Entomological Statistics associated with *Quercus Ilex* L. in a North African Forest

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Summary

The domanial forest of Tafat is situated in a subhumid bioclimatic zone in the north eastern region of Algeria. It occupies a wooded area of 1950 hectares and culminates at 1449 meters high. This forest is natural and is characterized by a diverse appearance. Holm oak (Quercus ilex L.) occupies 80% of the vegetation coverage. This rugged and resistant tree is however subject to multiple deterioration factors and insects constitute an important one. Our biotic analysis of the entomological fauna of Quercus ilex L. in the forest of Tafat has enabled the establishment of an inventory of all collected insects. We have identified 14 orders distributed in 125 families with 231 species and 11643 individuals. The study of dynamics of insects indicates that most species have a peak in May and June. The statistical analysis of the entomological settlements related to Quercus ilex L. shows a faunal homogeneity and those factors, namely, order, altitude, and density play a significant effect on the number of insects.

I- Introduction

The forest is considered, or should be considered, as an ecosystem with multiple roles which should be maintained or restored. It is a great biodiversity conservatory because there are more animal and plant species in this habitat than in open areas (Dajoz, 2007). Forests as dynamic elements existed already in the middle Devonian time; however, they were very different from what is known today. A feature of this change is the gradual increase of the relative importance of woody plants compared to herbaceous accompanied by variation of animal species and in particular insects. This shows how important the forest is in the establishment of animal diversity (RETALLACK, 1997).

Insects, which represent the richest group of species, play several very important roles in the forests. We can find, for example, insects, decomposers, pollinators, predators, parasites or vectors of pathogenic bodies. In Tafat forest, located in the town of Bougaa (Setif) with geographical coordinates 36° 16' 57" north and 5° 06' 33" east (Fig 1), the study of the entomofaunistical fauna showed that five orders are significant in number and in sorts. The order of Hymenopterans comes first with 4629 individuals, followed by that of the Dipterans which is of 1668 and that of the Hemipterans is of 1416 individuals.

For beetles, although their number of sorts is high, have 613 individuals, which is very low compared to those quoted previously. Lepidoptera with only 533 individuals comes at the end. All the species composing these orders meet at the level of the forest of Tafat in diverse strata of the vegetable (*Quercus ilex*) and can be sometimes found on other vegetables which divide up through all the forest.

Fig 1: Localization of Sétif and the zone of study (Bougaa).
(Google Maps©google)

At the level of the chosen site, that is the forest of Tafat, we opted for four stations situated at various heights. Two dense stations situated at 1267 meters and 900 meters and two clear stations situated at 1050 meters and 700 meters height (Fig.2). For every station we considered about thirty trees which we marked on-site with a red paint.
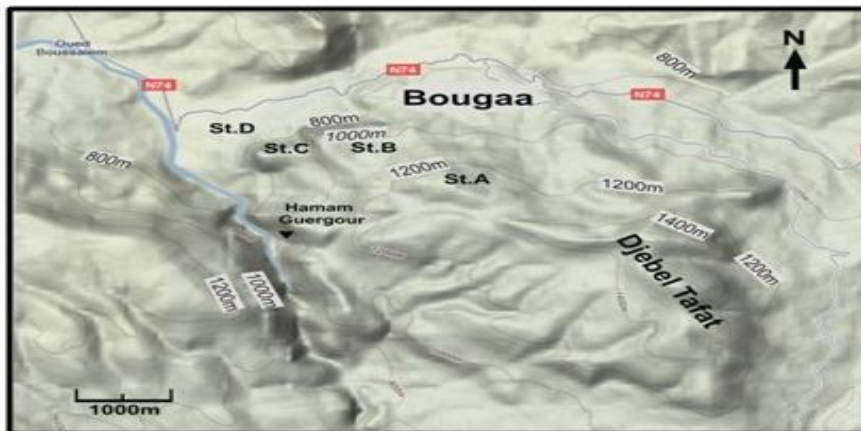
Fig. 2 : Localization of the djebel Tafat and the stations of study
(Imagery©2010Tetra.Matrics)

II- Characterization of stations

Station A: situated in 1267 meters, the trees (Quercus ilex) are squeezed from five to six feet for two of Juniperus oxycedrus. Foliage has contact, its exposure is north, the slope is 20 %, and the litter is thick.

