Scorpion Envenomations and Climate Conditions : the case of Naama Province in Algeria

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***Abstract*—Scorpion envenomations represent an actual public health problem in Algeria, at various levels, in three-fourths of the country provinces. A total of $903,461$ scorpion sting cases and 1996 induced deaths were reported in the country between 1991 and 2012. As the scorpion envenomation surveillance is based on passive system, the present study aims to analyse and to interpret the reported scorpion sting cases and to develop a forecasting model in order to perceive changes in the incidence early enough in Naama province, one of the endemic zone for scorpion envenomations.**

In addition to the epidemiological profile of scorpion stings, we performed time series analysis and regression analysis to estimate the relationship between scorpion sting cases and climate conditions. We also have explored the predictive power of alternative model incorporating seasonality. The epidemiological survey revealed that scorpion envenomations are observed through the year, round the clock, reaching peaks in July-August, and the more prone human body parts are upper and lower limbs. The time series analysis and regression analysis have shown that the scorpion activity in Naama province is climate dependent phenomenon; the temperature and precipitation are the main factors; they were used to derive the best predictive model for scorpion sting cases.

Regression models produce reliable models to predict the number of scorpion stings provided that involved climate variables are on hand, and could therefore assist public health services as to be in state of preparedness by providing in advance the health facilities by the appropriate number of antivenom vials necessary.

***Index Terms*—Naama province, Precipitation, Regression analysis, Scorpion sting, Seasonality, Temperature, Time series.**

I. Introduction

SCORPION stings represent a public health problem in many tropical and subtropical regions. North Saharan Africa, Sahelian Africa, South Africa, Near and Middle-East, South India, Mexico and South Latin America, East of the Andes are identified as at risk areas and so involving 2.3 billion at risk population. The annual number of scorpion stings exceeds 1.2 million leading to more than 3250 deaths worldwide [2].

Scorpions are venomous arthropods of the class Arachnida. They are easily recognizable because of their morphological structures. They are grouped into six families, 70 genera and more than 1500 species. Only 25 species are known to be deadly to humans. The most potentially lethal scorpions to human belong to the family Buthidae which primarily is distributed in Africa and Southeast Asia. Scorpions are primarily nocturnal, not aggressive, and fearful of nature and lucifugous. They withstand aggressive environmental factors either cold or hot. The longevity of the adult varies from 2 to 10 years or even twenty years. They feed essentially on insects and on spiders, preferring the alive or freshly killed prey. The big scorpions eat invertebrates, small lizards, snakes and even small mice. They are cannibals inter/intra species and even the mother can eat its young. Scorpions are found in diverse habitats: under stones, rocks, tree bark and old buildings. Some scorpions affect the neighborhood of houses; take place between sheets, in shoes, in kitchens and bathrooms. They detect their prey by senses of contact and sound. They use their venom to kill or paralyze their prey so it can be eaten. The sting of most scorpions can be very painful, like a bee sting. Although most are not lethal, scorpion stings should always be treated as a medical emergency that requires treatment as quickly as possible [2], [19].

In Algeria scorpion envenomations represent an actual public health problem. Twenty-eight species and fourteen genera of scorpions were identified in the country and the most important health threatening scorpions found belong to the Buthidae family. They include Androctonus australis and Leiurus quinquestriatus, and are found mostly in the southern highlands and in the Atlas and Hoggar mountain ranges [19]. The population at risk of scorpion envenomations is estimated at 68% of the total national population. Fourteen provinces belonging to Highlands and Sahara account together for almost 90% of patients stung and the totality of recorded induced deaths. The incidence varies between less than 7 scorpion stings per $100,000$ inhabitants in the Northern provinces and more than 1000 scorpion stings per $100,000$ inhabitants in those of the South [16].

The physical-geography and climate conditions make Naama province a conducive environment for scorpion species and an endemic zone for scorpion envenomations. The province records every year a high incidence of scorpion stings with a yearly average of 878 scorpion stings per $100,000$ inhabitants [16]. The public health authorities of the province are faced to scorpionism, and so they are required to establish prevention and control strategies. An early warning system is an essential tool for preparedness and effectiveness of scorpion stings control; it could help determine the appropriate number of antivenom vials necessary in health facilities and anticipate the demand for antivenoms and symptomatic drugs so that they can be distributed in advance in this endemic province.

The scorpion envenomation surveillance in Algeria is based on a passive system. Neither the analysis nor interpretations of data were undertaken; the only performed statistical approach to scorpionism is due to Selmane and El hadj [17]. In the aim to estimate the effects of climate variables on scorpion envenomations in Naama, we performed a regression analysis

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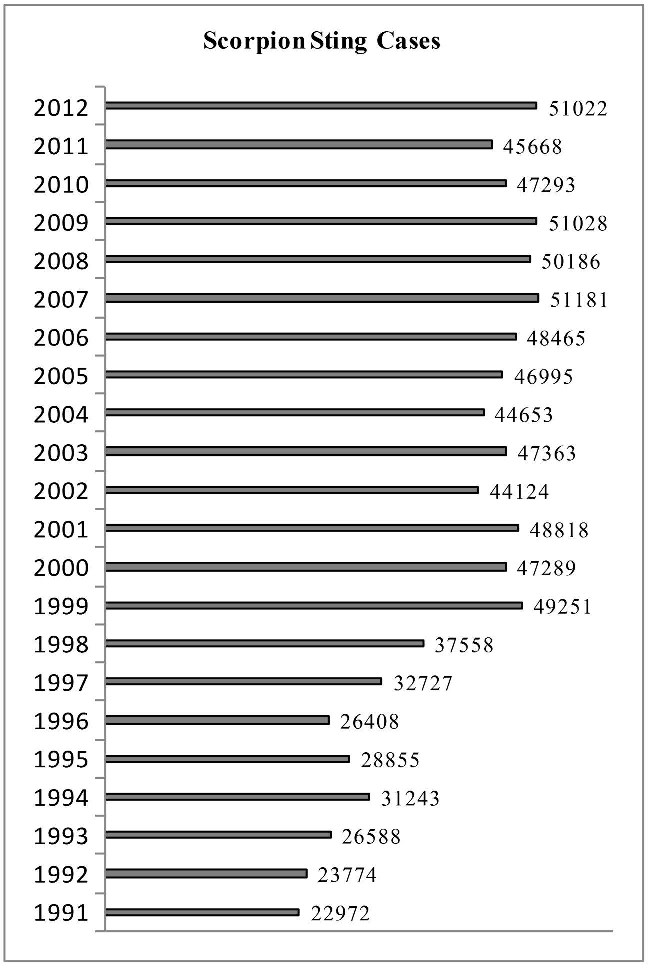

