

Materials and Methods

Study area

The study was conducted in Santa Rosa National Park (SRNP), Costa Rica, located 30 km north of Liberia city, Guanacaste province. Santa Rosa is 38,628 ha and is part of a continuous biogeographical block of 163,000 ha of protected areas. SRNP protects one of the better preserved dry forests of all Central America, characterized by a well-defined dry season, which usually starts in December and can continue until June. Average annual temperature is 28°C (22°C-33°C) with a low relative humidity. The annual rainfall between 1979 and 2012, based on data provided by the Santa Rosa Automatic Weather Station, was 1696mm (VC = 37.5%). The Naranjo sector is located in the southwestern part of SRNP and preserves mainly coastal-marine ecosystems (besides mangroves, lagoons and dry deciduous and semi-deciduous forests). Naranjo beach is located there, and has an extension of 5,640m. Naranjo beach represents one of the most important beaches because of sea turtle nesting, mainly *C. mydas* and *L. olivacea*, in the North Pacific region of the continent [16].

Monitoring predation events.

We use the south and north sections of Naranjo beach to monitoring predation events. We walked 5.64km per day by sand searching sea turtles tracks and carcasses (Fig. 1). Between August 2012 and September 2013 we walked Naranjo beach in order to search for sea turtles killed by jaguars. Between October 2012 and January 2013 we walked every day, and from February 2013 until September 2013, we walked only 15 days a month. Thus we monitored the peak of *C. mydas* and *L. olivacea* nesting arrivals, which is related to the rainy season in the study area [16-17]. Additionally, we searched from seashore to 200m inside the dry forest by trying to find turtles dragged inland by jaguars. We ink marked all turtle carapaces of individuals killed, we geo-referenced them in the Costa Rica Tranversal Mercartor projection (CRTM05) with a GPS unit. We identified each individual by name it after who found it. We also measured carapace width (ACC) and longitude (LCC), according to the methodology proposed by Bolten [18]. We recorded scratches, bites and any other marks caused by jaguar attack and dragging (if any) to the feeding site [9]. We set up a Bushnell camera trap next to each dead turtle within the first 12 hours after the killing, as jaguars return to the hunting site several hours later [9, 11]. Each predator jaguar was identified based on its spot pattern [19]. According to the Costa Rican National Meteorological Institute, sea turtle nesting behavior is influenced by variables such as tidal coefficient and moon phase; therefore, we recorded both variables less than 12 hours after each predation event. In addition, we conducted a qualitative description of jaguar predatory behavior on the turtles, including details about the hunting technique.

Fig. 1. Photo of sea turtle *Lepidochelys olivacea* and tracks on sand (A) and sea turtle carapaces killed by jaguar (B) in Naranjo beach, Santa Rosa National Park. 2016.

Analysis

To test our first prediction, we evaluated whether turtle ACC and LCC carapace length of individuals killed by jaguars was higher than the population mean for both species, based on the confidence interval estimation of the differences between the two sets of data means. The population mean was estimated from measurements of 1008 female *Lepidochelys olivacea* and 250 female *Chelonia mydas* (Fonseca et al., 2011, 2010 unpublished data). To evaluate our second prediction, we use carapace locations to estimate if an aggregation existed by means of the Local Convex Hull method (a-LoCoH), recommended for animal activity with high use frequency of a particular site within its home range. The method excludes areas not used by the monitored individual for daily activities. We use probabilities of 95%, 75% and 50% of the density volume of the surface using a-LoCoH. We interpreted the estimated areas as sites of greater jaguar hunting activity on turtles. The a-LoCoH uses the parameter *a* that is the maximum distance between two points of the locations, which, in our case, were the carapace locations. We examined the relevance of using the *a* parameter compared to the hunting area estimated by the Minimum Convex Polygon [21]. We evaluated the potential jaguar hunting area on sea turtles by means of different *a* values until we found a stable one that represented the hunting area. Selecting the *a* value represents a trade-off between type I and type II errors, where *a* low values underestimate the hunting area and high *a* values overestimate the hunting area.