Station B: 1050 meters in heights, trees are spaced out enough, its exposure is north but the slope is very abrupt (40 %), the ground is affected, and the litter is not much important. Quercus and Juniperus are in the same proportions as for the station A.

Station C: its height is 900 meters, but if foliage contact, trees are less squeezed than those of the station A, and the slope is 10 %. The exposure is always North, and the litter is thick. The presence of Juniperus is much less marked than for stations A and B.

Station D: at the level of this station the ground is very much degraded. Situated at a 700 meter height, it is very exposed to the anthropological factors in particular the pasture which is there constantly. Furthermore, the slope is rather abrupt (30 %), and a drinking trough is situated in hundred meters of the groupings of Quercus ilex, taken away from each other, accompanied with some feet far from Juniperus oxycedrus. The ground is stripped and the rock appears in numerous places.

III- Statistical methodology

1- The ecological indications

1.1. Specific wealth and stational abundance of species

In general it is not possible to make an absolved enumeration of the animal populations. As a consequence we make estimations of the staff, which remain the rule every time the absolute evaluations are not practicable (RAMADE, on 1984).

Results:

The used indications are: the abundance (absolute and relative), and the indications of diversity and equitability. We obtained the following results (Table 1).

Table 1: Presentation of the specific wealth and the abundance of the species

Stations	A 1267meters	B 1050meters	C 900meters	D 700meters
Specific Wealth	80	67	92	29
Abundance (number of individuals)	2804	1969	3219	927

Discussion:

The specific wealth is rather important at the level of the station C. This is understandable by the fact that this stations dense from the point of view trees and of more its height is of 900mètres. The station A joins the station C by the density of trees, but at a high enough height. On the other hand both stations B and D, where trees are spaced out, the wealth is lesser. However it should be noticed that the station B (67 species) is however richer than the station D (29species), because this latter possesses a completely stripped under wood, the pasture there is intense, and of this fact the poverty of this biotope is important (Fig.3). The abundance varies in the same direction as that of the specific wealth. Stations A, B and C are represented by a raised staff with regard to that of the station D. Although the station B is not dense, it is to notice that by its height, it escapes the over pasturage and thus keeps a significant undergrowth (Fig4). Furthermore, GASTON and LAWTON, (1988) think that the small-sized sorts seem more spread in all the stations than the large-sized species. Such is the case of *Dryomyia lichtensteini Mesopolobus lichtensteini* and whose abundance is very marked at the four stations. Thus the station C is the richest with 92 species and 3216 individuals while the station A account 80 species and 2802 individuals. These two stations get closer, contrary to stations B and D, but the station B contains the double of the number of species of the station D, although both are clear stations. The staff of the station B is also raised with regard to that of the station D which by its situation is subjected to numerous factors of degradation.
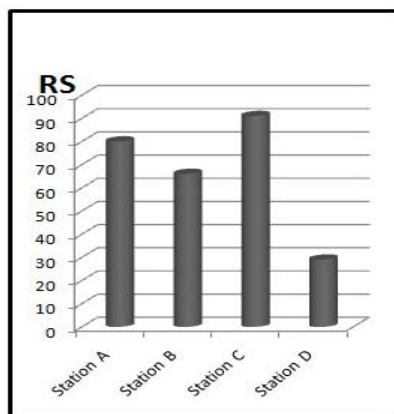
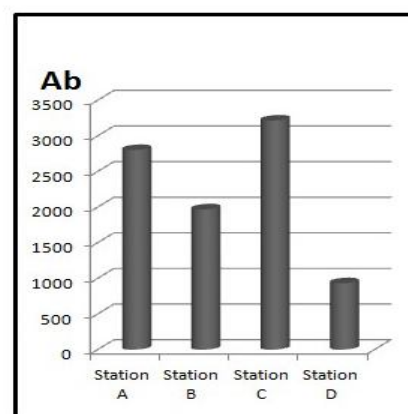Fig 3: specific wealth in the various stations

