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# DIET OF *CATAGLYPHIS BICOLOR* (HYMENOPTERA-FORMICIDAE) IN AN INSULAR CONDITION IN NORTH-EASTERN ALGERIA

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**Abstract.** A study of the adaptation of the ant *Cataglyphis bicolor* in terms of feeding under insular conditions was conducted on the north-eastern coast of Algeria. For this, three pairs of stations (island-continent) were chosen. Analyzing fragments of prey species found in *C. bicolor* nests, the diet in each station pair was studied. The results obtained indicate that *C. bicolor* has an opportunistic diet characterised by insectivory. Indeed, more than 95% of the prey consumed in the six study stations were insects with a clear preference for other ants, with frequencies ranging from 52 to 87%. Among the latter, *Messor barbarus*, *Camponotus* sp., *Camponotus laurenti*, *Pheidole pallidula* and *Tetramorium biskrense* were the ants most predated by *C. bicolor*. The diversity of continental prey seemed greater than that of island environments. For the two Cap Sigli stations, the prey richness was 94 species for the continent against only 28 species for the island environment. For Boulimat, there were 27 prey species for the mainland and 20 prey species for the islet. Finally, for the Sahel region, *C. bicolor* was able to harvest 42 prey species on the mainland and 28 species on the island. The diversity of *C. bicolor* prey in the island environments seems to be a function of insect richness (prey availability) and floral richness.

## INTRODUCTION

Through Von Humboldt's, Darwin's and Wallace's works, where islands were presented as singular and fragile ecosystems (Gros-Desormeaux 2012), dynamic equilibrium theory claims that specific diversity within an island ecosystem is explained by stability between colonization and territorial species extinction (Gros-Desormeaux et al. 2015). Biocenotic units suffering from insularity for a relatively long time were condemned to live under isolation conditions to ensure their survival (Gros-Desormeaux 2012).

Island systems are host to groups of great biological and biogeographic interest (Quezel et al. 1990). They have species assemblages that are very distinct from those living in the continent and appear to be more sensitive to disturbance (Vidal et al. 1998). Ants are one of the major groups of living organisms in many habitats (Hölldobler and Wilson 1990). They are ubiquitous – being found in forests as well as in open areas, near waters bodies as well as in dry places and on island environments (Cagniant 1973).

*Cataglyphis* genus ants appear to be uniquely "intelligent" because they have a great ability to vary their behaviour according to circumstance (Santschi 1929).

According to Cagniant (1973), *Cataglyphis* exhibit strictly diurnal activity. The worker ants look for their food and prey individually (Schmid-Hempel 1984); they never use odours and never cooperate in droves (Dietrich and Wehner 2003).

They are thermophilic scavengers collecting the dead bodies of other arthropods that have suffered heat and stress from their hostile environment (Wehner et al. 1983). Some species of the genus *Cataglyphis* bring a variety of live prey (caterpillars and other larvae, adult beetles and small spiders) to their nest (Cagniant 2009).

They are almost exclusively insectivores (Bernard 1968) but exceptions have been observed in some species like *C. fortis* which has been observed carrying a small stranded fish and skinning a dead seagull at Sebkhet el Mnikhra near Guerdane (Tunisia) (Cagniant 2009) and *C. floricola* from southern Spain which feeds on flower petals (Cerda et al. 1996).

*Cataglyphis bicolor* (Fabricius, 1793) is also considered insectivorous, but it is not uncommon to see workers carrying fruits or animal droppings (Foerster 1850). Its diet consists of a wide range of dead arthropods, rarely *Messor* larvae (Wehner et al. 1983).

In Algeria, the *C. bicolor* diet on islands is not well documented, despite the contributions of Molinari (1989), Barech (1999), Baouane (2002), Ziada and Doumandji (2008), Moulaï et al. (2006a) and Ouarab et al. (2006). All these authors have shown the insectivorous character of the species. On the other hand, none has documented this ant's diet under insular conditions. This study on

*C. bicolor* diet in an island environment seems to be the first to be undertaken in Algeria and North Africa.

The objective of this work was (1) to analyze the diet of *C. bicolor* in an island environment in comparison with these congeners from the nearby continent and (2) to see to what extent the conditions of insularity influence the trophic ecology of this ant.

## MATERIALS AND METHODS

The investigations were conducted in north-eastern Algeria, on the western coast of the Bejaia region where three pairs of stations (island-continent) were selected. Located from east to west were Sahel, Boulimat, and Cap Sigli stations.

The Sahel station was located in the locality of Adrar Oufarnou, 6.15 km from Bejaia (36°47′59.34″N 5° 0′50.28″E). The sampled nest of *C. bicolor* was situated on a slope about ten meters from the sea, in a wasteland near a degraded matorral composed of a tree stratum, which essentially contains Aleppo Pine (*Pinus halepensis*), and a shrub stratum dominated by *Phillyrea media*, *Pistacia lentiscus*, *Ficus carica*, *Cistus monspeliensis*, *Myrthus communis* and *Tamarix africana*.

Sahel Islet is separated from the shore by a distance of 7 meters; its surface area is 0.2 ha with a maximum height of 15 meters (36°47′37.83″N 5° 1′23.31″E).