Results

We conducted 220 walks of 5.64 km per day for a total distance of 1240.8 km. We found 28 turtle carapaces, 16 of them were predated within 12 hours and 12 were older events (more than 12 hours). Nine carapaces belonged to *L. olivacea* and 19 were *C. mydas*. We identified three adult jaguars, two males and one female. The female killed six turtles, male A killed eight and male B just one turtle for 15 killing events (Table 1). The female jaguar was seen with two cubs.

Table 1. Characteristics of sea turtle killing events by jaguars recorded within the first 12 hours after predation at Naranjo beach, Santa Rosa National Park Costa Rica. 2013.

	Species	Date	Individual	LCC	ACC	Tidal coefficient.
1	*Chelonia mydas*	27-Oct-12	female	80	87	High
2	*Chelonia mydas*	7-Nov-12	female	80	74	Low
3	*Chelonia mydas*	10-Nov-12	male A	88	80	High
4	*Chelonia mydas*	30-Nov-12	male A	82	76	High
5	*Chelonia mydas*	18-Dec-12	male A	77	69	High
6	*Chelonia mydas*	21-Dec-12	female	78	64	Low
7	*Chelonia mydas*	30-Dec-12	male B	87	78	High
8	*Chelonia mydas*	22-Jan-13	male A	88	80	Low
9	*Lepidochelys olivacea*	2-Feb-13	male A	64	66	Medium
10	*Chelonia mydas*	28-Feb-13	female	81	77	Very High
11	*Chelonia mydas*	11-Mar-13	female	86	82	Very High
12	*Chelonia mydas*	29-Mar-13	female	83	74	Very High
13	*Chelonia mydas*	25-May-13	male A	84	78	Very High
14	*Chelonia mydas*	7-Jul-13	male A	82	77	High
15	*Chelonia mydas*	27-Aug-13	male A	83	70	Low
16	*Chelonia mydas*	5-Sep-13	NA	92	78	Very High

Size of predated turtles

Mean ACC for predated *L. olivacea* was 66.4cm (SD±2.73, n = 9) and 85.19cm for *C. mydas* (SD±5.09, n = 19). Mean LCC for predated *L. olivacea* was 71.5cm (SD±2.91) and 81.2cm (SD±4.73) for *C. mydas*. Mean ACC of dead turtles was lower than the population mean (Fig. 2).

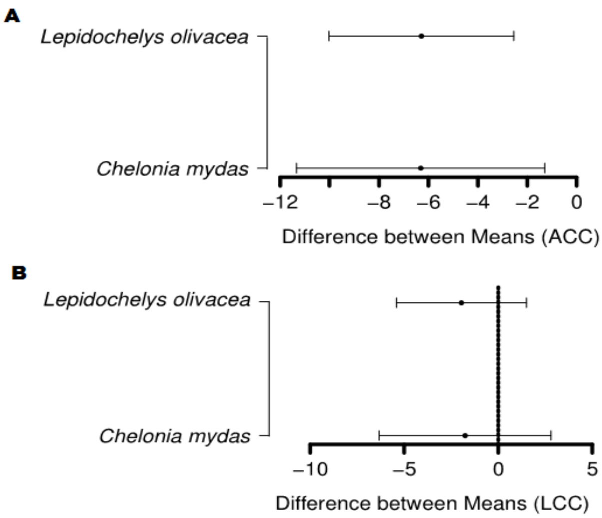

Fig. 2. Confidence interval for the difference between the mean carapace width (A) and carapace length (B) of sea turtles preyed and not preyed at Naranjo beach, Santa Rosa National Park, Costa Rica.

The interception of the dotted line means there is no significant difference and no interception means there is a significant difference. The confidence level is at 95 % probability. There was no difference between the LCC mean of dead turtles and the population mean (Fig. 2).

Spatial distribution of predation events.

The distribution of the 28 carapaces was grouped in the study area. The best value to represent the hunting area was 1800m (Fig. 3).

