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Climate, geographical distribution, and specific structure of phyllopods anostraca (Crustacea, Branchiopoda) communities in Morocco

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ABSTRACT

Many authors approached the study of the climate effect on the distribution and on the structure of the groupings of the botanical species while using "climatic" indications allowing to give a synthetic expression of the climate of the studied stations. The indication most used in Mediterranean climate is the pluviometric coefficient of Emberger noted « Q_2 ». The present work bases itself on the use of this indication, climatic parameters m, P and the thermal distance « M-m » of the studied stations to show the effect of the climate on the geographical distribution of Anostraca crustaceans and on the structure of their communities. The results show that, in Morocco, the climate is one of the main factors which control the geographical distribution of these crustaceans. The zones without extreme climatic conditions have a maximal specific variety of Anostraca. Also, and from the climatic characteristics of a given region we can determine the species and the structure of the communities of Shellfishes Anostraca which are potentially able of existing.

KEYWORDS

Crustacea;
Anostraca;
Biogeography;
Community;
Climate;
Morocco.

INTRODUCTION

Since the beginning of the century, several authors studied the effect of the climate on the geographical distribution of the botanical species and on the specific structure of their communities. Often, these researchers used mathematical indexes allowing giving a synthetic expression of the climatic characteristics of the biotope In Mediterranean climate, the coefficient of Emberger Q_2[1] is the most used as climatic indication. For a given meteorological station, this indication takes into account the height average of the annual precipitation (P), the average of the maximal temperatures of the warmest month (M) and the average of the minimal temperatures of the coldest month (m). The pluviometric climagram of Emberger (1930)[1] and Sauvage (1963)[2] is also widely used by many environmentalist botanists.

Let us remind that more the value of Q_2 is higher more the milieu is humid the mathematical expression of the index Q2 is:

$$Q_2 = \frac{100\,P}{\frac{M+m}{2}(M-m)}$$

with P in mm, M and m in °C

For the Animal Kingdom, many researches showed that the climatic factors in general, and the temperature and the precipitation in particular, have an important influence on the geographical distribution of many species and on the specific structure of their communities. To show this climatic influence, the authors used various demonstrative means but without giving a lot of importance for the methods used by the botanists for the same objectives in particular the coefficient Q_2 and the climagram of Emberger.

In this work, we studied the influence of the spatial variation of the climate on the distribution of the species and on the specific structure of Anostraca communities. Ecological characteristics of biotopes of this group of Arthropod are very exposed to the climatic influences. It is about one of the most characteristic systematic taxon of waters of temporary natural ponds and artificial ponds wich have biological cycles very influenced by the climatical data. Indeed, the precipitation, the temperature and the wind are the main factors which determine the supply in water and the annual durations of these ponds. But, in spite of this connection similar to the one linking the distribution of the botanical species to the climatic variability, very few previous works were interested to bring to light the relation between the climate and the quality of the fauna of the temporary ponds. Besides, in spite of large number of authors who studied the ecology of Anostraca Phyllopods from whom we quote Daday De Dées (1910)[3], Gauthier, 1928a-b[4,5]; Peres, 1939[6]; De Lepinez, 1961[7]; Boutin and *al.* (1982)[8], Browne and Mac Donald (1982)[9], Saadi (1986)[10], Fadli (1987)[11], Thiery (1987)[12] and Ben Raoui (1991)[13], the works getting the point on the relation between the variability of the climate and the distribution of the species, and on the specific composition of their associations were not directly approached.

So, the present work consists in the use of the pluviometric climagram, Emberger' coefficient Q2, m, and M-m to concretize the effect of the climate on the geographical distribution of Anostraca crustaceans the most represented in Morocco.

METHODOLOGY

In the way with which Bons (1975)[14] exploited the climagram of Emberger to explain the bioclimatic distribution of some Reptiles of Morocco and by combining Q_2 and the thermal distances 'M-m' (noted E_T) noted at the various chosen biotopes, we intended to study the effect of the main climatic factors on the geographical distribution of the species of the studied zoological group.