Fig. 4 : Abundance of the individuals in the various stations

1.2. Coefficient of coenotique affinity (Jaccard index)

Jaccard index allows comparing the populating between them, two-two. Furthermore, this coefficient takes into account only the presence or the absence of the individuals. So its use is going to allow us to highlight the factors which exercise the strongest influence on the distribution of the species through the various stations. (LANCE and WILLIAMS (1967).

Results

The similarity matrix contains the indications of Jaccard. The results are shown in Tables 2, 3 and 4 of similarity matrices. Figure 4 shows the interpretive dendrogram of similarity matrices derived from the Jaccard coefficient. The basic method of similarity is performed by the nearest neighbor method.

Table 2: First matrix of similarity between the populations of beetles, Hymenoptera, Hemiptera, Diptera and Lepidoptera of different stations.

Station	D	C	B	A
A	0,200	0.441	0.528	1
B	0.227	0,456	1	
C	0.200	1		
D	1			

It is found that the most similar stations (probability 0.528) are A and B. If stations are grouped together:
• Similarity between C and {A, B} is Max {0441, 0456} = 0.456
• Similarity between D and {A, B} is Max {0200, 0227} = 0.227
The new similarity matrix obtained is represented by Table 3

Table 3: Second matrix of similarity between the populations of beetles, Hymenoptera, Hemiptera, Diptera and Lepidoptera of different stations.

Station	D	C	A-B
A-B	0,227	0.456	1
C	0,200	1	
D	1		

From this second similarity matrix, we find that the stations {A, B} and C are similar (probability 0.456). We can then combine them. In that case:
Similarity between D and {A, B, C} is Max {0227, 0200} = 0.227.
One obtains the new matrix of similarity (Table 4).

Table 4: Third matrix of similarity between the populations of beetles, Hymenoptera, Hemiptera, Diptera and Lepidoptera of different stations.

Station	D	A-B-C
A-B-C	0,227	1
D	1	

We notice from this method of similarity matrices that two similar groups can be trained as well: the group of stations {A, B, C} and the group of the only station D.
The following dendrogram based on the nearest neighbor method, confirms the classification obtained (Fig 5).
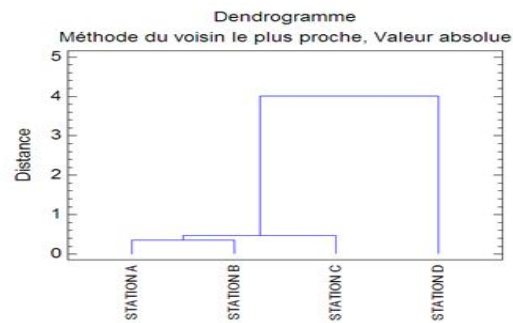
Fig. 5: interpretative Dendrogramme of the matrices of similarity from the coefficient of Jaccard

Discussion

By analyzing the matrices of similarity and the interpretive dendrogram of these matrices, we can notice that the highest rate of similarity is the one observed between stations A and B (0,528). To the same group can be integrated the station C with a rate of similarity of 0,456. From this fact two sets can be released. The first of which similarity is more or less low between stations A, B and C and the second set whose similarity is lower (0.227) and is represented by the station D. This can be explained by the fact that the three stations have a certain faunistic homogeneity on one hand and floral homogeneity on the other hand. Furthermore these Stations are situated at various heights.