Fig. 1. The annual evolution of recorded scorpion sting cases in Algeria.

to estimate the relationship between scorpion sting cases (the dependent variable) and climate conditions (the independent variables). We also have explored the predictive power of alternative model incorporating seasonality. The obtained results showed that the scorpion activity in Naama province is climate dependent phenomenon; the temperature and precipitation are the main factors; they were used to derive the best predictive model of scorpion sting cases.

II. Materials and Methods

A. Scorpionism in Algeria

Scorpion stings are common in Algeria and represent an actual public health problem. Health services have recorded between 1991 and 2012 a total number of $903,461$ scorpion stings and 1996 induced deaths [16]. The number of stings has doubled between 1996 and 1999 and from 1999 to 2012 a weak fluctuation of this number is perceived (Fig. 1), in contrast, the number of induced deaths has halved. The geographical distribution of the incidence per $100,000$ inhabitants of scorpion stings for the year 2012 mapped using MapInfo Professional 11.0 (Fig. 2.), shows that the incidence predominates in Highlands and Sahara.

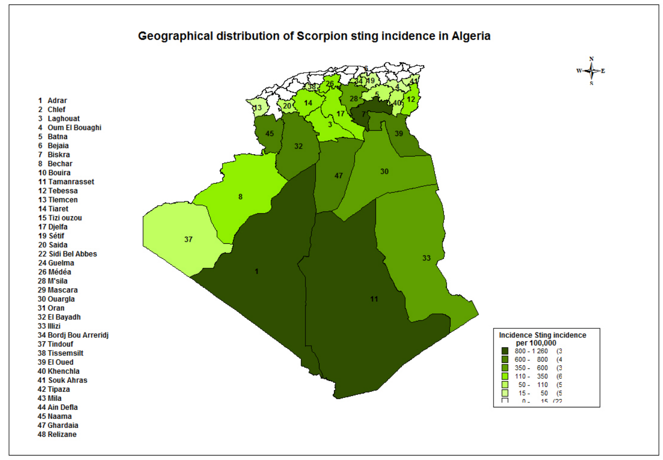

Fig. 2. Geographical distribution of scorpion sting incidence in Algeria.

B. Study Area : Naama Province

Naama is one of the 48 provinces of Algeria. It is situated in the west between the Tell Atlas and the Saharan Atlas at $33^o\ 16'\ N$ and $0^o\ 19'\ W$ of the equator and more than $1,000$ meters above sea level. The province is made up of seven districts gathering twelve municipalities over a land size of about $29,950\ km^2$ with an estimated population of $238,087$ as 2013, that is, a population density of 8 inhabitants per km^2 [14]. The climate is split into two main seasons; cold and relatively wet season which extends from November to April, and hot and dry season which extends from May to October. However, this climate is marked by irregularities. This is significant not only from one year to another, but also in the distribution between the different months. Rainfalls remain low and irregular; it is heterogeneous in time and space [13].

C. Data

The study period comprises 108 months from January 2003 to December 2011 and consists of two different monthly data sets : epidemiological data and meteorological data. The monthly scorpion sting cases were provided by the Department of Public Health of the province of Naama, and the monthly mean temperature (in ^oC), period of sunshine (in $hours$), precipitation amount (in mm), wind speed (in m/s), and relative humidity (in $\%$) recorded by the weather station of Naama (Latitude : $33^o\ 16'\ N$, Longitude : $0^o\ 18'\ W$, Altitude: $1166\ m$) were extracted from the National Office of Meteorology [13].

D. Statistical Modeling Method

As far as we know the first mathematical approach on predicting scorpion sting incidence is due to Chowell and al; they analysed the significance of climate variables to predict the incidence of scorpion stings in humans in the state of Colima (Mexico) using multiple linear regression [3]. Other studies on other regions on the influence of climate factors on scorpion envenomations following the statistical approach conducted by Chowell and al have been performed using simple statistical analysis and correlation between scorpion stings and climate variables [11], [18].

In this paper, descriptive statistics are performed to quantitatively describe the main features of the data. Time series analysis of scorpion sting cases and climate factors are also performed in order to extract meaningful statistics and other characteristics of the data and also to analysis of temporal trends of the variables. To find any significantly relationship between monthly recorded scorpion sting cases and monthly climate variables, first, the scatterplots and Pearson product-moment correlation coefficient are drawn up, then a regression analysis is undertaken. As the time series is observed to be seasonal, we have performed time series analysis based on Box and Jenkins method [1] to select the best fitted model while incorporating climate factors.

Regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. A regression model relates the dependent variable, Y to a specified function of independent variables, X, and unknown parameters, β :

$$Y \approx f(X, \beta).$$

The approximation is usually formalized as

$$E(Y|X) = f(X, \beta)$$

where $E(Y|X)$ is the average value of the dependent variable when the independent variables are fixed. One method of parameter estimation is ordinary least squares; which consists to minimize the sum of squared residuals [6].

A best regression model has to fulfill the following features :

- The value of $R-square$ should be more than 60 percent. Higher the $R-square$ value, better the data fitted.
- Most of the independent variables should be individually significant to influence the dependent variable (this matter can be checked using t-test).
- The independent variables should be jointly significant to influence or explain dependent variable (This can be checked using F-test).
- No serial correlation in the residual (can be tested using Bruesch-Godfrey serial correlation LM test).
- No heteroscesticty in the residual (can be tested using Bruesch-Pegan-Godfrey Test).
- Residuals should be normally distributed (can be tested using Jarque Bera statistics).

When all these features are met; the model can be used for forecasting [6].

Given a stationary time series of data X_t, $t = 1, ..., n$ and assume that the series is observed to be seasonal of period S, Box and Jenkins proposed that the series could be modelled by a multiplicative $(p, d, q) \times (P, S, Q)_S$ seasonal autoregressive integrated moving average model (SARIMA) defined by the expression :

$$A(L)\Phi(L^S)\nabla^d\nabla_S^D X_t = B(L)\Theta(L^S)\varepsilon_t$$

where

$$A(L) = 1 - \alpha_1 L - \alpha_2 L^2 - ... - \alpha_p L^p$$

and

$$B(L) = 1 + \beta_1 L + \beta_2 L^2 + ... + \beta_q L^q$$

and where L is the backward shift operator defined by $L^k X_t = X_{t-k}$, $\{\varepsilon_t\}$ is a white noise process defined as a sequence of uncorrelated zero mean random variables with constant variance, $\alpha' = (\alpha_1, \alpha_2, ..., \alpha_p)$ is a vector of autoregressive coefficients and $\beta' = (\beta_1, \beta_2, ..., \beta_q)$ is a vector of moving average coefficients such that the model is both stationary and invertible. $\Phi(L) = 1 + \phi_1 L + \phi_2 L^2 + ... + \phi_P L^P$ and $\Theta(L) = 1 + \theta_1 L + \theta_2 L^2 + ... + \theta_Q L^Q$ are respectively the seasonal autoregressive and the seasonal moving average operators, $\phi' = (\phi_1, \phi_2, ..., \phi_P)$ and $\theta' = (\theta_1, \theta_2, ..., \theta_Q)$ are constants such that the roots of the polynomials $\Phi(L)$ and $\Theta(L)$ are all outside the unit circle for stationary and invertible respectively. d is the degree of differencing necessary for stationary and $\nabla^d X_t$ is the d^{th} difference of X_t where $\nabla = 1 - L$ and ∇_S^D is the D^{th} seasonal difference operator where $\nabla_S = 1 - L^S$ [1].

All performed computations and generated figures were carried out with Eviews 7 software [5].

III. Data Analysis and Results

A. Annual evolution of recorded scorpion sting cases

A total of $22,498$ scorpion stings and 66 induced deaths were recorded by the Department of Public Health of Naama province between 1999 and 2013; the yearly distribution of cases is plotted in Fig. 3. The highest total yearly scorpion sting cases occurred in the years 2001 and 2008 with 1855 and 1911 respectively and the highest number of induced deaths were notified in 2001 with 10 deaths and in 2010 with 9 deaths [16]. We note pronounced fluctuations on the yearly evolution; this is to be expected due the fact that scorpion activity is related to climate and the latter is marked by irregularities.

B. Geographical distribution of scorpion envenomations

The geographical distribution of the incidence of scorpion stings per $100,000$ inhabitants for the year 2013 by municipality for Naama province is mapped using MapInfo Professional 11.0 (see Fig. 4.). Almost half of scorpion sting cases occurred in Mechria (27.1%) and Ain Sefra (21.9%); the incidence per $100,000$ inhabitants is 517.08 for Mechria and 487.33 for Ain Sefra. The highest incidence was recorded in Mekmen Ben Amar and Sfissifa with 1304 and 1501 per $100,000$ inhabitants respectively.

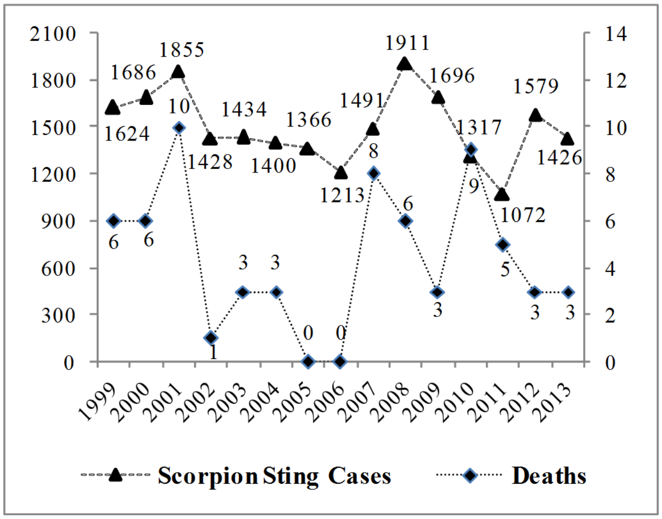

Fig. 3. Evolution of annual recorded scorpion sting cases and induced deaths in Naama province from 1999 to 2013.

