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The effects of nesting ground temperatures on incubation and hatchability of loggerhead turtle *Caretta caretta* inhabiting the Mediterranean Sea Coast, Libya

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ABSTRACT

Few studies were conducted on the long-term effect of temperature on loggerhead turtle *Caretta caretta* nesting ground and hatchability especially on the eastern coast of Libya. The period of turtle eggs´ incubation and their hatchability are heavily influenced by the ambient environmental factors. Temperatures have gained world attention in the last decades. The current study discusses the profile habitat temperatures (air, water, and nesting ground) of *C. caretta* during the breeding season from June to August 2019. In addition, rainfall and moisture were assessed to address and predict the factors threatening this biotope. The current study has revealed that the two studied sites (Al-Qurdaba and Umm-Alfraes shores) differed significantly in the ecological criteria from one month to another. Also, the percentages of hatchability differed in relevant to these criteria. Because climate change is an important threat to most poikilothermic animals worldwide, this study provided background information that should be considered in predicting models about the potential effects of global warming on the success of nesting in the eastern Mediterranean Sea coast of Libya.

INTRODUCTION

Sea turtles are migratory and geographically dispersed animals. Six of the seven marine turtle species worldwide have been identified as threatened with extinction **(IUCN, 2018)**. The loggerhead turtle *Caretta caretta* is widely distributed in the tropical and temperate regions **(Kamezaki *et al*., 2003 and Limpus and Limpus, 2003)**. *C. caretta* faces different threats during its life cycle, such as loss or alterations of nesting grounds, predation, ingestion of marine debris, environmental contamination, diseases, and interactions with various fisheries activities **(Witherington, 2003)**. The Mediterranean is frequented by large numbers of loggerhead turtles **(Carreras *et al*., 2011; Haddoud and Gomati, 2011 and Clusa *et al*., 2014)**. Libya has more than 1000 km of sandy coastline that are suitable for loggerhead turtle nesting **(Haddoud and

Gomati, 2011). The old information regarding loggerhead turtle nesting at Libyan coast dates back to 20 years ago **(Armsby, 1980)**. This basin is one of the most heavily exploited for recreational or industrial activities worldwide. Each year, tens of thousands of loggerhead turtles are accidentally injured because of the interaction with human activities **(Casale and Margaritoulis, 2010)**.

Temperature is the dominant environmental factor affecting sea turtle nests, as they play a direct role in the egg incubation period **(Spotila and Standora, 1985)**. Successful incubation in sea turtles occurs in a temperature range from 26°C to 33°C **(Miller *et al.*, 2003)**. Sea turtle eggs need adequate sand humidity, salinity, respiratory gases, and temperature for normal development, which can only be supplied by their local environment **(Ackerman, 1997)**. On the other hand, extreme low and high incubation temperatures affect hatchability and increase self-righting times, hatchling locomotors performance and post-hatching growth **(Fisher *et al*., 2014; Booth, 2017**). Several works have assessed the distribution of sea turtle nesting in the Mediterranean **(Casale and Margaritoulis, 2010; Haddoud and Gomati, 2011; Casale and Mariani, 2014; Stokes *et al.*, 2015 and Almpanidou *et al*., 2016)**. Given that sea turtles, and especially loggerheads, may potentially lay egg clutches throughout the Mediterranean, ranging from high density to scattered nesting activity, defining the Mediterranean nesting sites according to their relative importance is useful. Neither abundance nor density alone can capture the real importance of a nesting site. Most works done on loggerhead turtle in Libya were at west coast **(Jribi *et al*., 2013)**.

In addition to the global warming, the predators potently control the process of loggerhead turtle laying eggs and hatchability in the Libyan coast **(Haddoud and Gomati, 2011)**. The main objective of this study was to determine whether elevated temperatures affect the incubation period, the hatchability and the percentage of *C. caretta* nesting. Moreover, we aimed to address a good approach for future management plans for the threatened loggerhead turtle populating eastern Mediterranean Sea coat of Libya.

MATERIALS AND METHODS

1. Study Areas

A: Al-Qurdaba Shore

Al-Qurdaba shore is located in Al-Owainat Reserve (32 º. 17'. 44'' N, 23 º. 47'. 39'' E) about 55 km west of Tobruk. Its length about 3 km and its width is about 1.5 km, with no natural shading on the shore (Fig.1 A&B). This shore is considered an important site for the nesting of loggerhead sea turtle.