Indeed certain authors (MAHARI, on 1980; MOUNA, on 1982; BENKHELIL, on 1991), attribute the low similarities of the stations of study to factors well defined, namely the bioclimatic which can be different, the exposure, the height and the structure of the vegetation who can explain the location of the species in stations and the similarity of the latter. Other authors besides the quoted factors add that of the pollution and its influence on the forest and on the insects which are very important and those climate changes can modify the areas of distribution of insects (WILLIAM and LIEBHOL, on 1995). That's why certain species adapted to the low heights can be found in high height. Also we notice that stations A, B and C (where the altitudes are different) share 22 species represented mainly by frondicoles. We can mention the species *Eupteryx sp, Lepidosaphes ulmi, Wahlgreniella nervata, Pterochloroides persicae, Lachnus roboris, Pseudococcus sp, Phyllonorycter pseudojoviella, Tortrix viridana. Dryomyia lichtensteini, Bethylus sp, Mesopolobus lichtensteini, Clytra novempunctata, Clytra sp, Apanteles sp.* On the trunk we find *Camponotus sp, Crematogaster scutellaris, Plagiolepîs sp and Cetonia funeraria.* The species *Sitona sp* was collected on the trunk at ground level. If we look at the common species at stations A, B, C and D, only five (5) species are caught, Mesopolobus lichtensteini, Pterochloroides persicae, Lepidosaphes ulmi, Dryomyia lichtensteini et Phyllonorycter pseudojoviella

The similarity is only 22.7% which corresponds to a degraded station whose floor is largely bare part. Note however that 41 species are common to the stations A and B, and 43 species between stations A and C. These stations are located in a typical forest environment with rich undergrowth and species linked to the same forest species. If we use the absence-presence, the station B is more similar to the station A (rate of similarity equal to 0,525) than it is with the station C (rate of similarity equal to 0,456). It is however situated always between A and C which share together only 0,44 % of similarity. The absence of the species *Carcina quercana* and *Scopula sp* modifies slightly the value of the similarity.

1.3. Principal component analysis (PCA).

The principal components analysis can be seen as a dimensionality reduction technique. As a principal component analysis on the numbers of different stations (ABC and D) confirms the results obtained by the method of classification of nearest neighbors (Fig.6).
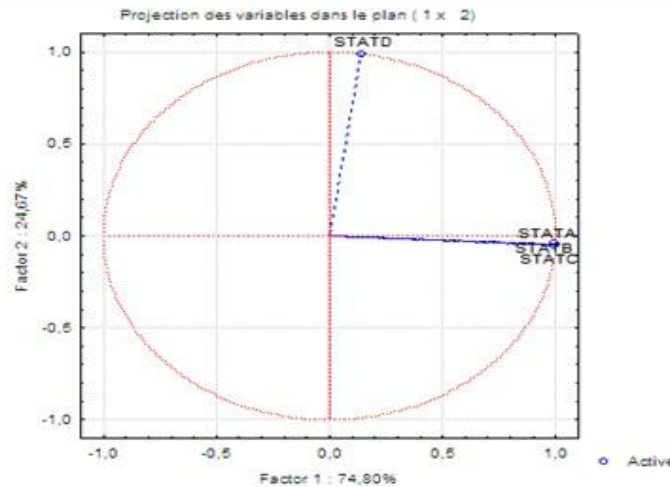
Fig. 6: Graphical representation of the two main axes of the PCA

We notice at the level of the chart of both main axes of the ACP that stations A, B and C are strongly correlated to the first axis which contains 74,80 % of the total information. Only the station D is correlated to the second axis which contains only 24, 67 % of the information.

The two distinct units formed are firstly stations A, B, C and also its poverty species and the other three stations are all located in a forest biotope well preserved, rich and not degraded. In this study, two groups were formed. The group with the similarity rate gets closer to 0.5, and which is formed by the stations A, B and C and the group having the station D whose similarity rate is from 0.5 and where vegetation is almost absent.