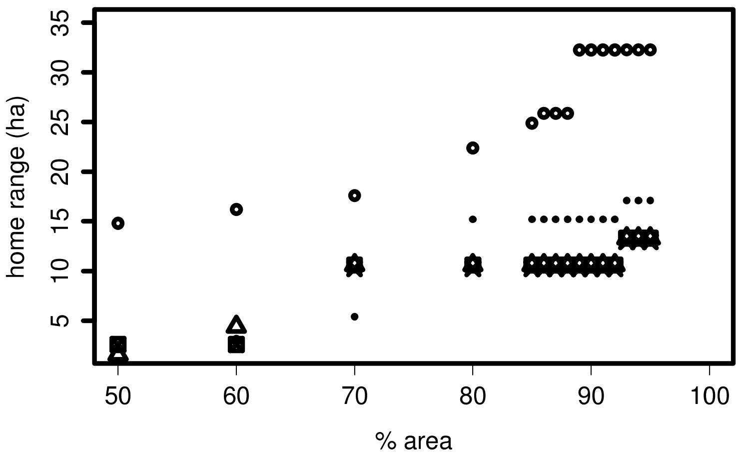

Fig. 3. Evaluation of the *a* parameter to estimate sea turtles hunting area by jaguars (*Panthera onca*). The hunting area estimated from the Minimum Convex Polygon is represented by open circles and a-LoCoH Adaptive Kernel with different values for the *a* parameter (• 1800m, ☐1700m × 1600m and Δ1500)

Carapaces were concentrated at the south section of Naranjo beach after the fitted distribution (Fig. 4). Half of the observations were grouped at only 11% of the whole area (Table 2).

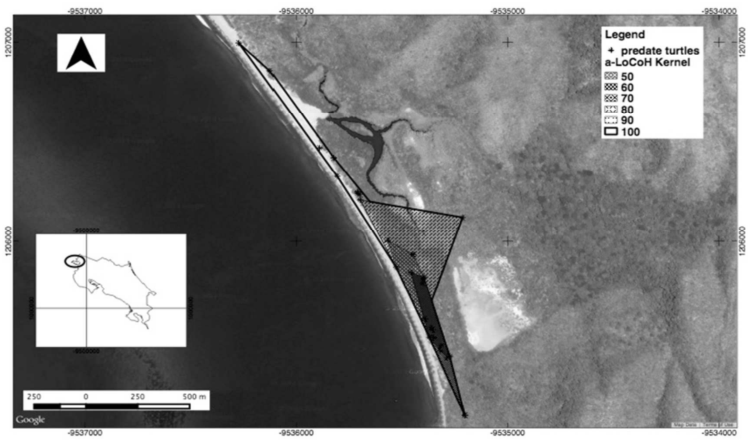

Fig. 4. Use areas estimated from Kernel a–LoCoh adaptive method with parameter a = 1800m at various levels of probability representing sites of higher (white color) or lower use (black color) for hunting and consumption of sea turtles by jaguars at Naranjo beach, Santa Rosa National Park, Costa Rica. 2013.

Table 2. Sea turtles hunting and consumption areas by jaguars estimated from the a - LoCoH Kernel method at Naranjo beach, Santa Rosa National Park, Costa Rica.

Use area ID	% Kernel probability.	Area (Ha)	Relation to total area.
1	100	19.46	1
2	90	15.25	0,78
3	80	15.25	0,78
4	70	5.41	0,28
5	60	3.19	0,16
6	50	2.24	0,12
	Total	60.80	

Predatory behavior

Twenty eight carapaces (78%) were *C. mydas*, and in the case of killing events detected during the first 12 hours, only one was *L. olivacea* (n = 15). The jaguar extirpated the head of all turtles found. Tracks indicate that turtle were in normal position until the jaguar encountered them, turned them upside and dragged them to the feeding site.

Jaguars had different consumption patterns. Male A bit, tore and broke a big carapace section near the turtle´s neck. Male B broke the carapace significantly less than male A. The female virtually did not destroy the carapace. The maximum dragging distance was 15m by the female and 40m by male A. After satisfying their needs, jaguars left the turtle and returned the following night to eat the rest of the meat. We found a carapace just 1.25km from the 200 high tide line, however, we were not able to identify the jaguar that killed that turtle.