B : Umm-Alfraes Shore

Umm-Alfraes shore is located in Al-Tamimi area (32 º. 25'. 18.5" N, 23 º. 05'. 17.9" E**)**, 100 km west of Tobruk (Fig. 1C&D). This shore is about 2 km long, its width is about 1km and it is one of the important points that turtle heads to lay their eggs.

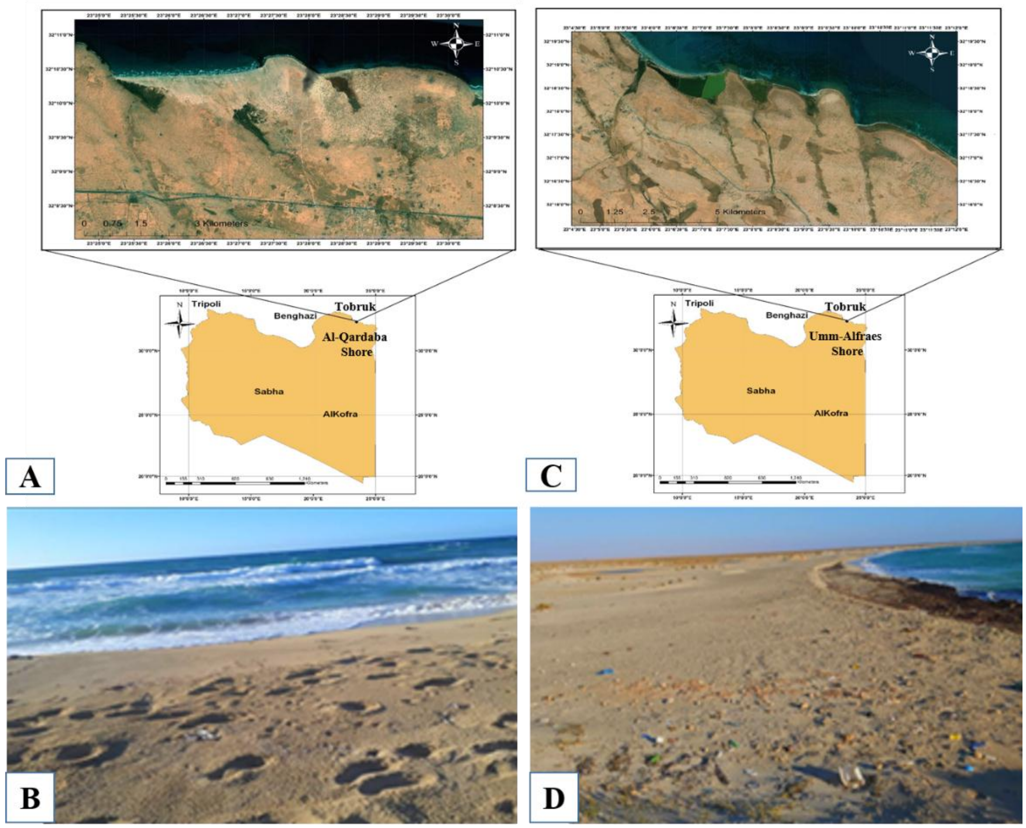

Fig. 1. Study sites at the Mediterranean Sea of Libyan: Al-Qurdaba Shore (A: Map & B: photograph) and Umm-Alfraes Shore (C: Map & D: photograph).

2. Shore Survey and Data Collection (Fig. 2)

The study started with the nesting season beginning from the end of May until the end of August 2019. During the time of the nesting season the two sites were daily surveyed, track was counted and nesting activities were recorded during the period from morning (6:00) till evening (18:00). Nesting activities were classified to true track (when turtle laid eggs), false track (if the turtle dug but didn't lay egg), U-track (turtles have journeyed a shore, but back to Sea without nesting) and C-track (old tracks, did not end with a nest). For each true nest, the eggs number was counted, the distance of the nest from the high tide line was measured, and also the depth of the nest was measured. The nest was then observed until it hatched, and then the time of incubation was calculated, the percentage of hatcheries success, and the percentage of success egg calculated (Fig. 2 C&D). Temperature (°C) was measured for the sea water surface, air and sand. Sand temperature was measured daily at three depths of true turtle nest (0 cm, 5 cm and 35 cm) from (13:00 to 14.00 o´clock) using thermometer. Sand moisture (humidity %) was measured in the field according to **Sukandar *et al*. (2020)**. Measurement of rainfall (mm) was obtained from the nearby Tobruk Metrological Station. Data about different threats for loggerhead turtles in both sites were recorded.