The adopted study method consists in the realization of sampling, by a net called cloudy-water, of anostraca crustaceans in 65 temporary ponds (dayas) distributed in various bioclimatic zones of Morocco. These dayas are chosen in order to be near known points in the Emberger climagram or, in some cases, with P, M and m extrapolated from the climatic data of the region. The Figure 1 represents the geographical distribution of the prospected bioclimatic floors. Also, the Figures 2 and 3 present the bioclimatic distribution of the collecting stations of Anostraca crusraceans collected in two types of climagrams.

Let us note that in climagramme 2 (Figure 3), the climatic classification of the studied stations is made by basing it on two factors which influence the duration of the flooding of temporary ponds: annual rainfall P, which by its importance facilitates the long lasting of the biotope, and the thermal extreme distance from the averages (M-m) which influences the intensity of the evaporation of superficial waters. Climagrammes 1 (Figure 2) is elaborated according to the principle of Emberger (1930)[1]. Besides, the zoological inventory concerns 8 taxons. We did not take into account the abundance of the species. So, for every collected species, only its presence or its absence was considered. Two other species (*A. salina* and *B. spinosa*) which the presence is determined by high rates of salinity are not studied.

RESULTS AND DISCUSSION

Results

Species

The Emberger climagram (Figure 2) shows that the area of the bioclimatic distribution of *B. schaefferi* ex-

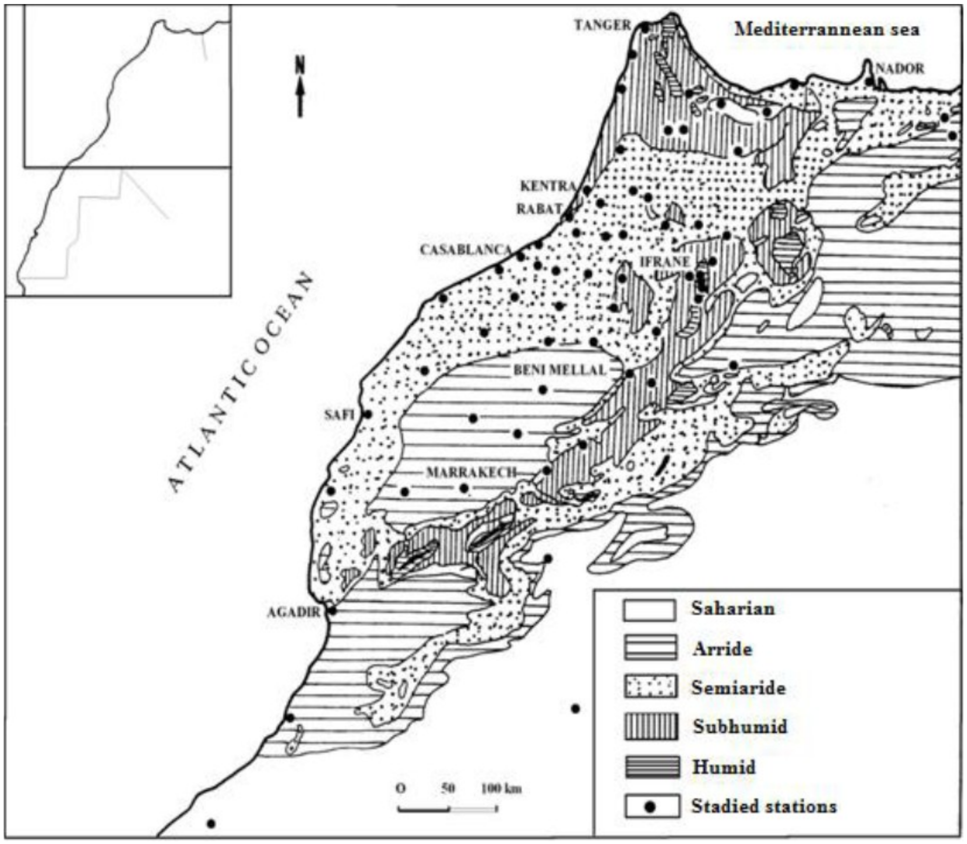

Figure 1 : Geographical distribution of the prospected bioclimatic floors

tends in all the variants of the various bioclimatic floors of Morocco. It is thus an eurytope specie regarding the "climate" factor. Contrary, *T. brtecki* (area A, Figure 2) and *T. jbilitica*. (area B, Figure 2) occupies more reduced bioclimatic areas that are different and symmetric, with regard to a line which is very close to the first bisector of the angle formed by the mark of axes Q_2 and 'm'. For *T. jbilitica,* let us note besides that as m becomes high the value Q_2 is higher also.