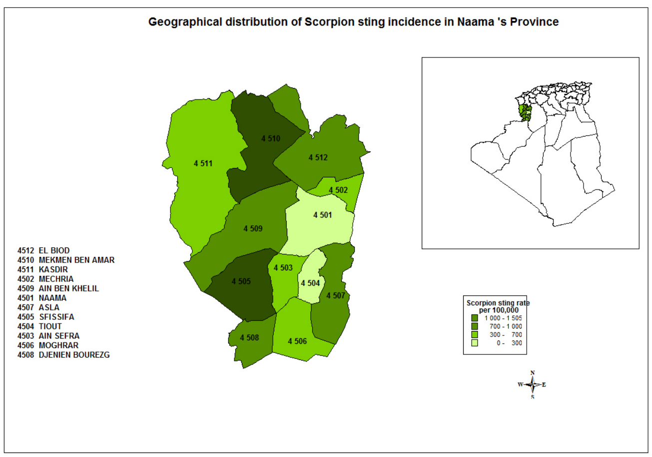

Fig. 4. Geographical distribution of scorpion sting incidence in Naama's province.

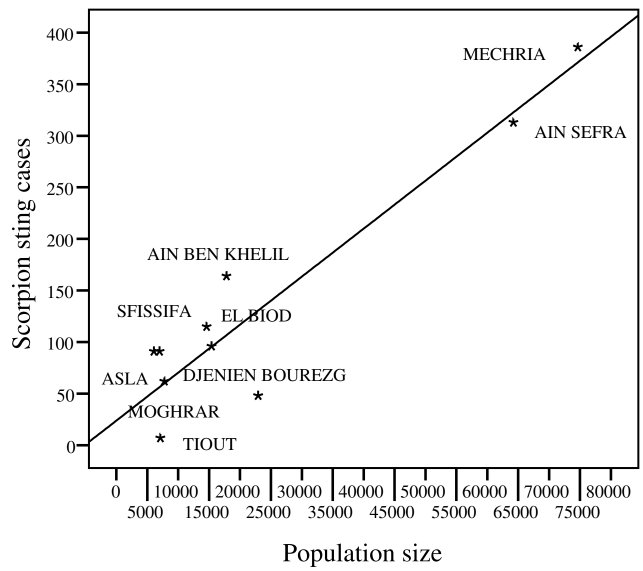

Fig. 5. The scatterplot of the number of recorded scorpion stings and the population size by municipality. The straight line represents the linear regression equation (1).

C. *Scorpion sting cases and population size by municipality*

To estimate the importance of the heterogeneity of the province, we analysed the correlation between the total number of scorpion stings, the population size, the population density, and the incidence per municipality for the year 2013. The number of scorpion stings showed a high degree of correlation with the population size ($r = 0.943$) (Fig. 5.) and a high degree of correlation with population density ($r = 0.909$). For all municipalities, the total number of recorded scorpion stings (S_{Mun}) and the population size (P_{Mun}) are related as follows :

$$S_{Mun} = 0.005\, P_{Mun} + \varepsilon \tag{1}$$

an equation that explains 86.5% of the observed variance.

D. *Epidemiological survey*

The scorpions sting round the clock with peak between $6\,pm$ and $6\,am$; more than half of recorded scorpion sting cases (55%) have took place during this time slot and 23% (resp. 22%) have took place between $6\,am$ and $12\,pm$ (resp. $12\,pm$ and $6\,pm$).

The more prone human body areas to scorpion stings are the upper limbs with 52% of cases followed by the lower limbs with 40% of cases. The fact that the upper and lower limbs are the most affected parts of the body (92% of reported victims) suggests that it is the human who has a great deal for liability in these accidents through its negligence and/or its ignorance. Thus a program to educate the population could significantly reduce the incidence.

The most frequently affected age group ranges between 15 to 49 year, with 62% of stung cases. Children less than 14 years old represent 24% of cases, and the envenomations are more severe and mortality is dramatically higher for this category than in adults. As a whole there is no sex predominance.

Finally, the reported scorpion envenomations were graded as follows : 95.7% of cases were mild, 3.2% of cases were moderate, and 1.1% of cases were severe.

E. *Descriptive statistics of the variables*

The descriptive statistics of the monthly data over the study period $2003-2011$, and the Pearson product-moment correlation coefficient (r) between scorpion sting cases (S) and climate variables are displayed in Table I. The climate variables with strong positive correlation coefficient with scorpion sting cases are mean temperature (T), mean maximum temperature ($MaxT$) and mean minimum ($MinT$). This confirms the increasing activity of scorpion with increasing the environment temperature as stipulated in [3], [11], [17], [18]. There is strong negative correlation between scorpion sting cases and relative humidity (RH), maximum relative humidity ($MaxRH$) and minimum relative humidity ($MinRH$).

TABLE I
DESCRIPTIVE STATISTICS OF VARIABLES

Variables	Minimum	Maximum	Mean	SD	r
S	0	584	124,89	152,35	
T	3,50	30,40	16,82	8,11	0.891**
$MinT$	-3	22,30	10,20	7,27	0.887**
$MaxT$	7,90	38,70	23,43	9.02	0.888**
P	0	157,30	19.23	22.15	-0.153
RH	23	82	50.36	15,63	-0.799**
$MinRH$	4	63	26.53	13,85	-0.740**
$MaxRH$	40	96	74.61	14,71	-0.854**
I	134,90	361,90	251,34	51,18	0.609**
W	1,40	5,10	3,12	0,86	0.182
$MaxW$	6,30	16,70	12,30	2,55	0.530**

** The correlation is significant at the 0.01 level (bilateral).

The correlation between sunshine time (I) (resp. maximum wind speed ($MaxW$)) and the scorpion sting cases is mild ($r = 0.609$) (resp. $r = 0.530$). The correlation between accumulated precipitation (P) amount (resp. wind speed (W)) and the scorpion sting cases is very weaker ($r = -0.153$) (resp. ($r = 0.182$)).
The coefficient of variation CV ($CV = SD/Mean = 1,22$ where SD is the standard deviance) is closer to 1, which means the greater the variability of scorpion data.