1.4. Analysis of the variance of two factors (ANOVA)

This statistical method was chosen and used to study the effect of the maximum of factors on the variable number of insects. A factor allows explaining differences in the answers (SAPORTA, on 2006). The studied factors are: order (15 levels: Hym, Coleo, Dipt, Hémip (Homo, Hetero), Lepi, Coll, Derm, Thys, Pscop, Dict, Zyg, Plani, Trich, Orth), Stations (4 levels: Height: station A (1267m), Station B (1050m), Station C (900m), Station D (700m)), Density (2 levels: Dense, Clearing).

Results

• Existence of the Order factor effect

The results show that F = 8.72, p = 0.00.

p = 0.00 (0.05), so there is an effect of the Order factor. The order has a significant effect on the number of insects (there is a significant difference between multiple orders) (Table 5).

Table 5: Table of average and homogeneous groups of order factor

Orders	Average	homogeneous Groups	
Hym	377	X	
Col	36		X
Dipt	130	X	
Homo	40		X
Hétéro	11		X
Lépi	18		X
Coll	27		X
Derm	21		X
Thys	15		X
Psocop	10		X
Dict	15		X
Zyg	2		X
Nevro	1		X
Trich	1		X
Orth	3		X

Each order is represented by a number of species of its own. The order in which the average enrollment is the highest is that of Hymenoptera, it is an isolated homogenous group. The order Diptera is represented by an average workforce equal to 130 also as an isolated homogenous group. The following orders namely Coleoptera, Homoptera, Heteroptera, Lepidoptera, Collembola, Dermaptera, Thysanoptera, Psocoptera, and Dyctioptères whose average is between 40 and 10 constitute a homogeneous whole and the Zygentoma, the Neuroptera, Trichoptera, and Orthoptera alone form a homogeneous group. Also as there is difference between orders, we can, thanks to Student's test, form four homogeneous groups: The group comprising {Hym} the group of {Dipt} the group formed of {Coleo, homo, hetero, Lepi, Coll, Derm, Thys, Psocop, Dict} and the group consisting of {Zyg, neuro, Trich Orth}. Figure 7 shows the large number of insects with respect to orders.
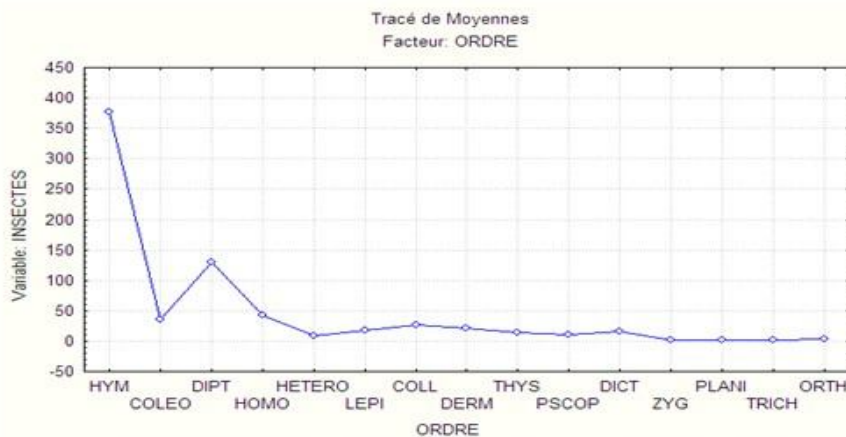

Fig. 7 : Curve representing the average of the Order factor on the variable number of insects.

We notice two peaks at the level of the curve, the one formed by the order of Hymenopterans represented mainly by the species *Mesopolobus lichtensteini* to which are added *Crematogaster scutellaris, Camponotus sp and Plagiolepis sp* and the other constituted by Dipterans represented in particular by *Dryomyia lichtensteini*. Other orders are more or less representative.