- If we do not consider a single spot of *B. ferox* which has been indicated at the South of Casablanca by Thierry (1987)[12] and which has a m superior to 7 °C, the bioclimatic area of *L. africana* and of *B. ferox* (area C, represents 2) occupy a bioclimatic surface characterized by low values of m (lower than 2 °C) and values of Q_2 included between 50 and 120.
- The bioclimatic area D (Figure 2), largely in common to *C. diaphanus* and *S. torviconus bucheti* extends about, between m = 1 °C and m = 8 °C. The values of the coefficient Q_2 are superior to 45°C.
- With Q_2 included between 45°C and 90°C and m included between 3°C and 8°C the bioclimatic area of *T. affinis* (area E, Figure 2) occupy a non extreme climatic conditions zone. This one, reduced and lengthened, occupies the average region of the bisector of the mark formed by the axes of coordinates Q_2 and m of the climagram 1. It coincides, partially, with the lower zone of the bioclimatic distribution of *B. schaefferi* and *C. diaphhanus*.

Besides, the analysis of the climagram elaborated by the combination of the average height of the annual precipitation (P) and the thermal distance E_T (Figure 3) also show:

- The ubiquity of *B. schaefferi* in the Moroccan territory.
- An opposition, regarding to the bisector of the mark formed by the axes of coordinates P and (M-m), the bioclimatic area of *T. brteki* (area A') and the area of *T. jbilitica* (area B'). For *T. brteki*, approximately of E_T = 20 °C, P is nearby of 200 mm/year. But, as E_T takes higher values P must be more important. This is also the case for *T. jbilitica*.
- The overlapping of the bioclimatic areas of *C. diaphanus* and *S. torvicornis bucheti* constitute a common area (area C'). This one is characterized by a P value superior to 350 mm and E_T included

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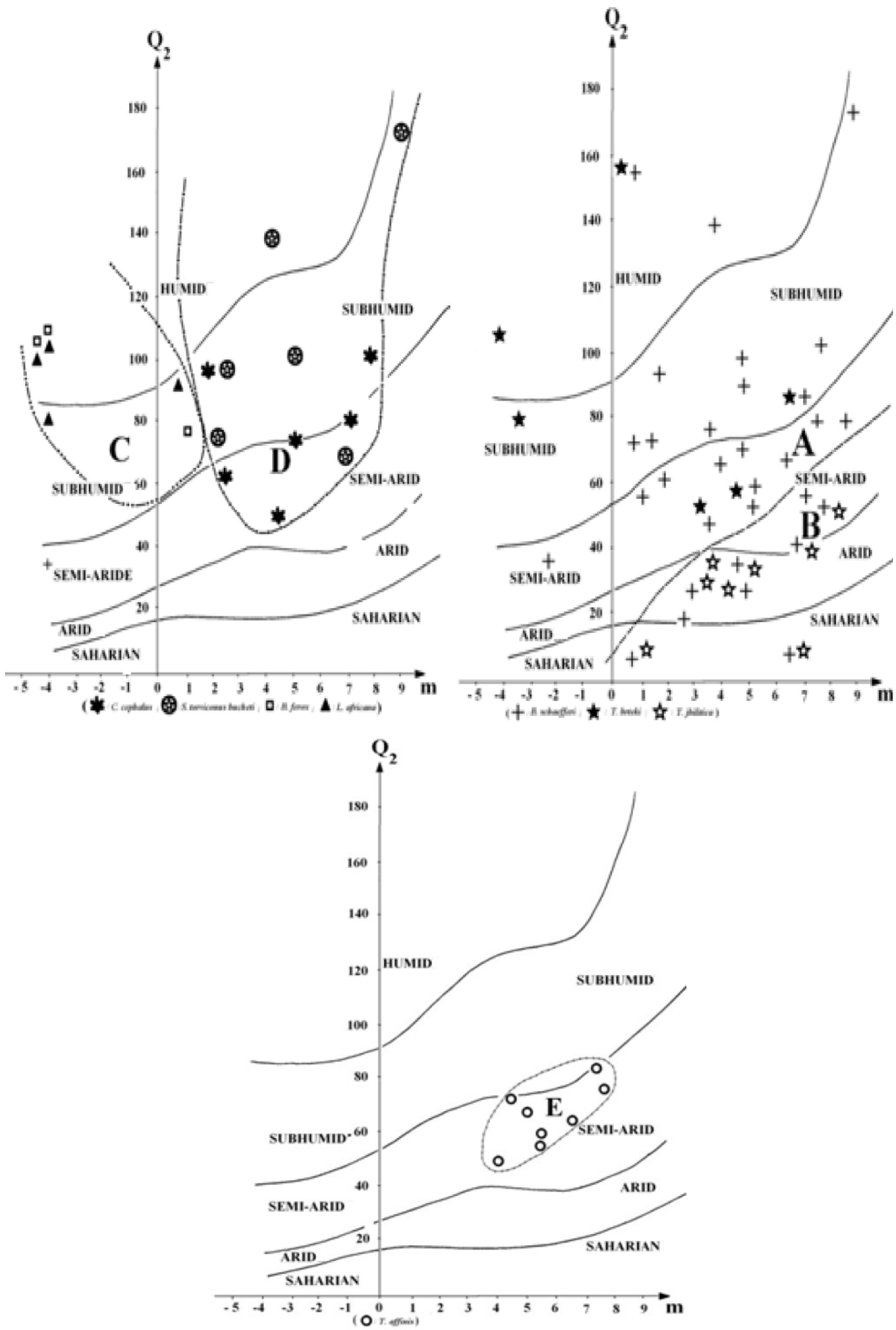