F. Time Series Analysis

The epidemiological year for scorpion envenomations starts from March-April onwards with lowest scorpion sting cases, reaches its peak in July-August then resumes its lowest rate toward November-December (Fig 6 (A)). The monthly peaks are observed in July (27.9% of cases) and in August (27.9% of cases) accounting to them alone over half of reported cases (55.8% of cases). The maximum recorded scorpion sting cases during the study period occurred in July and August 2008 with 584 and 570 cases respectively. Most of the cases (70.4%) were notified during the summer period followed by Autumn period (16.7%), then Spring period (12.3%) (Fig. 6 (B)).

The monthly recorded scorpion sting cases with monthly mean maximum temperature and mean minimum temperature and with monthly accumulated precipitation are plotted in Fig. 7. The temperature follows the same trends as scorpion sting cases, confirming thus conclusions on previous studies on the influence of temperature on the activity of scorpions [11], [18]. The highest amount of accumulated precipitations were recorded in October 2008 and in September 2005 with 157.3 mm and 93.2 mm respectively and the corresponding recorded scorpion sting cases were 76 (average number is 79 and minimum is 40) and 134 (average number is 169 and minimum is 130) recorded cases respectively; this is against the stated conclusion about precipitation impact on scorpion's activity in [3].

G. Regression Analysis

The data were divided into two period : data over the period from January 2003 to December 2010 used for model

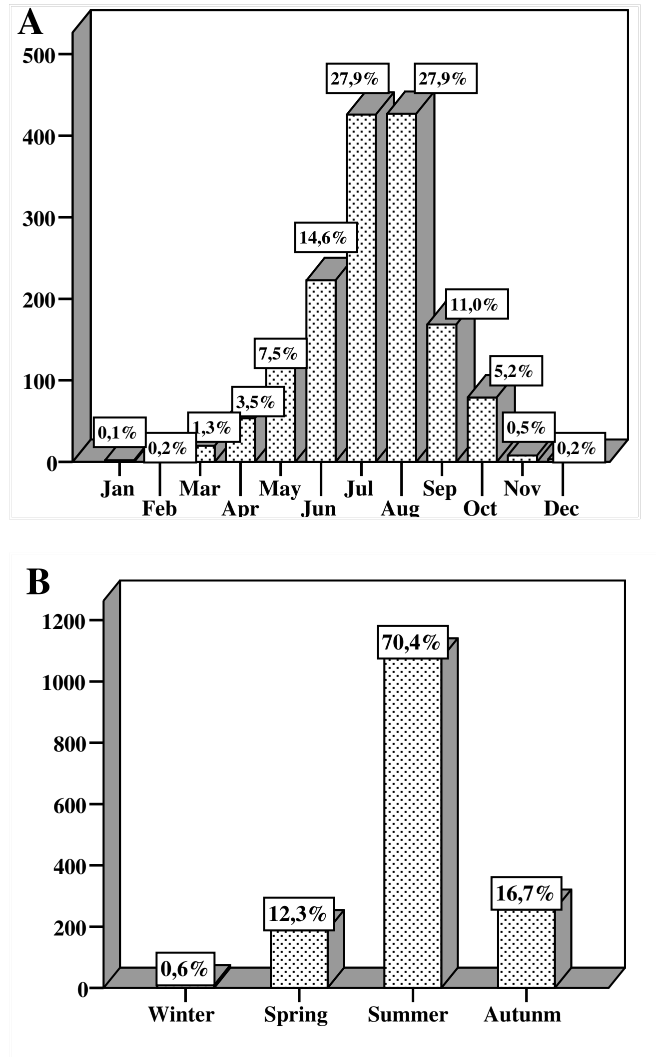

Fig. 6. **A** Monthly average distribution of recorded scorpion sting cases. **B** Seasonal average distribution of recorded scorpion sting cases in Naama province for the period $2003 - 2010$.

estimation and those from January 2011 to December 2011 used for validating the model and forecasting.

Temperature, relative humidity, and sunshine time are highly pairwise correlated; the Pearson product-moment correlation coefficient between temperature and relative humidity is $r = -0.901$, between temperature and sunshine time is $r = 0.734$ and between relative humidity and sunshine is $r = -0.823$. Therefore these variables will impart nearly exactly the same information to a regression model. To avoid the multicollinearity and the unreliability of the regression model's regression coefficients related to these highly pairwise correlated variables, we included into the model only the temperature. The choice of the temperature is justified by the fact that the activity of scorpions increases with increasing temperature [11], [17], [18].

The scatterplot between the monthly scorpion sting cases and the monthly mean temperature shows a quadratic relationship (Fig. 8. A). We therefore performed a regression analysis considering S as dependent variable, and T, T^2, and a trend