• **Existence of the effect of the factor Height (station)**

The results show that: f = 1.787, with p=0.047 p=0.047 (<0.05), there is an effect of the factor Height. The number of insects is influenced by the heights (Table 6).

Table 6: table representing the averages and the homogeneous groups of the factor Station (height).

Station	Average	Homogeneous group	
Station A	58	X	
Station B	41	X	
Station C	71	X	
Station D	17		X

The station A, situated in 1267 meters possess an average of the staff equal to 56, it is a rich station and possesses numerous species, such as *Lachnea vicina, Ptinus obesus*, *Sycophila binotata*, *Plagiotrochus amenti*, *Limantria dispar*. whom we did not meet at the level of the other stations. The station B is as height as 1050 meters, its average is 41, and numerous species characterize it, we quote as an *Synergus clandestinus*, *Plagiotrochus yeusei*, *Synergus crassicornis*, *Plagiotrochus vilageliui*, *Bibio hortulanus* and the station C is at 900 meters with 71 of average, represented by numerous species: *Orthotomicus sp*, *Anthaxia sp*, *Agrilus viridis*, *Cerambyx cerdo*, *Plagiotrochus gibbosus*, *Spilostethus pandurus*, *Plagiotrochus razeti*. Each station has a definite number of species affected by the altitude.

However, their averages are considered close, and therefore we can through Student test, form two homogeneous groups: The group formed of stations {A, B, C} and the group formed of the station D.   Indeed, station D has an average of only 17 and it is marked especially by the presence of the species Whiteflies sp whose number is high. Nevertheless it remains far away from the other stations. The curve of Figure 8 represents the average of the altitude factor.
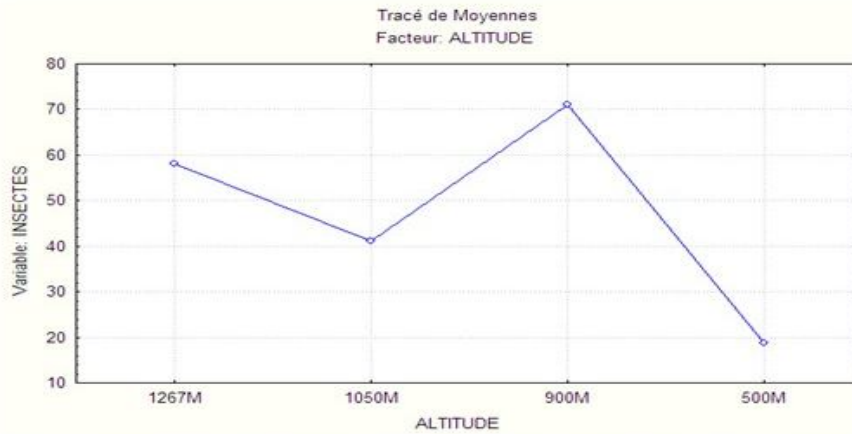

Fig. 8: curve representing the averages of the factor Height

The curve then shows a peak for the station C, the second peak is represented by the station A, lower is the value of the station B and the lowest is the one of the station D. It is at the height of 900m that the staff is the highest.

• Existence of the effect of the factor Density
The results show that f = 4.957, with p=0.0274, p=0.0274 (<0.05), there is eventually an effect of the factor Density. The density of the stations has a significant effect on the number of insects (Table 7).

Table 7: The average and the homogeneous groups for the factor Density

Density	Average	Homogeneous groups	
Dense (Station A ans C)	64	X	
Clearing (Station B and D)	30		X

The stations A and C consist of trees whose tops are flush and hence are dense stations. B and D stations for their part are formed of spaced trees, the tops do not touch, they are clearings or gaps. Table 7 shows that both stations A and C possess an average of staff equal to 64, they are rich stations while that of B and D stations is equal at 30. They are less wealthy stations in particular the station D because the trees at that level are further apart than to station B. As there is difference between the densities, thanks to the test of Student, two groups can be so formed: the group formed of {Dense}, holding stations A and C, the group formed of {Clearing}, and they are stations B and D. The chart of the averages of the factor density is represented in figure 9.