The floristic inventory for the islet shows the existence of 44 species. The vegetation structure shows a dominance of *Olea europea* and *Pistacia lentiscus* (Benhamiche-Hanifi and Moulaï 2012). The *C. bicolor* nest was located along a cliff at approximately 5 m above sea level.

The station of Boulimat was located about 10 km from the city of Bejaia (36°48′44.90″N 4°58′42.48″E). The nest was located near a wasteland dominated by the following plant species: *Dittrichia viscosa*, *Coleostephus myconis*, *Malvaneglecta*, *Reseda alba*, *Convolvulus althaeoides* and *Rubus ulmifolius*. The wasteland was bordered by *Arundodonax* and *Tamarix africana.*

Garlic Islet (36°48′54.91″N 4°58′41.94″E), locally nicknamed because its vegetation is dominated by large stems of the mainland summer flowering species *Allium commutatum* (Vela et al. 2012). These authors inventoried 23 plant species on this islet.

This islet is located only 100 m from the shore (Boulimat Beach), measures approximately 0.4 ha, only half is covered with vegetation, the islet's northern part is too heavily sprayed. Its topography is relatively flat, although its coasts are raised a few meters above sea level. The nest was located near vegetation.

The Sigli station was located 50 km west of Bejaia and 3 km east of Cap Sigli (36°53′13.49″N 4°47′11.87″E). The nest was found on a small path of a degraded matorral based on *Phyllirea angustifolia*, *Cistus monspelliensis*, *Ampelodesmos mauretanicus* and *Helichrysum stoechas*.

El Euch Island, also known as Doves Island, is about 120 m from the mainland and covers an area of 0.8 ha with a maximum height of 20 m (36°53′33.17″N 4°47′18.48″E). The floristic richness is estimated at 60 species (Benhamiche-Hanifi and Moulaï 2012). The vegetation cover is dominated by *Phyllirea angustifolia* and *Atriplex halimus* (Moulaï et al. 2006b). The nest was found on a flat area 4 m above sea level.

To study *C. bicolor* diet in an insular condition and on the nearby continent, fragments of prey species contained in active nests of *C. bicolor* were recovered in May 2016. Two samples were taken from each station. Skinning, which consisted of digging the nest delicately with a pickaxe starting from the nest opening and then, with a knife, carefully following the galleries so as not to destroy them, was used to gain access to nests. All fragments found were collected into Petri dishes.

In the laboratory, the various fragments were grouped together by systematic affinity before further identification and enumeration. Prey identification was possible up to family or genus, and exceptionally up to species level, by relying on the form, aspect, cuticle ornamentation, colour, gloss and size of important parts such as heads, mandibles, thorax, leg elements, elytra, and wings (Moulaï et al. 2006a).

In order to quantify the results and to avoid counting the same individual twice (because of different body parts), only the cephalic capsules were counted, as this is the body fragment that lasts longer and therefore is the most abundant. In some cases, this criterion was modified because cephalic capsules were rarer than other parts of the body; for example, the right hind limbs in Orthoptera and the right elytra in Coleoptera were counted (Cerda 1988).

Major constraints were reported in this work: accessibility to islands was only possible with a boat that was often unavailable and the weather conditions were not always favourable.

Data were summarised using ecological composition indexes, such as species richness (S) and centesimal frequency (Fc %), and structure indexes: maximum diversity index (Hmax) and equitability index (E). Several mathematical indexes could quantify species diversity. In our case, we chose the Shannon and Weaver index (H).

The Mann-Whitney test was applied to variations in diet between the mainland and the respective islands.

The relationship between prey species richness and physiographic data (floral richness, insect richness, island surface area and distance from mainland) of the different islands was tested by calculating correlation coefficients ($r^2$).

## RESULTS

Among the proportions of different prey items found in *C. bicolor* nests, insects predominated, with frequencies exceeding 95% at all stations (Table 1). Within the insects, two orders were heavily consumed: Hymenoptera, represented mainly by Formicidae with frequencies exceeding 55% in the six stations studied, and Coleoptera (especially the families Tenebrionidae, Curculionidae and Chrysomelidae) (Appendix 1).

Within the Formicidae, the ants of genus *Camponotus* and *Messor barbarus* were well in the lead in the *C. bicolor* diet. *M. barbarus* frequencies were 28.15% in the Sahel and 37.55% in Boulimat. On Sahel Islet, it is the ants of *Camponotus* genus that were preferred by *C. bicolor* with a frequency of 61.17%, while in Sigli, *Camponotus laurenti* was the most consumed (Fc = 14.09%). On Garlic Islet and El Euch Island, smaller ants were the most captured by *C. bicolor*: respectively, *Pheidole pallidula* (43.17%) and *Tetramorium biskrense* (39.81%).

In the Sahel and Sigli regions and on Garlic Islet and El Euch Island, *Apis mellifera* was the most consumed Apidae with, respectively, 5.09, 11.48, 7.10 and 12.03% frequencies. In Boulimat, *Polistes dominula* was present in the diet of *C. bicolor* with a rate of 10.20%.