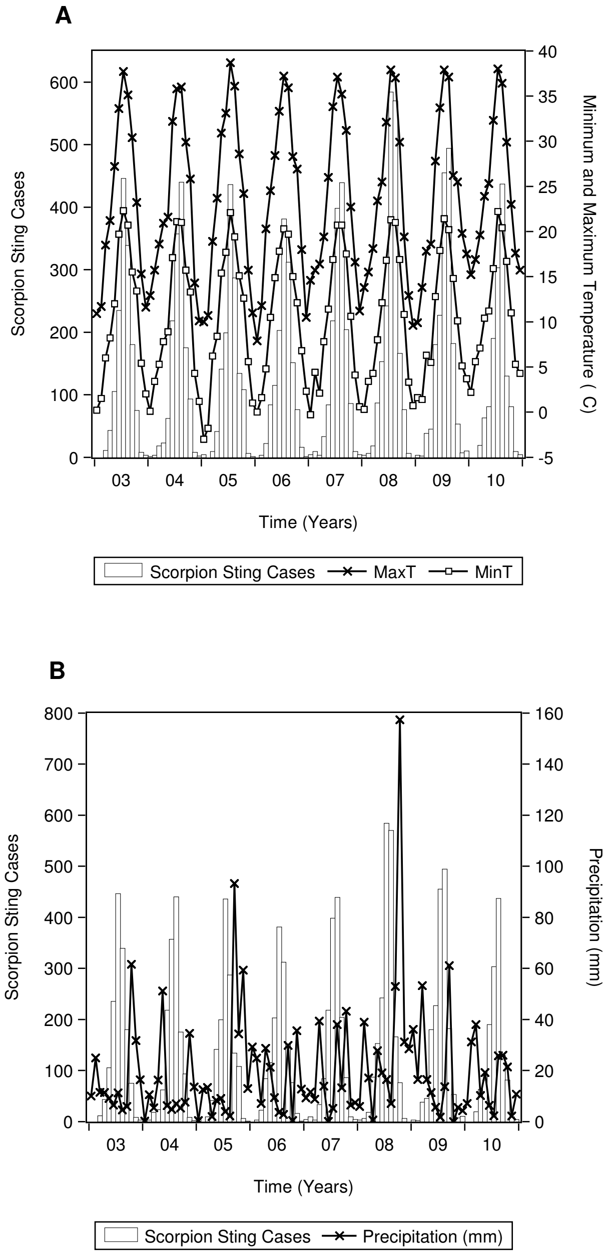

Fig. 7. Time series of the monthly recorded scorpion sting cases (bars); **A** with monthly average of the maximum and minimum temperature and **B** with monthly accumulated precipitation in Naama province for the period $2003 - 2010$.

variable (to account for non-climatic factors) as independent variables. Even though the model is good, however, it cannot be used for forecasting; the residuals were heteroscedastic and the residuals were not normally distributed.

The scatterplot of the monthly square root of scorpion sting cases ($Y = \sqrt{S}$) and the monthly square of mean temperature (T^2) shows a linear relationship (Fig. 8. B); Y is strongly positively correlated with T^2 with Pearson product-moment correlation coefficient $r = 0.978$. We therefore performed a regression analysis to regard Y as dependent variable and T^2 and all the other climate variables, as well as a trend variable to account for non-climatic factors such human behavior, degradation of the environment and other factors that could influence the number of sting cases, as independent variables.

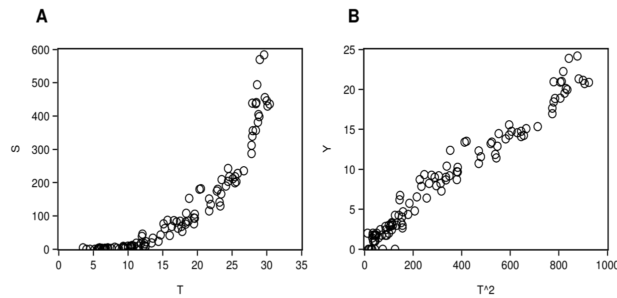

Fig. 8. The scatterplot : (**A**) of recorded scorpion sting cases and temperature, (**B**) of square root of scorpion sting cases and square of temperature.

The choice of the model was based on the coefficient of determination R^2, the Akaike Information Criterion (AIC), and Standard Error (SE). To deal with serial correlation in the residuals, we have included first-order autoregressive (AR) term in the model equation. A model with higher R^2, smallest AIC, and lower standard error and fulfilling the features of the best regression model for forecasting corresponds to the model incorporating only T^2, P, and AR(1) as independent variables, and Y as dependent variable. The regression results using least squares are displayed in Table II.

TABLE II
MODEL 1 OUTCOMES

Dependent Variable: Y
Method: Least Squares
Sample (adjusted) : 2003Month2 2010Month12
Included observations: 95 after adjustments
Convergence achieved after 6 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
T^2	0.024149	0.000408	59.24174	0.0000
P	0.020503	0.005302	3.866833	0.0002
AR(1)	0.279962	0.100359	2.789616	0.0064

R-squared	0.966784	Akaike info criterion	3.365628
Adjusted R-squared	0.966062	Durbin-Watson stat	2.009616
S.E. of regression	1.281897	Log likelihood	-156.8673
Sum squared resid	151.1798	Schwarz criterion	3.446277

Inverted AR Roots .28

Note that the equation is estimated from 2003 Month 2 to 2010 Month 12 since one observation is dropped to account for the first-order autoregressive (AR) term.

▷ The value of R^2 is more than 60% hence the model is acceptably fitted. It indicates also that 96.7% variance in the dependent variable can be explained jointly by the temperature and precipitation; the remaining 3.3 percent variation in the dependent variable can be explained by residuals or other variables other than the selected independent variables.

▷ The estimated coefficients are statistically significant under a 5% level of significance.

▷ The residuals are normally distributed; Jarque-Bera value 0.53 is less than 5.99 and the corresponding $p - value = 0.7662$ is more than 5%.
▷ The residuals are not serially correlated; the Bruesch-Godfrey serial correlation LM test shows that corresponding $p - value = 0.7704$ is more than 5%.
▷ According to Bruesch-Pegan-Godfrey Test, the residuals are not heteroscedastic; the corresponding $p - value = 0.1871$ is more than 5%.
▷ Finally, to test the significance of explanatory variables in the model, we performed the Wald test. Individually and jointly the Wald tests were statistically significant, therefore, all incorporated independent variables should be included in the model.
All features of a best regression model are fulfilled, thus the model 1 can be used for forecasting.