3. Statistical Analysis.

The collected data was statistically analyzed using SPSS (V. 20). By using the statistical program the following quotation and relations were concluded: means ± SD, Analysis of Variance (ANOVA), the Multiple Range Comparisons (Least Significant Difference; LSD) was selected from Post Hoc window, Pearson correlation coefficients were applied in the present data. Probability values of <0.05 and <0.01 were defined as significant throughout the current work. Statistically non-significant, significant and highly significant outputs were accompanied by symbols ^{NS}, ^{a} and ^{aa}, respectively.

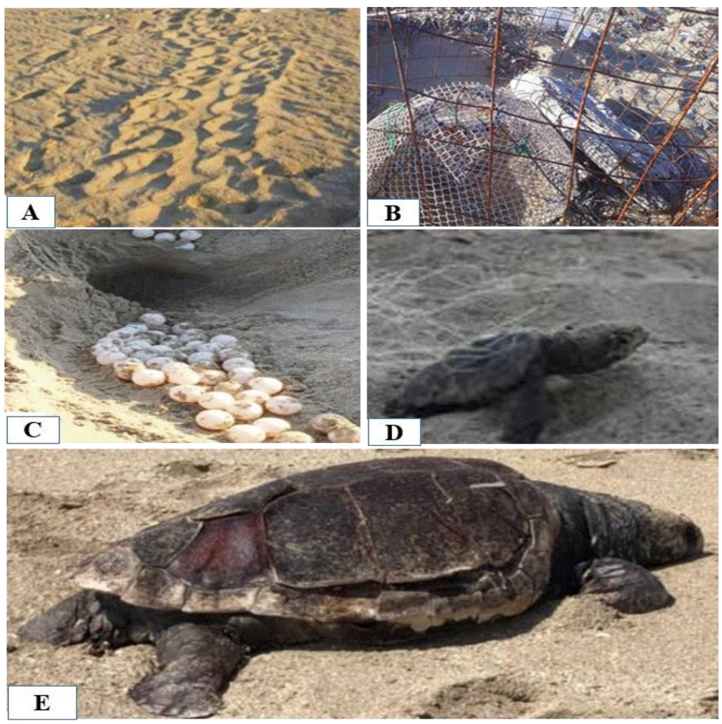

Fig. 2. Loggerhead turtle true track (A), Nest protecting cag at Al-Qurdaba Shore (B), Eggs counting at Umm-Alfraes shore (C), Loggerhead hatchling (D), and adult (E).

RESULTS

1. Loggerhead Turtle *Caretta caretta* Threats

During the current monitoring, different tracks were counted (Fig. 2A). The loggerhead turtle *C. caretta* is facing many threats at its natural environments, particularly on the nesting grounds. During the current study, we recorded the natural predators including crab, red foxes (*Vulpes vulpes*), and golden jackal (*Canis anthus*) threating not only the hatchlings but also the eggs. Cages have been made to protect turtle nests from predators during the nesting season (Fig. 2B). In addition, the presence of fishing boats, scattered garbage, wood, plastics make the female turtle to lose their proper nesting behavior. Consequently, many females were found turned to sea after searching for a suitable nest without eggs laying. At Al-Qurdaba shore, 4 nests were predated, plus 5 false nests, 8 (U-tracks) and 6 (C-tracks) were recorded. Regarding Umm-Alfraes shore, the false nests were 11, i.e. more than twice than those of Al-Qurdaba shore, in addition to 2 predated nests, 15 U-tracks and 11 C-tracks that were all recorded (Table 1). In the current study, some turtle observed had fractures in their carapace (Fig. 2E), possibly as a result of predation or an accident with fishing boats.