Our analysis of the fragments allowed us to identify two unexpected classes in the *C. bicolor* diet: Aves (represented by *Larus michahellis*) and Pisces (unidentified species). The first class was noted on two islands: Sahel Islet and El Euch Island with, respectively, 0.15% and 0.46% frequencies. The second class was only found on El Euch Island with a frequency of 0.46%. The least voluminous items called "trace elements" represented less than 1% of the diet of *C. bicolor*. Some exceptions were nevertheless observed, such as Stylommatophora (Gastropoda) in Boulimat (Fc = 3.26% for the continent and Fc = 2.84% for the islet) and Hemiptera in the Sigli station and on Garlic Islet (2.48% and 3.69%, respectively) (Table 1).

### Comparison of the *C. bicolor* diet between islands and mainland

The results showed that the diversity of prey on the continent was greater than that of island environments. For the Cap Sigli station pair, the prey richness obtained was 94 species for the continent, while it was only 29 species for the island environment. For the Boulimat region, there were 27 prey species for the mainland and 20 prey species for the islet. Finally, for the Sahel region, the ant *C. bicolor* was able to harvest 42 prey

Table 1. Frequencies of *C. bicolor* food items by class and order in the six study stations (mainland and islands).

| Classes and orders | Continental environment | | | Island environment | | |
|---|---|---|---|---|---|---|
| | F% (Sahel) | F% (Boulimat) | F% (Sigli) | F% (S.I) | F% (G.I) | F% (E.I) |
| Aves | – | – | – | 0.15 | – | 0.46 |
| Charadriiformes | – | – | – | 0.15 | – | 0.46 |
| Pisces | – | – | – | – | – | 0.46 |
| Pisces | – | – | – | – | – | 0.46 |
| Gastropoda | – | 3.26 | 0.39 | – | 2.84 | – |
| Stylommatophora | – | 3.26 | 0.39 | – | 2.84 | – |
| Arachnida | – | – | – | 0.15 | – | – |
| Araneae | – | – | – | 0.15 | – | – |
| Malacostraca | 0.73 | 0.81 | 0.65 | – | – | – |
| Isopoda | 0.73 | 0.81 | 0.65 | – | – | – |
| Diplopoda | 0.42 | – | 0.26 | – | – | – |
| Julida | 0.42 | – | 0.13 | – | – | – |
| Polydesmida | – | – | 0.13 | – | – | – |
| Insecta | 99.03 | 95.92 | 98.68 | 99.7 | 97.16 | 99.07 |
| Orthoptera | 0.48 | – | 0.13 | – | 0.28 | – |
| Dermaptera | – | – | 0.39 | – | – | – |
| Hemiptera | 0.48 | – | 2.48 | 0.88 | 3.69 | 0.46 |
| Coleoptera | 20.39 | 33.06 | 23.23 | 7.94 | 9.66 | 32.41 |
| Hymenoptera | 77.67 | 62.86 | 72.45 | 90.88 | 83.52 | 66.20 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

Notes: S.I: Sahel Islet, G.I: Garlic Islet, E.I: El Euch Island.

Table 2. Different ecological indicators applied to *C. bicolor*'s prey species in the six study stations: total wealth (S), number of individuals (N), Shannon-Weaver index (H′), maximum diversity (Hmax) and equity index (E).

| Parameters \ Localities | Sahel | Sahel Islet | Boulimat | Garlic Islet | Sigli | El-Euch Island |
|---|---|---|---|---|---|---|
| N | 412 | 680 | 245 | 352 | 766 | 216 |
| S | 42 | 29 | 27 | 20 | 94 | 28 |
| H′ (bits) | 3.41 | 2.11 | 3.16 | 2.88 | 4.59 | 3.29 |
| $H_{max}$ (bits) | 5.39 | 4.81 | 4.75 | 4.32 | 6.55 | 4.81 |
| E | 0.63 | 0.44 | 0.66 | 0.67 | 0.7 | 0.68 |
| Sorensen | 20% | | 21.27% | | 19.67% | |
| Jaccard | 11% | | 10.63% | | 10.91 | |

species on the mainland and 28 species on the island (Table 2).

In terms of abundance, the greatest prey number was found in the nest of the Sigli station (N = 766) against only 216 prey on El Euch Island (Table 2). The difference between the samples is significant (confirmed by the Mann-Whitney test, Z = 7.13, $p < 0.0001$). In the other two station pairs, however, the opposite was true. Abundances were greater on the islands with, respectively, 680 and 352 prey in the nests of Sahel Islet and Garlic Islet, while on the continent, prey numbers were, respectively, 412 and 245 in Sahel and Boulimat nests (Table 2). The difference between the samples from these two station pairs was nonsignificant (confirmed by the Mann-Whitney test, respectively, Z = 1.54, $p$ = 1.22 and Z = 0.93, $p$ = 0.35).

The calculated amplitude of the trophic niche for the three station pairs was quite different: the diversity and equity indices obtained differed between stations (Table 2).

Notably, Sahel Islet presented the lowest diversity (H = 2.11), while at Cap Sigli, the diversity was quite high (H = 4.59). This station seems to be the most balanced with a fairness value equal to 0.7.

The similarity indices (Sorensen and Jaccard) calculated between each station pair were low (Table 2). Therefore, there is no great similarity in terms of prey taxa between the mainland and the islands.