Figure 2 : Bioclimatic distribution of eight species of anostraca crustceans, collected in Morocco, in the climagram of Emberger

between 15°C and 33°C.

- *L. africana* and *B. ferox*, show a common bioclimatic area (area D') characterized by precipitation superior to 450 mm and thermal distances (M-m) which, with the exception of the station of *B. ferox* indicated to the South of Casablanca, is around 30°C. E_T is thus reduced.
- The occupation of the average pluviometric condi-

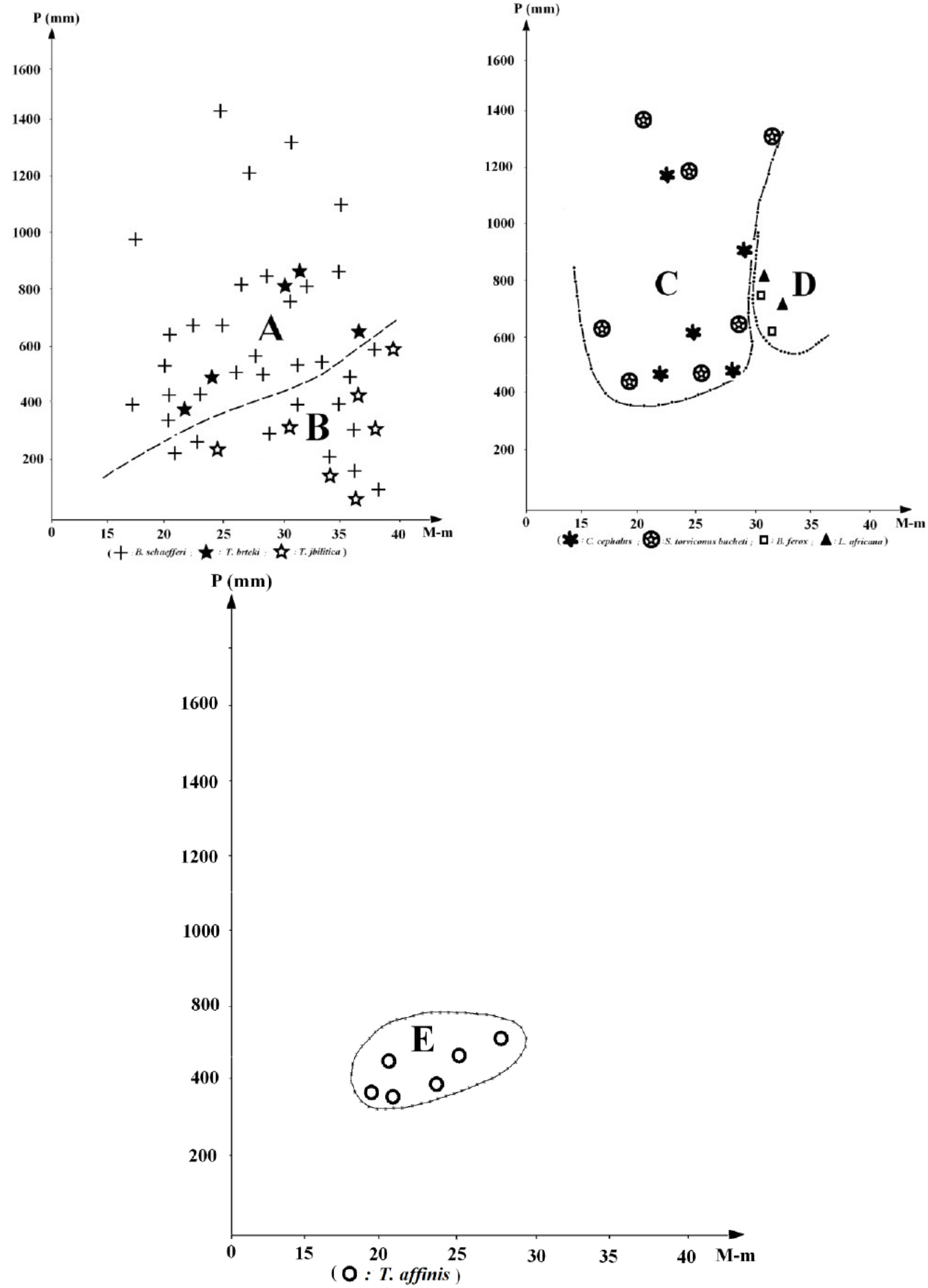

Figure 3 : Bioclimatic distribution of eight species of anostraca custaceans, collected in Morocco, in the climagram elaborated from P and 'M-m'

tions (area E') by *T. affinis* P is included between 380 mm and 650 mm and E_T varies from 18 mm to 30 mm.

Associations

From the comparative analysis of the bioclimatic areas of the various species, illustrated in the various studied climagrams, we can deduct the existence of common bioclimatic zones for two or several species. So, in theory we can determine possible associations between the various studied species and characterize the main climatic conditions necessary for the realization of these associations. In theory, four types of associations were differentiated:

A_1: composed of three species: *B. ferox*, *L. africana*, *B. schaefferi* and *T brteki*. In theory, the climatic condictions that encourage this kind of association are:
m < 2°C, 50 < Q_2 <120, P > 450 mm and M – m > 30°C

A_2: Formed by *T. jbilitica* and *B. schaeffedri* and requiring m >1°C; Q_2 < 70; P > 400 mm, and M–m > 15 °C; and where step by step m is going away from 1°C Q_2 and M - m takes higher values.

A_3: Gathering in the same biotope *B. schaefferi*, *S torvicornus torvicornus* and *C. diaphanous* characterized by
1°C< m < 8°C, Q_2 > 90, P > 600 mm and 15 °C < M – m < 33 °C.

A_4: Gathering *B. schaefferi*, *S torvicornus torvicornus*, *C. diaphanous* and *T. affinis*
In the same climatic milieu characterized by
3 °C < m < 8 °C; 40 < Q_2 < 90 ; 380 < mm P < 600 mm and 18°C < M – m < 28°C.

Besides, all these types of associations were noted in the natural environment. No different association was illustrated. It is necessary to indicate, besides, that A_4 association (constituted by *B. schaefferi*., *S torvicornus torvicornus*, *C. diaphanous* and *T. affinis*) was observed only in one temporary pond (Daya Laacel) situated in the forest of western Mamora. Also, it is necessary to note that in the given geographical zone, the specific structure in theory deducted from the overlappings of the bioclimatic areas' characteristics of the species still corresponds to what we can find in the nature.