2. Biology of the Loggerhead Nests

At Al-Qurdaba shore only one true nest was found. It contained 92 eggs that were incubated for 67 days and the hatch percent was 11% (Table 2). At Umm-Alfraes shore, 4 true nests were found, having a total number of 463 eggs, with an average count of 100-132 eggs (Table 2, Fig. 2C). Unfortunately, about 65 eggs of the counted nests were broken at Umm-Alfraes shore. Despite this, Umm-Alfraes shore exhibited a variety of hatchability rates (Fig. 2D) that ranged from 38% to 62%. The distances of the nests from the shore line was 10 m and 15-20 m at Al-Qurdaba and Umm-Alfraes shore, respectively (Table 2). The nests depths ranged from 34-49 cm at Umm-Alfraes and 42 cm at Al-Qurdaba (Table 2). The eggs incubation period for the four nests at Umm-Alfraes were (Nest 1F= 56, Nest 2F= 57, Nest 3F= 56 and Nest 4F= 67 days) (Table 2).

Table 1. Nesting tracks activity at the two nesting sites Al-Qurdaba Shore and Umm-Alfraes Shore.

Sites	True Nest	False Nest	Predated Nest	U-Track	C-Track
Al-Qurdaba Shore	1	5	4	8	6
Umm-Alfraes Shore	4	11	2	15	11

Table 2. True nest data of loggerhead turtles in the two sites, Al-Qurdaba Shore and Umm-Alfraes Shore.

Data collected	Sites				
	Al-Qurdaba Shore	Umm-Alfraes Shore			
True Nest (Code)	Nest Q	Nest 1F	Nest 2F	Nest 3F	Nest 4F
Distance to Shore Line (m)	١٠	٢٠	١٦	١٧	١٥
Nest Depth (cm)	٤٢	٤٦	٤٠	٤٩	٣٤
Eggs Laying Date (June)	10	15	18	21	23
Eggs Hatching Date (August)	١٦	10	14	16	29
Incubation Period (day)	٦٧	٥٦	٥٧	٥٦	٦٧
N of Eggs/True Nest	92	100	120	132	111
N of Broken Eggs	12	12	4	36	13
N of Unfertilized Eggs	22	0	0	12	0
N of Fertilized eggs	58	88	116	84	98
N of Hatch Eggs	10	52	46	64	69
Hatch Eggs %	11%	52%	38%	49%	62%

3. Ecology of the Nesting Ground

the loggerhead turtle *C. caretta* started to lay their eggs between the 10th to the 23rd of June, 2019, when one nest (protected) was recorded out of 4 nests that were preyed in the Al-Qurdaba shore, and 4 (protected) out of 6 nests were preyed in Umm-Alfraes (Table 2). The daily mean air temperature in Al-Qurdaba shore was 28.9±2.2 °C, and 29.4±3.4 °C in Umm-Alfraes shore (Table 3). The average of sand temperatures at the surface were 30.8±2.2 °C and 31.4±3.4 °C in Al-Qurdaba and Umm-Alfraes shores, respectively (Table 3). The sand humidity's were ٦.٧±٣.٢ % and ٥.2±١.٣ % in Al-Qurdaba shore and Umm-Alfraes, respectively (Table 3). The mean values of rainfall at Al-Qurdaba shore and Umm-Alfraes shore were 4.4±1.1 mm and 2.8±0.3 mm, respectively (Table 3). The water and nest temperatures at different depths were correlated strongly (with the ambient air temperatures ($\mathbf{R}^2$ between 0.52-0.94) (Fig. 3 A-D).

Table 3. Means ± SD of physical parameters recorded from the two investigated sites, Al-Qurdaba shore and Umm-Alfraes shore during the period of study.

Parameter (unit)	**Sites**	
	Al-Qurdaba	Umm-Alfraes
Air Temp. (°C)	28.9±2.2	29.4±3.4
Sand (0cm) Temp. (°C)	30.8±2.2	31.4±3.4
Sand (5cm) Temp. (°C)	30.9±2.0	30.9±2.0
Sand (35cm) Temp. (°C)	31.7±3.0	31.7±3.0
Sand humidity (%)	٦.٧±٣.٢	٥.2±١.٣
Rainfall (mm)	4.4±1.1	2.8±0.3