**Comparison of the *C. bicolor* trophic regime between the three islands**

Our analysis of prey fragments found near the nests of *C. bicolor* on the three islands showed clear dominance of insects in the ant's diet with frequencies of 97.16% for Garlic Islet, 99.07% for El Euch Island and 99.7% for Sahel Islet.

Within insects, two orders were strongly consumed: Hymenoptera and Coleoptera (Table 1). Among Hymenoptera, ants were the most consumed by *C. bicolor*. They constituted 87.05% of the trophic regime on Sahel Islet, 75% on Garlic Islet and 53.7% on El Euch Island (Appendix 1). In terms of ant species, *Tetramorium biskrense* (Fc = 39.81%) was the most consumed on El Euch Island. On Garlic Islet, it is *Pheidole pallidula* ant (Fc = 43.18%) that was most predated, whereas on Sahel Islet, *Camponotus* sp. (Fc = 61.17%) dominated the trophic regime of *C. bicolor.* Among the Apidae, *Apis mellifera* was the most consumed on El Euch Island and Garlic Islet with frequencies of 12.03 and 7.10%, respectively, whereas on Sahel Islet, it came only in the second position (Fc = 1.17%) after Sphecidae sp. (Fc = 1.47%) (Appendix 1).

Coleoptera had frequencies of least importance in the trophic regime of *C. bicolor*. On Sahel Islet, they represented only 7.94% of the predatory ant's diet against 32.41% on El Euch Island. On Garlic Islet, the beetles represented 9.66% of the diet. On these, last two islands, *Heliotaurus ruficollis* was the most consumed beetle with, respectively, 6.94 and 5.39%. The classes of Aves and Pisces represented less than 1% of the *C. bicolor* diet (Appendix 1).

The similarity coefficients, calculated between the three islands (two to two), had low similarity rates.

The Sorensen index showed that prey species on Sahel Islet and El Euch Island as well as those of Garlic Islet and El Euch Island were not similar (25%). The lowest similarity was recorded between Sahel Islet and the islet of Garlic (12.5%).

Although dissimilar, these three islands shared some common species, such as *Pheidole pallidula*, *Vespula germanica* and *Apis mellifera.*

The relationship between the richness of prey species and the topographic variables considered, such as floristic richness, insect richness (probable food availability), island area and distance from the mainland, were the subject of a correlation study.

These statistical tests revealed significant correlations only between the richness of prey species and floristic richness ($R^2 = 0.8807$ and $p < 0.05$; $y = 3.0616x - 39.582$) and insect richness ($R^2 = 0.4702$ and $p < 0.05$; $y = 1.6986x + 1.0685$). However, there was no correlation between the species richness of prey and the island's surface ($R^2 = 0.0078$ and $p < 0.05$ $y = 0.0055x + 0.326$) and the distance to the mainland ($R^2 = 0.1959$ and $p < 0.05$ $y = –5.411x + 214.55$).

## DISCUSSION

The main result from this study was that *C. bicolor* feeds on various food items ranging from insects, birds or fish. This characteristic is not mentioned in a large number of works on this subject, which only highlight the "insectivore" character of this ant (Bernard 1968; Harkness and Wehner 1977; Knaden and Wehner 2005; Moulaï et al. 2006a; Cagniant 2009; Ouarab et al. 2006). These latter authors reported two individuals from the Reptilia class in fragments found near a nest in Tigzirt, Algeria, while Wehner et al. (1983) reported that Isopods account for 52.8% of the *C. bicolor* diet in Maharès, in southern Tunisia.

Some species of the *Cataglyphis* genus are generalist, like *C. halophila*, which was found nesting in a salty crust (Chott Djerrid in Tunisia) and eating rodents' excrement, as the only food available on the site (Bernard 1968). *Cataglyphis fortis* has been seen carrying small stranded fish and tearing a dead seagull (Cagniant 2009) and *C. floricola* from southern Spain feeds on floral petals (between 50 and 82% of its diet) (Cerda et al. 1996).

This study confirms the predominance of insects and more particularly Hymenoptera and Coleoptera in the diet of *C. bicolor*. These results are consistent with those of Ouarab et al. (2006) where Hymenoptera represent more than 85% of the prey caught by *C. bicolor* in the Reghaia marsh. In the same study, the authors identified a high frequency (56.25%) of beetles in a nest located in Béni Belaid. In Bejaia, Moulai et al. (2006a) found a Hymenoptera rate of 89.19% in a wasteland and 76.48% in a scrubland.

Among Hymenoptera, *C. bicolor* has a clear preference for Formicidae, especially ants of the genus *Camponotus*, *Tapinoma nigerrimum*, *Pheidole pallidula* or *Messor barbarous.* Many authors who studied the diet of *C. bicolor* mention this species (Bernard 1968; Moulaï et al. 2006a; Cagniant 2009; Ouarab et al. 2006). Harkness and Wehner (1977) observed a case where *C. bicolor* searched mainly for *Messor wasmanii*'s corpses.

In northern Thessalia in Greece, formicids represent 68.6% of the diet of *C. bicolor* against 10% near the village of Maharès in southern Tunisia (Wehner *et al.* 1983).