Discussion

Morocco presents a varied and contrasted climate with seasonal variations. The action of the diverse elements of the climate on the biology and the ecology of the life is obvious. Often, from some threshold values, each climatic element can be a limiting factor to the life of certain living species.

The method of study, based on the elaboration of climagrams, has allowed us to individualize the bioclimatic areas respectively favorable to diverse Anostraca crustaceans of Morocco. For these crustaceans, the extension of these areas and the comparison of their shape and their limits are thus of a big interest to bring to light the effect of the main climatic factors on the geographical distribution of these life species. So, the large distribution of the diverse circles of collecting of *B. schaefferi* on the studied climagrams shows a climatic eurytopia of this species in the Moroccan territory. This result suits to the other previous conclusions in particular those of Fadli (1987)[11] and Thiery (1987)[12].

Also the used method shows that the bioclimatic area of *T. Affinis* is restricted and characterized by average values of Q_2, P and M-m. Contrary to *B. schaefferi*, this species does not support all the bioclimatic variants of Morocco. It is observed only in no extreme climatic conditions about which we can say that it is indicator. Moreover, this shows that besides the nature of the bottom and the presence of a botanic covering of the biotope, suggested as determining factors of some geographical distribution of this species[12], the factor 'climate' influences also this distribution.

Besides, by combining the main elements of the climate P, M and m, we elaborated climagrams which have allowed us to characterize the climatic conditions of life for the studied Anostraca Crustaceans. Let us note that many works showed that these climatic elements can influence the life of diverse Anostraca of fresh water and, as a consequence, control their respective geographical expansion.

Indeed, many authors[10,11,13,15-17,19-23] evoke the stimulating or unfavorable action of some temperature values on the hatching of eggs, speed of embryonic development, the lifespan or on the fertility of Anostraca of fresh water. Also, rainfall quantity and the evaporation intensity of superficial waters control the flooding duration of the temporary ponds and their chemical stability. In the desert, dry regions or even in some parts of semi-arid areas, these two climatic factors are thus potentially the cause of the absence of the species which need long periods of flooding of the biotope to finish their developments.

The absence of *T. brteki*, *C. diaphanus*., and *B.*

ferox in these zones characterized by short-term flooded phases could be a case. These conclusion was already confirmed on the field by many authors among whom Fadli (1987)[11] and Thiery (1987)[12] whom have showed that, even inside their respective bioclimatic areas, these species appear only in temporary ponds of a flooding durations from the average to long. Besides, Eder and his team (1997)[24] noted, in Austria, a qualitative variation of Anostraca crustaceans and a variation of the structure of their communities according to the seasons and then, according to the climatic conditions of the environment. In this country, *Branchinecta ferox* appears in spring, *Streptocephalus torvicornus* and *Tanymastix stagnalis* in summer and *B. schaefferi* in summer and in autumn.

Also the climatic factor m seems to be determining. Indeed, *C. diaphanus* and *S. Torvicornus bucheti* develops only in the zones where m is superior to 1°C, while *T. brteki* seems to need m lower than this value. Let us note that, even if Mura and *al*. (2003)[25] noted that *C. diaphhanus* is able to adapt the characteristics of its biological cycle with the conditions offered in the Italian milieu, it seems that, at least for the population of Morocco, m inferior to 1°C inhibits the appearance of this species. Zarratini (2004)[26] noted, also, that at *C. diaphanus* the percentage of hatching varies from a temporary pond to another and this according to the duration of flooding because this duration mainly depends on climatic characteristics of the environment in particular the rainfall and the local temperature.

For *T. brteki*, the climatic conditions (important P values and low M values) are possible in Morocco only from a certain height. It seems that *T. brteki* is mountainous specie; this is in agreement with the previous observations[12].

The results show that *T. jbelitica* is the specie which develops in the dry zones of Morocco, what is in accordance with the other observations among which those of Fadli (1987)[11], Thiery (1987)[12], and Roux and Thiery (1988)[27]. Besides the intervention of the thermal distance M-m in the determination of the presence or the absence of *T. jbelitica* in a daya can be also highlighted. Indeed, of the altitude level of Agadir city and until the North of the Tadla plain, the distribution of dayas, the most northern colonized by *T. jbelitica* follow an increasing continental gradient.