The time series of the monthly scorpion sting data shows seasonal pattern of length 12 but no secular trend (Fig. 7), we therefore incorporated into the model 1 the seasonality effect in the aim to improve forecasting. The 12-month differencing of the transformed time series, that is, $Y = (Y_1, Y_2, ...Y_{108})$ is stationary. The output of the model 2 are displayed in Table III. All features of a best regression model are fulfilled and the invertibility condition is satisfied. The residuals exhibit no specific pattern and are white noise. Thus, the model is proved to be adequate and can therefore be used for forecasting.

TABLE III
MODEL 2 OUTCOMES

Dependent Variable: Y
Method: Least Squares
Sample: 2004M02 2010M12
Included observations: 83 after adjustments
Convergence achieved after 6 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
T^2	0.019181	0.002011	9.539612	0.0000
$Y(-12)$	0.212620	0.082187	2.857033	0.0115
P	0.016087	0.005903	2.725279	0.0079
$AR(1)$	0.249491	0.110724	2.253264	0.0270

R-squared	0.967384	Akaike info criterion	3.381772
Adjusted R-squared	0.966145	Durbin-Watson stat	2.008064
S.E. of regression	1.282038	Log likelihood	-136.3435
Inverted AR Roots	.25		

The simulated scorpion sting cases for the period $2003 - 2010$ computed using estimation equation for model 1 and estimation equation for model 2 are closely approximated to the recorded data (see Fig. 9.) with correlation $r = 0.981$ and $r = 0.982$ respectively.

The predicted number of scorpion stings for the year 2011 were computed for both models using estimation equations and temperature and precipitation for 2011 [13] and were compared with recorded scorpion stings for the same year and plotted in Fig. 10. The correlation between simulated and recorded scorpion sting cases for this year were very strong, $r = 0.9965$, for model 1 and $r = 0.9977$, for model 2.

Both models produce reliable models to predict the number

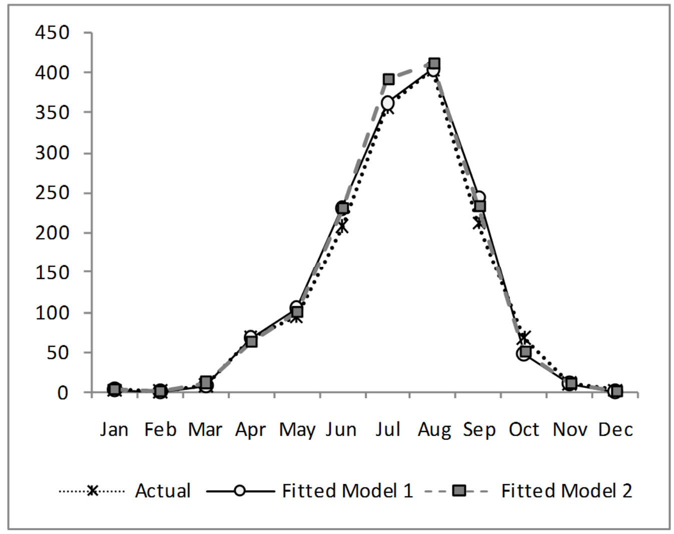

Fig. 10. Actual versus forecasted scorpion sting cases for model 1 and model 2 for the year 2011.

of scorpion stings with high accuracy provided that involved climate variables are on hand, and could therefore assist public health services as to be in state of preparedness by providing in advance the health facilities by the appropriate number of antivenom vials necessary.

IV. DISCUSSION

The physical-geography, favorable climate, and environmental degradation make the province of Naama an ecological environment for scorpion species, and explain the endemicity for scorpion envenomations in this province. It remains that the high incidence is incumbent upon the man, in accordance with conclusions by the review of the epidemiological profile and to errors committed by human being. Indeed, the epidemiological survey revealed that the human has a great responsibility in scorpion accidents. With rurbanisation people build directly on scorpion shelters. Detritus litter the streets and public spaces thereby promoting pullulations of cockroaches, flies and other arthropods; which represent preferred prey of the scorpion. Faced with the resignation of the man and even with the man's assistance, the scorpion colonizes this ideal habitat. Thereby, man offers to scorpion supportive environment, place to be and prey abundance, that is abundant food safely and above all without the need to use its venom, and thus the man contributes to the reduction of cannibalism and to the proliferation of scorpions. In compensation, the scorpion offers him what is most precious: its venom.

An important component of the surveillance system, in addition to data collection, is data analysis, interpretation, and prediction. The incorporation of forecasting models into surveillance is needful. The present study has shown that regression models produce reliable models to predict the number of scorpion stings provided that involved climate variables are on hand.

Using the monthly recorded scorpion sting data for the period $2003 - 2010$ for Naama province, the linkage between scorpion stings and weather conditions was demonstrated