4. Pre-Hatching Ecology

In Al-Qurdaba, the loggerhead turtle laid their eggs in the10th of June and the eggs hatched in the 16th of August 2019 (Table 2). The four turtles in Umm-Alfraes laid the eggs in 15, 18, 21, and 23rd of June, and the eggs start to hatch in the 10th, 14th, 16th and 29th of August (Table 2). The result of temperature (one week before hatching) of air, water and nesting sand increased. In contrast, rainfall and sand humidity decreased (Table 4). Air temperature fluctuated from 30.6±0.7 °C at Al-Qurdaba to 31.0±1.6 °C & 31.3 ±1.4°C at Umm-Alfraes (Table 4). Responding to this, water and nest temperatures also increased remarkably. At 35 cm nest depth, the mean temperature reached 31.4±1.7 °C at Al-Qurdaba and ranged from 32.0±2.1°C, (in Nest 4F) to 33.9±2.3°C (in Nest 2F) at Umm-Alfraes (Table 4). Sand humidity was 6.0±0.1 % at Al-Qurdaba, and ranged from 4.7±0.1 % to 6.1± 0.1% at Umm-Alfraes. Rainfall was recorded as 4.0±0.5 mm at Al-Qurdaba and 1.6±0.6 mm at Umm-Alfraes (Table4).

Table 4. Means ± SD of physical parameters recorded during one week before hatching from the two investigated sites (Q= Al-Qurdaba Shore, F= Umm-Alfraes Shore).

Nests Code			Nest (Q)	Nest (1F)	Nest (2F)	Nest (3F)	Nest (4F)
Temperature °C)	Sand	35 cm	31.4 ±1.7	33.4±2.2	33.9±2.3	33.4±1.0	32.0±2.1
		5 cm	32.9±1.8	31.7±3.0	٣٢.0±2.0	32.9±2.0	31.9±0.8
		0 cm	32.6±1.4	33.4±2.3	٣٣.0±1.2	٣٣.0±2.0	32.1±0.3
	Water		25.6±1.0	26.3±0.9	26.4±1.2	26.6±2.2	25.1±1.7
	Air		30.6±0.7	31.3±1.4	31.1±3.0	31.1±0.9	31.0±1.6
Sand humidity %			6.0±0.1	6.1±0.12	4.7±0.1	6.1±0.1	5.0±0.0
Rainfall (mm)			4.0±0.5	1.6±0.6			

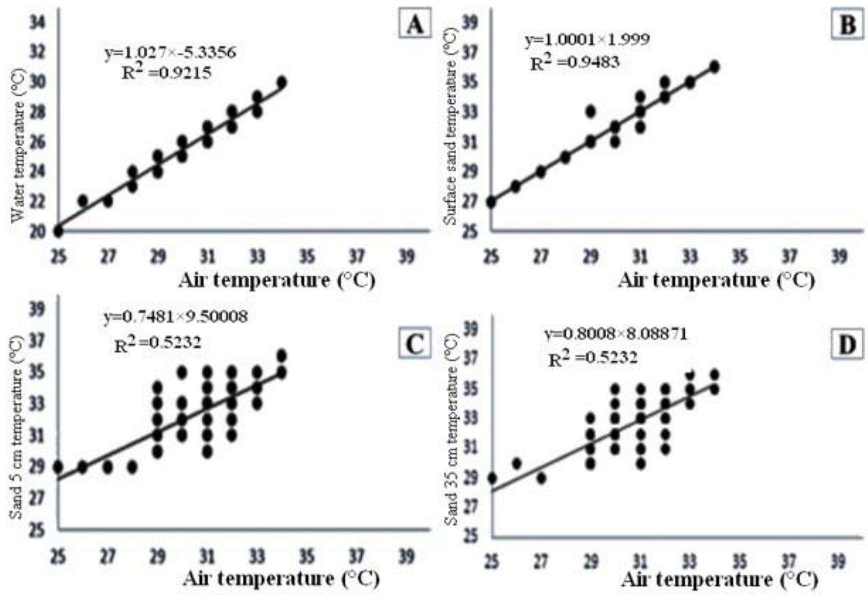

Fig. 3. Relationship between air and water temperatures (A); air and surface sand temperatures (B); air and 5cm sand temperatures (C); and air and 35 cm sand temperatures (D); during the period of study.

5. Monthly Fluctuation of Ecological Factors

To test the monthly changes of temperatures, rainfall and sand humidity, Least Significant Differences LSD was performed (Table 5) for each site separately. At the two shores, air, water and sand (surface, 5 cm and 35 cm depth) temperatures differed significantly (P<0.01) between June-July and June-August (Table 5). Rainfall and sand humidity differed significantly between July & August (P<0.05) (Table 5).