The choice of these ants is certainly due to the fact that these prey are the most available at the six stations studied. Furthermore, the fact that ants are social insects which live in colonies with a great number of individuals increases the likelihood of finding dead ants in the surroundings of the nests (Cerda 1988).

Nadji et al. (2016) found that formicids are strongly involved in the diet of *C. viatica*, in particular *Messor barbarus* which reaches 84.8% in Zeralda, Algeria. Cerda (1988) found the same choice of ants in the diet of its Iberian Peninsula counterpart, *Cataglyphis iberica.* This author found that the proximity of *C. iberica* nests with nests of other species is reflected in the diet. This hypothesis is confirmed for *C. bicolor* but only for the mainland. During our study, we found that the Sahel nest was near to *Crematogaster laestrygon* and that Boulimat's nest was near that of *Messor barbarus.* The same situation was observed in Sigli where the nest of *C. bicolor* was located not far from those of *Camponotus laurenti* and *Messor striaticeps*.

The presence of *Apis mellifera* in the diet of *C. bicolor* is probably due to the richness of these stations (Sahel, Sigli, Garlic Islet and El Euch Island) with nectar-bearing plants, which attract floricultural species like *A. mellifera*.

This order of beetles is much more conspicuous by the diversity of families and species than by the number of individuals per species (Du Chatenet 1986). In all six stations the number of beetle species was much higher than that of Hymenopterans. For instance, at Sigli station, we counted 50 species of beetles against 23 Hymenoptera species.

The presence of bone and egg shell fragments belonging to the Yellow-legged Gull (*Larus michahellis*) in the nests of Sahel Islet and El Euch Island is explained by the presence in large numbers of this bird in these two islands (54 and 164 breeding pairs, respectively) (Moulaï et al. 2006b). Fish remains found in the nest of *C. bicolor* (El Euch Island) probably came from the gull's food.

On the islands, *C. bicolor* ants expand their ecological niches, optimizing their local resource use. In Lack's conception (1976), island environments are favourable for species' ability to expand their resources range, that is, their ecological niche.

During our investigations, we were able to observe *C. bicolor* carrying Dicotyledon seeds as well as young *Pinus halepensis* cones (Aleppo Pine) in the Sahel station and a leaf of *Lotus cytisoides* on Garlic Islet.

According to Schmid-Hempel (1984), *Nitraria retusa* berries represent 15% of the *C. bicolor* diet. Plants represent 10% of the prey collected by *C. cursor* (Cerda et al. 1989) and less than 6% of prey harvested by *C. iberica* (Cerda 1988). In addition, most of the plant remnants collected by the *Cataglyphis* species are elaiosome seeds, which, from an ant perspective are similar to insect corpses (Hughes et al. 1994).

At first consideration, in terms of food item richness, the mainland provides more than the island environment, which means that *Cataglyphis* on the mainland can find prey more easily than their island counterparts. The difference observed between the species number consumed on the mainland and on the islands can be explained by the entomofauna in island environments being poorer than on the mainland. Indeed, at an equivalent surface and the same latitude, less than 20% of the mainland wealth is observed (Touroult 2011).

MacArthur and Wilson (1967) explained this in terms of a spatial isolation factor. Lack (1976) argues that this reduction in species wealth would be the result of other barriers to colonization. Accordingly, the main determinants are ecological and would result from a community organization. In this context, resistance of island communities to immigrant colonization may explain the species wealth decline.

The difference in prey species richness observed among the three continental stations (94 species for Sigli, 42 for Sahel, and 27 for Boulimat) can be explained by the activity and the number of worker ants present in the nests of the three stations. The nest sampled at Sigli was more active and more populous (we found that it was richer in worker ants) than those of Sahel and Boulimat, and it's population exhibited a much greater food intake. The number worker ants also depended on location and its topography. The nest sampled at Sahel was on a slope. In a study of Morocco's *Cataglyphis*, Cagniant (2009) found that colonies establish more often in flat areas, avoiding steep slopes or rocky scree.

Although mainland nests contained more prey species than their island counterparts in each of the three regions sampled, in terms of overall abundance, the nests of Sahel Islet and Garlic Islets' contained the greatest prey numbers (680 and 352 prey in Garlic Islet respectively) when compared with their mainland in each instance (412 in the Sahel and 245 in the Boulimat nests). Cap Sigli had the highest abundance of all stations and its island counterpart had the least abundance, illustrating that total prey population numbers were not necessarily related to island biogeography.

In the approach of the island biogeography model, the greater the surface area of a territory, the more varied habitat conditions it offers: the number of species found within a particular territory increases with its surface area (Blondel 1995). However, this model of island biogeography cannot be generalized. The island community's dynamics varies according to different parameters: differences exist in their topographical characteristics, in their biotopic diversity, in characteristics intrinsic to the colonizers, in their resources, predator numbers and history (Lomolino 2000; Gros-Desormeaux et al. 2015). This explains the lack of similarity between the species of the three islands studied. Sahel Islet has an area (0.2 ha) smaller than that of El Euch Island (0.8 ha), though they both have very close numbers of prey species (29 and 28, respectively). Their floristic richness is also very close, with, respectively, 44 and 52 plant species (Benhamiche-Hanifi and Moulaï 2012). Despite an area of 0.4 ha and its 21 plant species (Vela et al. 2012), only 20 prey species were observed at Garlic Islet. In our case, the diversity of vegetation cover seems to be a determining factor in the insect populations' structure. According to a study carried out on Greek islets between 0.2 and 35 ha (Panitsa et al. 2008), the island height better explains its biotic wealth because habitat diversity is linked to altitude. Médail and Vidal (1998) and Triantis et al. (2003) have advanced this hypothesis. Indeed, El Euch Island culminates at 20 m and Sahel Islet at 15 m compared with 2 to 3 m for Garlic Islet.