Fig.9: Curve representing the average of the factor Density

The curve in figure 9 shows that the value of the variable insects is represented by a peak at the level of the factor density and that the minimal value is represented by the factor clearing.

Discussion

The analysis of variance of two factors on the variable number of insects, taking into account all orders, showed that the effect of the order factor on the number of insects is significant with $p = 0.00$, which is below 0.05. Between orders, there is a significant difference, each order has a specific number of insects and the Hymenoptera's is the highest number with an average of 377 individuals, it is followed by the order Diptera with a number of individuals equal to 130. Each of these orders alone constitutes what is called a homogeneous group. The orders which the number of insects is between 10 and 40 constitute a homogeneous group and finally the orders of insects having a number between 10 and 1, also form a homogeneous group. Therefore, as there is a difference between orders, four (4) groups can thus be formed through the Student test. The group formed by Hymenoptera, one formed by Diptera, the one constituted of Coleoptera, Hemiptera, Lepidoptera, Collembola, Psocoptera, Thysanoptera, Dermaptera Dictyoptera, and the fourth group formed by Zygentoma, Trichoptera, Orthoptera and Neuroptera.

The factor height with $p=0,047$ (lower than 0, 05), has an effect on the number of insects. That is to say that the number of insects is influenced by the height. However there is no interaction between Order factor and height factor because the level of meaning $p=0,919$ is upper to 0, 05. The various orders can be met as well in station A as well as in station C or B or D.

The effect of density factor on the number of insects gives $p = 0.0274$ (less than 0.05). Density therefore has a significant effect on the number of insects. Stations A and C are richer than the stations B and D. There is interaction between order and density, p being equal to 0, 0241.

The application of ANOVA on the variable number of insects when all the orders are taken into account, has shown that the order factors, Station (Altitude) and density have a significant effect on the number of insects.

1.5. Study of the spatial configuration

In this section, we detect the spatial distribution of species within communities.

In communities three types of configuration are discerned: random, in bouquets and uniform. To determine the configuration, we use the adjustment Kolmogorov-Smirnov (Saporta, 2006) based on statistics:

$$D_n = \sup_{x \in R} \left| F_n(x) - F_0(x) \right|$$

Where $F_n(x)$ indicates the function of empirical distribution of the sample and $F_0(x)$ the function of distribution of the law with which we want to adjust. If the value of the probability p (smaller risk than we agree to take) is lower than 5 %, we reject the adjustment by $F_0(x)$ and we end that the variable counts of individuals does not follow the law $F_0(x)$.

Results

• *Adjustment by Poisson distribution*

We want to adjust the variable "Number of people" with a Poisson distribution F_0 of parameter equal to 556 (the parameter of the Poisson distribution is estimated by the empirical mean of the sample). We get:

$$D_n = \sup_{x \in R} |F_n(x) - F_0(x)| = 2.895 \quad \text{with} \quad p = 0.0001$$

$p = 0.0001 < 0.05$ therefore, the variable number of insects do not follow a Poisson distribution. This means that "the distribution of the number of individuals per sampling unit is not random.
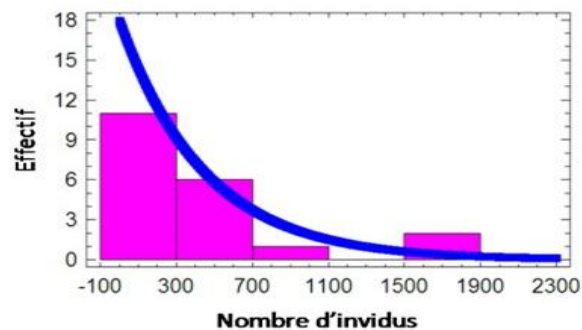
• *Adjustment by a negative binomial distribution*

We want to adjust the variable "Number of people" with a negative binomial distribution F_0 of parameters $k = 1$ and $\alpha = 0.002$ we obtain:

$$D_n = \sup_{x \in R} |F_n(x) - F_0(x)| = 0.610 \qquad p = 0.851$$

$p = 0.851 > 0.05$, therefore, the variable number of insects follows a negative binomial distribution. This means that "the distribution of the number of individuals per sampling unit is in bouquets (also called "contagious" distributions or "aggregative") (Fig.10).