Table 5. LSD multiple comparison of mean physical at the two studied sites, Al-Qurdaba Shore and Umm-Alfraes Shore.

Parameters (unit)	Al-Qurdaba Shore		
	June & July	June & August	July & August
Air Temp. (°C)	-2.46 ^{aa}, P=0.00	-2.69 ^{aa}, P=0.00	-0.22^{NS}, P>0.05
Water Temp. (°C)	-1.70 ^{aa}, P=0.00	-1.83 ^{aa}, P=0.00	-0.13^{NS}, P>0.05
Sand (0cm) Temp. (°C)	-2.20 ^{aa}, P=0.00	-2.69 ^{aa}, P=0.00	-0.49^{NS}, P>0.05
Sand (5cm) Temp. (°C)	-1.86^{aa}, P=0.00	-2.82 ^{aa}, P=0.00	-0.95^{aa}, P=0.01
Sand (35cm) Temp. (°C)	-2.50^{aa}, P=0.00	-2.32 ^{aa}, P=0.00	0.17^{NS}, P>0.05
Sand humidity %	0.06 ^{NS}, P>0.05	0.16^{NS}, P>0.05	0.10 ^{a,} P <0.05
Rainfall (mm)	2.33^{NS}, P>0.05	2.66^{NS}, P>0.05	0.33^{a}, P <0.05
	Umm-Alfraes Shore		
Air Temp. (°C)	-4.16 ^{aa}, P=0.00	-4.26 ^{aa}, P=0.00	-0.10^{NS}, P>0.05
Water Temp. (°C)	-3.48^{aa}, P=0.001	-2.80^{aa}, P=0.005	0.67^{NS}, P>0.05
Sand (0cm) Temp. (°C)	-4.26 ^{aa}, P=0.00	-4. 05 ^{aa}, P=0.00	0.21^{NS}, P>0.05
Sand (5cm) Temp. (°C)	-2.21^{aa}, P=0.00	-3.06 ^{aa}, P=0.00	-0.85^{a}, P=0.02
Sand (35cm) Temp. (°C)	-3.43^{aa}, P=0.00	-3.21 ^{aa}, P=0.00	0.21^{NS}, P>0.05
Sand humidity %	0.28 ^{NS}, P>0.05	0.04^{NS}, P>0.05	0.21^{a,} P <0.05
Rainfall (mm)	1.00 ^{NS}, P>0.05	-0.35^{NS}, P>0.05	-1.35^{a,} P <0.05

^{aa}: The mean difference is significant at the 0.01 levels
^{a}: The mean difference is significant at the 0.05 levels
^{NS}: The mean difference is not significant

6. Nesting Ground and Hatchability

The hatchability of the loggerhead turtle has been affected adversely with sand temperature, rainfall, sand humidity and nest depth. At a nest depth of 5 and 35 cm, the hatched eggs correlated negatively with sand temperatures (r=-0.62, *P*<0.01 at 5cm) and (r=-0.58, *P*<0.01 at 35cm), respectively (Table 6). Furthermore, increased sand temperatures, rainfall (r=-0.54, *P*<0.01), sand humidity (r=-0.73, *P*<0.01) and nest depth (r=-0.39, *P*<0.05) deteriorated the hatchability (Table 6). In contrast, the farther the nest from the shore line the greater the hatchability encountered (r=0.43, *P*=0.01) (Table 6). The incubation period of the loggerhead turtle affected adversely with sand temperature especially at nest depth of 35cm ($\mathbf{R^2}$=-0.91) (Fig. 4A), in the same manner as the increase of sand humidity near the Sea shore line did ($\mathbf{R^2}$=-0.66) (Fig. 4B).

Table 6. Correlation coefficients between hatch % and sand temperature at 5cm &35 cm, rainfall, sand humidity nest depth and distance from Shore Line (DFSL).