We detected a positive correlation between probable food availability and prey species richness. The abundance of the latter is proportional to those islands' insect richness. In fact, El Euch Island and Sahel Islet are the richest (respectively, 58 and 42 species), while Garlic Islet is less rich with only 34 species (Aissat 2017). This is reflected in the richness of prey of *C. bicolor* on the three islands. There were no correlations between distance to the mainland and prey species richness; according to Panitsa et al. (2008), when the distance to the coast is small, it does not have much influence on biotic wealth. The worker ant numbers in the nests on El Euch Island and Sahel Islet was greater than that in nests on the Garlic Islets. This is probably due to the soil composition on these islands. In fact, Sahel Islet is dominated by carbonate tuff, and El Euch Island by fine siliceous cement sandstone (Quartzite) (Duplan 1952), whereas Garlic Islet is an outcrop of Quaternary sandstone (fossil beach) heavily eroded by sea spray, so that its surface is very sharp (Vela et al. 2012). This islet is not suitable for *Cataglyphis*, as it precludes them digging their nests deep enough into the ground (Bernard 1968). The lack of elevation on this islet also causes it to submergee in stormy seas, frequently flooding the *C. bicolor* nests.

## CONCLUSION

According to the different results obtained during this study, we can draw the following conclusions: (i) The *C. bicolor* populations of Algerian island environments have generalist and opportunistic predation characteristics since they are able to feed on several food categories. The frequencies of the latter vary according to their availability in the environment, (ii) however, the diet of these ants is composed mainly of Hymenoptera, in particular other ants, and (iii) prey species diversity increases with floristic richness and associated insect richness of its island environments (available prey). In island environments, *C. bicolor* seems to have a significant capacity to adapt to the islands' habitats, despite some constraints, such as a reduction in available trophic resources. The trophic ecology study of *C. bicolor* needs to be extended on a larger scale to encompass more island environments, to enable a better assessment of the adaptability of this ant to the ecological conditions prevalent among the small islands of the Mediterranean.

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**Appendix 1**. List of food items found in the *C. bicolor*'s nests. Island and mainland stations (S: Sahel, S.I: Sahel Islet, B: Boulimat, G.I: Garlic Islet, C.S: Cap Sigli, E.I: El Euch Island).

| Taxa | Species | S | S.I | B | G.I | C.S | E.I |
|---|---|---|---|---|---|---|---|
| Laridae | *Larus mechahelis* | – | 1 | – | – | – | 1 |
| Pisces | indet. sp. | – | – | – | – | – | 1 |
| Salticidae | indet. sp. | – | 1 | – | - | – | – |
| Helicidae | *Theba pisana* | – | – | 8 | 10 | 3 | – |
| Myriapoda | *Polydesmus* sp. | – | – | – | – | 1 | – |
| Julidae | indet. sp. | 1 | – | – | – | 1 | – |
| Armadillidiidae | *Armadillidium vulgare* | 3 | – | – | – | 5 | – |
| | *Armadillidium* sp. | – | – | 2 | – | – | – |
| Acrididae | *Calliptamus barbarus* | 1 | – | – | 1 | – | – |
| Gryllidae | *Gryllus* sp. | 1 | – | – | – | 1 | – |
| Lubiduridae | *Anisolabis mauritanicus* | – | – | – | – | 2 | – |
| Forficulidae | *Forficula auricularia* | – | – | – | – | 1 | – |
| Coreidae | indet. sp. 1 | – | 3 | – | – | 1 | – |
| | indet. sp. 2 | – | – | – | – | 1 | – |
| | *Coreus* sp. | – | – | – | – | 2 | – |
| Cydnidae | *Sehirus* sp. 1 | – | – | – | – | 1 | – |
| | *Sehirus* sp. 2 | – | 2 | – | – | | – |
| | indet. sp. | – | – | – | – | 1 | – |
| Acanthosomatidae | *Elasmucha* sp. | – | – | – | – | 2 | – |
| Miridae | indet. sp. | – | – | – | – | 1 | – |
| | *Lygus* sp. 1 | – | – | – | 2 | – | – |
| | *Lygus* sp. 2 | – | – | – | 3 | – | – |
| Pentatomidae | indet. sp. 1 | 1 | – | – | – | – | – |
| | indet. sp. 2 | 1 | – | – | – | 1 | – |
| | indet. sp. 3 | – | 1 | – | – | 1 | – |
| | *Stollia* sp. | – | – | – | – | 1 | – |
| | *Nezara viridula* | – | – | – | 4 | – | – |
| | *Picromerus* sp. | – | – | – | – | 2 | – |
| | *Coenus* sp. | – | – | – | – | 2 | – |
| Lygaeidae | indet. sp. | - | - | - | - | 1 | - |
| Cicadellidae | *Cicadella* sp. | – | – | – | 3 | – | – |
| Reduviidae | indet. sp. 1 | – | – | – | 1 | 1 | – |
| | indet. sp. 2 | – | – | – | – | 1 | 1 |
| Byturidae | *Byturus* sp. | – | – | – | – | 1 | 2 |
| Byrrhidae | *Pedilophorus* sp. | – | – | – | – | 37 | |
| Bostrychidae | *Bostrychus capucinus* | – | – | – | – | 8 | |
| Carabidae | *Bembidinae* sp. | – | 1 | 1 | – | – | – |
| | indet. sp. | – | 3 | – | – | – | – |
| | indet. sp. 1 (Harpalinae) | 4 | | – | – | – | 1 |
| | indet. sp. 2 (Harpalinae) | – | 1 | – | – | – | 2 |
| | *Licinius punctatus* | – | – | 1 | – | – | – |
| | *Licinius* sp. | – | 1 | – | – | – | – |
| | *Scaratinae* sp. | – | – | – | – | 2 | – |
| | *Scarites* sp. | – | 1 | – | – | – | – |
| | indet. sp. 1 (Pterostichinae) | 5 | – | – | – | 1 | 1 |
| | indet. sp. 2 (Pterostichinae) | 1 | – | – | – | 1 | – |
| | indet. sp. 3 (Pterostichinae) | 3 | – | – | – | 4 | – |
| | *Odontocarus* sp. | – | – | – | – | 1 | – |
| | *Molops* sp. | – | – | – | – | 2 | – |
| | *Dinodes* sp. | – | – | – | – | 1 | – |
| | *Nebria* sp. 1 | – | – | – | – | – | 1 |
| | *Nebria* sp. 2 | – | – | – | – | – | 1 |
| | *Carabus* sp. | – | – | – | – | 1 | – |