Besides, the overlapping between the respective bioclimatic areas for two or several species, illustrated by the cilmagrams (Figure 2 and 3), can determine the specific structure of associations theatrically possible in the nature. For a given climatic zone, these specific determined structures do not correspond necessarily to what we can observe in some dayas of the studied zone. Indeed, the results of the work of several authors among whom Fadli (1987)[11], Thiery (1987)[12] and Ben Raoui (1990)[13] we conclude that dayas situated in zones common to various bioclimatic areas do not present necessarily all of the species respective to these areas. This difference between the theory and the reality on the field seems for us to be explained as a consequence of the intervention of other non climatic conditions, that the same bioclimatic zone can undertake, in particular edaphic or topographic, chemical or bioticks factors. Indeed, local restrictive factors can limit the existence of certain species and it can occur even if the climatic conditions are favorable. So, a phenomenon of replacement or exclusion between species, climatically able to live together, can modify the specific structure of the communities of Anostraca species. But, it is in the zones of intersection between different bioclimatic areas where we observed dayas with maximal specific variety. This last conclusion is in accordance with the field observations of Fadli (1987)[11] and Thiery (1987)[12]. Let us note, for example, that in the same geographical zone the duration of flooding of the biotope does not depend only on the influence of the main climatic parameters P, m and M-m. Other factors can intervene to stretch out or to shorten this duration. Indeed, for similar climatic conditions, a clay soil and local basin shape topography facilitate the formation of ponds with long flooding duration. On the contrary, a sandy soil reduces this duration. So, this phenomenon can be responsible of the difference of the specific composition of associations noted in the same bioclimatic zone.

Another phenomenon of trophic order facilitates the life in community of the species: a daya presents an association of several Anostraca Crustaceans, the embryonic life expectancy and the longevity of the individuals vary from a species to another. This seems to facilitate a good distribution of the resources of the environment between the co-existing species.

Finally, the zone corresponding to the bioclimatic area of *T. affinis* should present a maximal variety of Anostraca crustaceans. This one corresponds to an overlapping zone of a significant number of respective bioclimatic areas with various species. The climatic conditions (Q_2, m, P, M-m) are average. Indeed, in a restricted number of dayas, spread on some hectares bioclimatically located in this area, Thiery (1987)[12] inventoried 6 Anostraca species, i.e. 75 % of the fresh water species collected in Morocco. These results are also in accordance with those of Connel (1978)[28] and Huston (1979)[29] who suggest that in a perturbed environment the maximal specific wealth would be observed in average ecological conditions.

It is interesting to note that, in a given environment, other physical and chemical factors can combine with climatic factors to facilitate or, on the contrary, inhibit the existence of some species. We quote the degree of salinity of waters[30,31] and the conductivity[32,33]. This addition of the action of other physical and chemical factors, which its nature can varies from a place to another, with climatic factors explains the variability of the specific structure of the communities that we noted in geographical zones with more or less similar climate.

In Morocco, as example, *B. ferox* coexists with *A. salina* while Samraoui et *al*. (2006)[30] have indicated that in Algeria this species lives with *Artemia tumisiana*.

CONCLUSION

The climatic factors (Q_2, m, P, M-m) play a determining role in the geographical distribution of Anostraca Crustaceans and in the composition of their communities. Indeed, *T. affinis* colonizes zones with average climatic conditions; *C. Diaphanes* and *S. tovicornus bucheti* occupy mainly areas where annual rainfalls exceeding 350 mm and with cool or temperated winter; *T. brteki* and *B. ferox* in the zones with important P values and with cold winter and *T. jbelitica* in the driest zones of Morocco. Only *B. schaefferi* is eurytopic climatically. The zones of intersection between respective bioclimatic areas of the various species present maximal specific varieties.

Also, the results show that the main constituents of the climatic conditions can intervene in an important way concerning the determination of the systematic structure of coexisting Anostraca species. In theory, this allows determining various types of associations of Anostraca crustaceans that we expect to observe in certain bioclimatic zones. So, from the climatic characteristics of a region, the approached method allows to determine its potential fauna of Anostraca species.

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