Correlation	**Hatch %**					
	Sand T (5 cm)	Sand T (35 cm)	Rainfall (mm)	Sand Humidity%	Nest depth (35 cm)	DFSL (m)
(r)	-٠.62$^{a\,a}$	-٠.58^{aa}	-٠.54^{aa}	-٠.73^{aa}	-0.39^{a}	0.43^{aa}
(Sig.)	000	0.001	0.002	000	0.037	0.018

^{aa}: The mean difference is significant at the 0.01 levels
^{a}: The mean difference is significant at the 0.05 levels

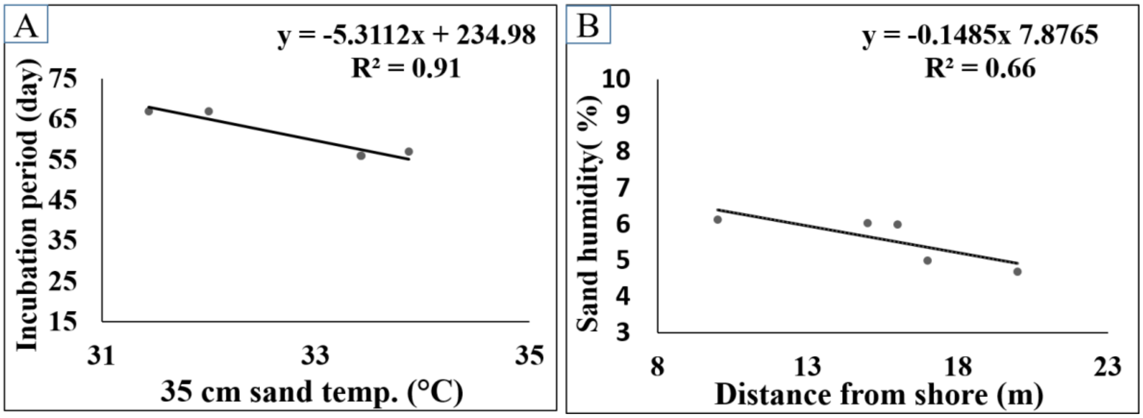

Fig. 4. Relationship between eggs incubation period and nest temperature at 35cm (A) and relationship between sand humidity and distance of nest from shore (B), at one week before hatching.

DISCUSSION

Marine turtles are facing rapid decline during the last decades, due to environmental changes and human activities. Habitat perturbation is an issue which has received little attention. About 86% decline of turtles nesting ground have been reported annually **(Mortimer and Donnelly, 2007 and IUCN, 2018**). This destruction in the natural environment is likely attributed to the degradation of nesting shores, intensive fishing, boating, wastes including plastic bags, empty bottles, wooden pieces, oxidized metallic substances, garbage and oil debris **(Meylan and Redlow, 2006 and El Kafrawy *et al*., 2018)**. During the present investigation, the several false nests, tracks of different shapes, in addition to the predated nests present at both areas of study. This alteration is one of the factors responsible for population loss may be related to the extremely high predatory percentages. In the current study, different predators have been recorded including crabs, fox, and Jackal. The same finding in the Libyan coast was reported previously by **Haddoud and Gomati (2011)**. There are few studies conducted on the Mediterranean coasts about the physical characteristics of sea turtle nesting shore, for example **(Türkozan *et al*.,2003)**. Several studies pointed to the climate change as serious threat to species that demonstrate temperature-dependent sex determination, including marine turtles **(Butt *et al*., 2016)**. The current findings provide important clued regarding that changes in air temperatures will lead to increased variations in sand temperatures and hence the nest temperature, which was directly related to the decrease in sea turtle hatchability. This rise in temperature was the cause of small fluctuations in the incubation period. On the other hand, higher nest temperatures are often associated with lower hatchability in reptiles, due to the increased metabolic rate, reducing the length of the incubation period and the amount of egg yolks that can be converted to hatching tissues **(Hawkes *et al*., 2009 and Booth and Evans, 2011)**. Laboratory experiments showed that sea turtle eggs fail to hatch upon brooding under 24°C or above 34°C **(Usategui-Martín *et al*., 2019)**. Likewise, high sand temperatures above 32°C in sea turtle nests increased the mortality ratios for small-headed turtles **(Matsuzawa *et al*., 2002)**. In the current study, the mean temperature (Table 1) of the sand in the week before hatching was around 32°C, and this degree is an accurate indication of hatchability and lie on the optimal temperature of nesting threshold **(Maulany, 2013)**. At Al-Qurdaba and Umm-Alfraes shore, the rates of hatching and conservative appearance gave an evidence that the most hatching-limiting environmental factors were the unbalanced temperatures. The current results (Fig. 3 B-D) indicated that the sand temperature was significantly correlate to air temperature ($\mathbf{R^2}$ from 0.52 to 0.94). The current study (Fig. 4A) also exhibited that the incubation period of eggs decreased with the increasing nest temperatures ($\mathbf{R^2}$ = 0.90).