| Taxa | Species | S | S.I | B | G.I | C.S | E.I |
|---|---|---|---|---|---|---|---|
| Silvanidae | *Silvanus* sp. | – | – | – | – | – | 4 |
| Staphylinidae | *Xantholinus linearis* | 1 | – | – | – | – | – |
| | *Ocypus olens* | – | – | – | – | – | 3 |
| | indet. sp. | – | – | 1 | – | 1 | – |
| Silphidae | *Silpha granulosa* | – | – | 1 | – | – | – |
| | *Silpha* sp. | – | – | – | – | 1 | – |
| | indet. sp. | – | 3 | – | – | 1 | – |
| Scarabaeidae | *Onthophagus* sp. | 1 | – | – | – | 1 | – |
| | *Hoplia bilineata* | – | – | 2 | – | – | – |
| | *Gymnoplereus* sp. | – | – | 1 | – | 2 | – |
| | indet. sp. (Melolonthinae) | – | – | – | – | – | 1 |
| | *Euonthophagus* sp. | – | – | – | – | – | 3 |
| | *Polyphylla* sp. | – | – | 2 | – | – | – |
| | *Sisyphus* sp. 1 | – | – | – | – | 2 | – |
| | *Sisyphus* sp. 2 | – | – | 1 | – | 2 | – |
| Cetoniidae | *Oxythyrea funesta* | 17 | – | 1 | – | 6 | – |
| | *Tropinota hirta* | 1 | – | – | – | – | – |
| Aphodiidae | *Aphodius* sp. | 1 | – | – | – | 1 | – |
| Elateridae | indet. sp. 1 | 2 | – | – | – | 1 | 2 |
| | indet. sp. 2 | 1 | – | – | – | 1 | – |
| | indet. sp. 3 | 1 | – | – | – | 1 | – |
| | indet. sp. 4 | – | 4 | – | – | 1 | – |
| Cleridae | *Korynetes* sp. | – | – | – | – | – | 1 |
| | indet. sp. | – | – | – | – | 3 | – |
| Oedemeridae | indet. sp. | – | – | – | 2 | 1 | – |
| Cantharidae | *Atalantycha* sp. | – | – | – | – | 1 | – |
| Buprestidae | indet. sp. | – | – | – | – | 1 | – |
| | *Acromaedera* sp. | – | – | – | – | 1 | – |
| | *Anthaxia* sp. | – | – | – | – | 1 | – |
| | *Trachys* sp. | – | – | 3 | – | – | – |
| | *Julodis* sp. | – | – | – | – | 1 | – |
| Tenebrionidae | *Pachychila* sp. | 1 | – | 1 | – | 2 | – |
| | *Heliotaurus ruficollis* | – | – | 4 | 19 | – | 15 |
| | *Tenebrio* sp. | - | - | 3 | - | 1 | - |
| | *Stenosis* sp. 1 | – | – | – | – | 1 | 9 |
| | *Stenosis* sp. 2 | – | – | – | – | – | 1 |
| | indet. sp. 1 | – | 5 | 4 | – | 1 | 6 |
| | indet. sp. 2 | – | – | – | – | – | – |
| Hydrophilidae | indet. sp. | – | – | – | – | 1 | – |
| Melyridae | *Psilothrix* sp. | 1 | – | – | 1 | – | 1 |
| | *Dasytes* sp. | – | 7 | – | – | | – |
| Chrysomelidae | *Chrysomela* sp. | – | – | – | – | 1 | – |
| | *Lachnaia tristigma* | – | 3 | – | – | – | – |
| | *Lachnaia* sp. | – | – | – | – | 1 | – |
| | *Psylliodes* sp. | – | – | – | – | 2 | – |
| | *Cassida viridis* | – | – | – | 6 | – | – |
| | *Cassida* sp. | – | – | – | – | – | 15 |
| | indet. sp. | 29 | – | – | – | 1 | – |
| Cicindelidae | *Cicindela* sp. | – | – | – | – | 1 | – |
| Dermestidae | indet. sp. | – | 4 | – | – | – | – |
| Histeridae | *Hister* sp. 1 | – | – | – | – | 3 | – |
| | *Hister* sp. 2 | – | – | – | – | 1 | – |
| | indet. sp. | – | – | – | – | 1 | – |
| Nitidulidae | indet. sp. | – | 6 | – | – | | – |