Fig. 10: Adjustment of the variable "Number of individuals"

In Figure 10, the curve shows the distribution of the number of individuals, which in our case follows a negative binomial distribution.

Discussion

The distribution of the number of individuals per sampling unit is not random, it does not meet Poisson distribution. This shows that insects are not found at the forest Tafat by chance, but because there are plant/insect defined relationship, relationship between *Quercus ilex* and the vast majority of insects that are subservient to it in particular herbivorous. The random distribution indicates that the middle is homogeneous and that the behavior of the species is not selective. This does not apply to species associated with holm oak, case of Hymenoptera gallicoles for example. on another hand, the distribution of the number of individuals per sampling unit in bouquets, which responds to the negative binomial distribution, explains the fact that the constraints are exerted on people, such as the relationship between 'hosts and parasites', the effect of abiotic factors, the plants of the undergrowth, which are all interrelated processes that can promote the configuration. Furthermore the bouquets configuration suggests that individuals are clustered in the most favorable locations, which is the case of species related to holm oak, either by their behavior, or in relation to the heterogeneity of the environment, sight the richness of undergrowth and wood, either by their mode of reproduction and development, as is the case of the species *Tortrix viridana* that appears with the budding of the oak.

1.6. Multiple linear regressions

The multiple linear regression (Saporta, 2006) aims to study and model the linear relationship between a variable response Y which is represented by "the number of individuals" and several explanatory variables X_1, X_2, X_3, X_4, X_5 and X_6 which are represented by:

X_1: Wind speed.

X_2 : monthly average humidity.

X_3: monthly maximum average temperature.
X_4: Monthly minimum average temperature.
X_5: monthly average temperature.
X_6: Monthly rainfall.

The model is written as: $\qquad Y = \beta_1 X_1 + \beta_2 X_2 \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon$

ε is the residual part of the model (not explained by the regression).

Results: The results obtained are shown in Table 8.

Table 8: Table showing the results of the linear regression

Variables	Coefficient $\hat{\beta}_j$	Standard deviation (SD) $\hat{\sigma}(\hat{\beta}_j)$	Student's statistics T_{b_j}	Level p
Constant	-10509,2	5653,991	-1,858	0,100
X_1	0,362	0,260	1,391	0,201
X_2	1,983	0,750	2,643	0,029
X_3	-1,088	3,001	-0,362	0,726
X_4	0,796	1,408	0,565	0,587
X_5	1,905	2,312	0,823	0,433
X_6	-1,092	0,421	-2,594	0,031

The results of the multiple linear regression (Table 8), allow us to suggest that only the variables X2 (monthly average humidity) and X6 (monthly rainfall) are significant because their level p is respectively equal to 0.029 and 0.031, which is below 0.05. Indeed humidity and rainfall play a significant role in the development of insects and thus on their workforce. The final model is then written in the form:

$$Y = 1,893 X_2 - 1,092 X_6 + \varepsilon$$

The coefficient of determination R2 = 0.926, meaning that 92.6% of the information is found in the obtained model that explains very well the variable Y "number of people" and that the pace of activity of many forest insects is under the control of climatic factors like humidity (case of the species *Cerambyx cerdo*) and rainfall.

Conclusion

From the 14 different orders it turns out that each order is represented by a number of families and species. The role of these species within the forest is remarkable and significant not only with respect to species themselves but also with respect to the woody plant Quercus ilex on which they are dependent.

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