Discussion

According to field observations, jaguars killed sea turtles during nesting and nest building, just like they did at Tortuguero and Corcovado National Parks [9-10]. *C. mydas* prefers to nest in areas with vegetation [22], but *L. olivacea* nests in the sand [23-24]. In general, beach conditions facilitate jaguar sea turtle hunting. Jaguars usually kill by biting the turtle´s neck, then they turn the plastron up and drag the turtle to the feeding site where they consume it. Usually jaguars take the fins and the head and tear out the inside of the carapace with their claws to eat the flesh, while most of the guts were already scattered on the beach during dragging.

Our first prediction was not fulfilled, since jaguars killed sea turtles with ACC values lower than the study area population mean (Fig. 2). Those wide and elongated shape carapaces make it easier for them to flip the turtle over and drag it to the feeding site, because the contact surface with sand diminishes. The clutch size of nesting turtles is directly related to the carapace size; as a result jaguars are hunting individuals with lower reproductive potential [25].

The beach area was not used uniformly as turtle hunting ground by jaguars (Fig. 4), a fact also reported in Tortuguero National Park [26]. This may be explained by the fact that hunting areas are located farther from camping areas (with higher tourist concentration) and because they have a higher density of nesting turtles [16]. So, our second prediction is not fulfilled. Our data showed at least three jaguars sharing a sea turtle hunting area, although just two individuals hunted and consumed almost all the dead turtles found (Table 1). Other studies have showed that jaguars may overlap home ranges, including hunting areas (1, 12].

Jaguars killed more individuals of *C. mydas*, despite being less abundant than *L. olivacea* in our study area. For example, in Naranjo beach, 37 *C. mydas* nests and 126 *L. olivacea* ones were recorded. In Nancite, an "arribada" beach, thousands of female *L. olivacea* nest at a time [17, 23], while only a handful of *C. mydas* nest can be found.

Herbivores can survive on poor quality food when it is in large quantities, while strictly carnivores such as jaguars depend on differences in weight, visibility, ease of capture, or associated risk of injury during prey capture, rather than differences in nutritional quality [6]. The risk of hunting sea turtle species is practically the same, so proportionally *C. mydas* (average weight 70kg) provides more food [27] than *L. olivacea* (35 - 40kg weight). The number of turtles killed by each jaguar at SRNP in 285 days of sampling was less than one every 30 days (Table 1). However, it was found that a single female jaguar monitored by VHF telemetry predated on 16 sea turtles in a period of 33 months [28]. Between July 2005 and June 2010, 676 turtles were killed by jaguars at Tortuguero National Park [26], however, the park has a larger nesting area (29 km).

Seventy five percent of the 16 predation events recorded during the study period happened during high or very high tide levels (Table 1). Tide dynamics is a very important factor for sea turtle arrival to their nesting beaches. The arrival time near high tide provides access to the sand, mainly for *C. mydas* [29]. Knowledge of the relationship tides-sea turtle by jaguars might be part of their successful hunting strategy. *Ursus arctos*, for example, developed several strategies from social and cognitive skills to increase their success of salmon hunting

[30]. Jaguars change their behavior in relation to lunar phase and the type of prey consumed at Corcovado National Park, Costa Rica [28].

Conclusions

Jaguars' predation pattern found in this study showed that they hunt on both species of sea turtles with larger carapaces than the population mean. A less wide carapace is more elliptical which facilitates the turtles' flip over and dragging to the sand surface. Jaguars' hunting site was limited to a low percentage of this research area, which should be taken into account for future researches regarding tourism restricted areas within protected areas. In terms of predation, C. mydas was the turtle specie with a higher number of predated individuals due to its nest behavior; this turtle prefers nesting in vegetation areas. In spite of a higher amount of L. olivacea nests, C. mydas has a larger biomass which is considered by jaguars as a good energy source. Naranjo beach tide dynamics influence jaguars' predation on sea turtles. When food availability is higher, jaguars can overcome hunting areas as in the highest concentration site of reported preys evidenced in this study.

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