Consequently, the high air temperatures led to higher sand temperatures and higher nest temperatures, as also recorded by **Girondot and Kaska, (2015)**. On the other hand, the warming of the sand threshold temperatures is the main signal that young turtles use to determine the appropriate timing for the nest to appear **Drake and Spotila (2002)**. During the last decades, global warming has gained cosmopolitan attention. The severity of the risks to regional sea turtles due to climate change will depend largely on their ability to adapt to changing conditions. Sand humidity is also a signal for nest success due to the fact that when sand moisture is above 8%, either too low or no hatchability occurred **(Yalçın-Özdilek *et al*., 2007)**. The female turtles are known to discriminate between nesting grounds and select the suitable ones. We could identify a negative correlation (Table 6) between sand humidity and nesting success in the current study (r=-٠.73, *P<0.01*). In fact, sand humidity (Fig. 4B) correlated negatively with distance of nest from the shore line ($\mathbf{R^2}$=0.65), and this may be due to the decreasing water spray and leaching toward the above coastal sand and vice versa.

CONCLUSION

The present study attempted to address current gaps in the knowledge surrounding sensitivity of loggerhead turtle *Caretta caretta* to global warming changes. The current work elucidated the impact of temperature in relevant to hatchability and incubation. In addition, the position of nests, the presence of predators and the alteration of nesting ground were reported here as factors affecting the success of incubation and hatchability. Consequently, we recommend to carry out more studies to gather and demonstrate demographic data for population modelling to conserve sea turtles in general and loggerhead turtles in particular. While Libyan coast is a shelter and a vital ground of nesting, more attention is required to manage and maintain this biotope.

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ARABIC SUMMARY

تأثير درجة حرارة أماكن التعشيش علي عمليتي حضانة وفقس البيض للسلحفاة البحرية كبيرة الرأس *Caretta caretta* ، القاطنة لساحل البحر المتوسط ، ليبيا

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طبقاً للدراسات السابقة فإن الأبحاث التي تناولت تأثير درجة حرارة أماكن التعشيش (رمال العش) ونجاح عملية الفقس في السلاحف البحرية كبيرة الرأس ***Caretta caretta*** علي شواطئ البحر المتوسط بليبيا لا تزال قليلة أو ربما منعدمة خاصةً في الجزء الشرقي من الساح الليبى . مما لا شك فيه أن التغير في العوامل البيئية له تأثير ملحوظ علي بيض تلك الكائنات؛ خاصةً بفترة الحضانة و عملية الفقس. من ناحية أخري فإن التغير في درجة الحرارة قد لاقي إهتماماً عالمياً في الآونة الأخيرة باعتبارها واحداً من أهم العوامل البيئية التى تؤثر بالسلب او الايجاب على الكثير من العمليات الحيوية للكائن الحى. تناولت هذه الدراسة قياس درجة الحرارة بالبيئة المحيطة لوضع البيض (الهواء – البحر – أماكن التعشيش) للسلحفاة كبيرة الرأس ***Caretta caretta*** خلال موسم التكاثر من شهر يونيه إلي شهر أغسطس 2019 . علاوةً علي ذلك فقد تم تسجيل كمية الأمطار والرطوبة في أماكن التعشيش لربطها مع نجاح عملية إنتاج الصغار من عدمه. أوضحت الدراسة الحالية مدي تأثير التغير في تلك العوامل البيئية خاصة درجة الحرارة علي عملية التعشيش برمتها في منطقتي الدراسة (ساحل القرضبة و أم الفرائس) بمنطقة طبرق ، ليبيا طبقاً لتباين المنطقتين في العوامل البيئية. وحيث أن هذا النوع من الحيوانات متغيرة درجة الحرارة فان درجة الحرارة لها دور أساسي في جميع مراحل حياته. بناءًا علي ذلك فان هذه الدراسة قد ساهمت في وضع حجر أساس لتتبع التغير المناخي وتأثيره علي مثل هذه المجموعة من الزواحف بمنطقة الدراسة بشرق ليبيا بساحل البحر المتوسط للحد من إنقراضها وتناقص أعدادها.