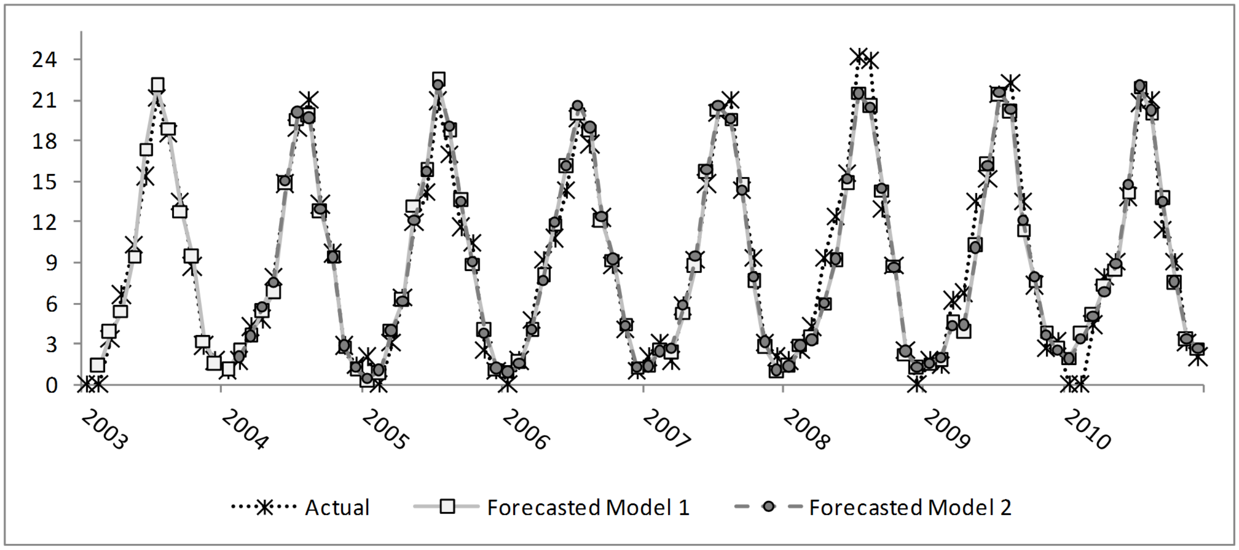

Fig. 9. Recorded scorpion sting cases versus simulated scorpion sting cases

using a regression analysis. The temperature and precipitation are the retained climate factors for this province. This raises optimism for forecasting scorpion stings provided that appropriate climate information are at our disposal. If we know beforehand the change in the climate variables, we can use the built models to estimate how much the change in the value of those variables influence the number of cases of scorpion stings. This could be used to help health authorities determine the appropriate number of antivenom vials necessary for the province in advance. This study represents also an important step to find a way to help in the designing of a control strategy.

In conclusion, our study shows optimism for weather-based forecasting of scorpion stings. It represents an important support for designing of intervention strategies. However, further studies are needed to explore whether other independent variables, such as land cover index, can improve the prediction. As the epidemiology of scorpion envenomation is determined, besides scorpions, by man and environment, the modeling incorporating environmental conditions and human behavior is to be undertaken.

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REFERENCES

[1] G. E. P. Box, G. M. Jenkins, *Time Series Analysis, Forecasting and Control*, Holden-Day: San Francisco; 1976.

[2] J. P. Chippaux, M. Goyffon, *Epidemiology of scorpionism: A global appraisal*, Acta Trop, 107(2), 71-79 (2008).

[3] G. Chowell , J. M. Hyman, P. Díaz-Duenas, N. W. Hengartne , *Predicting scorpion sting incidence in an endemic region using climatologically variables*, Int J Environ health Res, 15(6), 425-435 (2005).

[4] C. G. Dascălu, C. D. Cozma *The principal components analysis method to reduce the collinearity in multiple linear regression model; application in medical studies*, Proceedings of the 2nd WSEAS International Conference on Multivariate Analysis and its Application in Science and Engineering.

[5] EViews 7. URL : http://www.eviews.com/

[6] J. Fox, *Applied Regression Analysis, Linear Models, and Related Methods*, SAGE Publications, Social Science (1997).

[7] M. Goyffon, *Le role de l'homme dans l'expansion territoriale de quelques especes de scorpions*, Bulletin de la Société Zoologique de France Évolution et Zoologie, 1171: 15-19 (1992).

[8] M. Goyffon, J. P. Chippaux, *Les envenimations scorpioniques en Afrique*, Rev. Medicopharmaceutique 53(4), 17-21 (2009).

[9] C. Guarnaccia, J. Quartieri, *Modelling and Simulation in Environmental Data Analysis*, Proceedings of the 8th WSEAS International Conference on Applied Mathematics, Simulation, Modelling (ASM '14), 229-238 (2014).

[10] V. Jowaheer, B. C.. Sutradhar, *On AR(1) versus MA(1) Models for Non-stationary Time Series of Poisson Counts: Part II (Application)*, Proceedings of the 8th WSEAS International Conference on Applied Mathematics, Tenerife, Spain, December 16-18, 363-366 (2005).

[11] H. Kassiri, K. Shemshad, A. Kassiri, M. Shemshad, A. Valipor, A. Teimori *Epidemiological and Climatological Factors Influencing on Scorpion Envenoming in Baghmalek County, Iran*, Academic Journal of Entomology 6 (2): 47-54 (2013).

[12] J. Neter, M. Kutner, W. Wasserman, *Applied Linear Statistical Models*, (1996).

[13] *Office national de météorologie*. URL : http://www.onm.meteo.dz

[14] *Office national des statistiques*. URL : http://www.ons.dz

[15] *Prise en charge de l'envenimation scorpionique*, Comité national de lutte contre l'envenimation scorpionique (2009).

[16] *Relevé épidémiologique mensuel, Institut national de la santé publique*. URL: http://www.ands.dz/insp/scorpionisme.html.

[17] S. Selmane, M. El Hadj, *Regression Analysis on Scorpion Envenomation and Climate Variables in M'Sila Province, Algeria from 2001 to 2010*, International Journal of Mathematical Trends and Technology (IJMTT). V13:1-9 Sep 2014.

[18] S. Taj, M. Vazirian, B. Vazirianzadeh, S. Bigdeli, Z. Salehzadeh, *Effects of climatological variables on scorpion sting incidence in Ramshir area south west of Iran*, Journal of Experimental Zoology, India Vol. 15 No. 2 pp. 575-577 (2012).

[19] M. Vachon, *Etude sur les scorpions*, 479p. Institut Pasteur d'Algérie, Alger (1952).