| Taxa | Species | S | S.I | B | G.I | C.S | E.I |
|---|---|---|---|---|---|---|---|
| Curculionidae | indet. sp. 1 | 3 | – | 1 | – | 1 | – |
| | indet. sp. 2 | 2 | – | 25 | – | – | – |
| | indet. sp.3 | – | 11 | 26 | – | – | – |
| | indet. sp.4 | – | 1 | 2 | – | – | – |
| | indet. sp. 5 | – | 1 | – | – | – | – |
| | indet. sp.6 | | | – | – | 2 | – |
| | *Sitona* sp. | – | 1 | – | – | – | – |
| | *Otiorhynchus* sp. 1 | 1 | – | – | – | 2 | – |
| | *Otiorhynchus* sp. 2 | 1 | – | – | – | – | – |
| | *Brachysomus* sp. | – | – | – | – | 27 | – |
| | *Phyllobius* sp. | – | – | – | – | 1 | – |
| | *Sciaphilus* sp. | – | – | – | | 39 | – |
| | *Bothynoderes* sp. | – | – | – | – | – | – |
| Apionidae | *Apion* sp. 1 | 1 | – | – | 5 | – | – |
| | *Apion* sp. 2 | 7 | – | – | 1 | – | – |
| Cerambycidae | indet. sp. 1 | – | 1 | – | – | – | – |
| | indet. sp. 2 | - | - | - | - | - | 1 |
| Mutillidae | indet. sp. | 1 | – | – | – | – | – |
| Formicidae | *Camponotus laurenti* | 113 | – | – | – | 108 | – |
| | *Camponotus gestroi* | – | – | – | – | 68 | – |
| | *Camponotus micans* | – | – | – | – | 21 | – |
| | *Camponotus ruber* | – | – | – | – | 13 | – |
| | *Camponotus* sp. | 26 | 416 | – | – | – | – |
| | *Cataglyphis bicolor* | 8 | – | 2 | 8 | 3 | 9 |
| | *Plagiolepis schmitzii* | – | – | – | 30 | – | – |
| | *Aphaenogaster testaceo-pilosa* | – | – | – | 19 | 77 | – |
| | *Messor barbarus* | 116 | 7 | 92 | – | 37 | 6 |
| | *Messor minor* | 17 | 40 | – | – | – | – |
| | *Messor striaticeps* | – | – | – | – | 65 | – |
| | *Crematogaster auberti* | – | – | – | – | 12 | – |
| | *Pheidole pallidula* | 6 | 129 | 4 | 152 | 31 | 15 |
| | *Tetramorium biskrense* | – | – | – | – | 10 | 86 |
| | *Tapinoma nigerrimum* | – | – | – | – | 6 | – |
| | *Tapinoma simrothi* | – | – | 30 | 55 | – | – |
| Vespidae | *Polistes dominula* | 1 | – | 25 | – | – | – |
| | *Vespula germanica* | 1 | 8 | – | 5 | 1 | 1 |
| | *Vespula* sp. | – | – | – | – | – | – |
| Sphecidae | indet. sp. | 1 | 10 | – | – | – | – |
| Apidae | indet. sp. 1 | 6 | – | – | – | 1 | – |
| | indet. sp. 2 | 1 | – | – | – | 1 | – |
| | indet. sp. 3 | 1 | – | 1 | – | 1 | – |
| | indet. sp. 4 | – | – | – | – | 1 | – |
| | indet. sp. 5 | – | – | – | – | 1 | – |
| | *Apis mellifera* | 21 | 8 | – | 25 | 88 | 26 |
| | *Ceratina* sp. | – | – | – | – | 4 | – |
| Crabronidae | indet. sp. 1 (Bembicinae) | – | – | – | – | 5 | – |
| | indet. sp. 2 (Bembicinae) | – | – | – | – | 1 | – |
| Total of specimens | | 412 | 680 | 245 | 352 | 766 | 216 |
| Total of species | | 42 | 28 | 27 | 20 | 94 | 28 |