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Previous volumes (2010-2016): 250 € / year (4 issues)
Acarologia, CBGP, CS 30016, 34988 MONTFERRIER-sur-LEZ Cedex, France

The digitalization of Acarologia papers prior to 2000 was supported by Agropolis Fondation under the reference ID 1500-024 through the « Investissements d’avenir » programme (Labex Agro: ANR-10-LABX-0001-01)

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ACARINE BIODIVERSITY. I. A NEW DATABASE.
PRELIMINARY EXAMPLES OF ITS USE IN STATISTICAL BIOSYSTEMATICS

by F. ATHIAS-BINCHE*

SUMMARY: The present paper proposes a new database which constitutes a starting point for study of the various aspects of acarine biodiversity. The characters selected are briefly presented and their use in combination with ecological items is presented. One of the numerous possible applications of this tool, a mathematical analysis of statistical biosystematics, will provide a base for further papers devoted to acarine biodiversity.

These preliminary results indicate that simple systematic data may lead to, among other things, considerations of the ecological biodiversity of mites, the habits of specialists, and the systematic heterogeneity of some taxonomic groups. The “upgrading” of the systematic criteria used for the classification of Oribatida is clearly demonstrated and quantified by a remarkably low specific richness of the different superfamilies.

INTRODUCTION

Since the Rio Conference in 1992, the biodiversity of living organisms has given rise to considerable interest in the scientific community. Since biodiversity covers many different levels, from intra-specific genetic diversity to functional diversity along the food chains in an ecosystem, or the whole specific diversity within the biosphere, it appears that this topic needs tools for quantification and characterization of its various aspects (MAY, 1994).

Among Metazoa, the size relations (mean body length plotted against the number of species belonging to any taxonomic group) clearly demonstrate that small species are generally more abundant than

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larger ones. Therefore, mites being certainly the smallest known arthropods, one could predict that they should be more numerous than insects, usually considered as the most abundant group of Metazoa (May, 1992). Such a hypothesis needs first of all an appropriate means for the quantification of the size of mites.

A mathematical quantification of the size also allows us to tackle the concept of phylogenetic constraints. The body length of a given systematic group never exceeds certain limits. As an example, among Acari, an adult tarsonomid is never larger than a thrombidiid. Thus, the computerization of the body-size categories can offer opportunities in biosystematics at any systematic level.

Life history traits, ecological niches and diet constitute as many features of biodiversity. In mites, a quantification of such characters may allow us to represent in concrete form the often stated, but not yet computerized, extraordinary ecological diversity of mites.

The present paper constitutes an introduction to a series of papers devoted to the various aspects of acarine biodiversity (excluding ticks). It presents a new database which represents the starting point for such studies (Athias-Binche, 1995). The listed characters are briefly presented and the use of combinations of the cross-referenced items in ecological diversity is presented. One of the numerous possible applications of these data will open the series with a rapid preliminary analysis of the statistical biosystematics of mites.

**METHODS**

*Selection and sources of data*

One of the first aims of the present database was to compute sizes of mites, so only papers mentioning this measure were taken into account. This review revealed the existence of a considerable number of papers which either did not indicate the size of a described species or did not represent a scale in the drawings. Sometimes also, the actual length of the scale bar was not specified. In addition, some taxonomic groups are considerably underestimated. This is particularly the case for the Acaridida, because many of these have only been described at the hypopop stage (deutonymph). The same applies to chigger mites (Trombiculidae), which are usually only known for the parasitic larval stage. However, as the database is open, specialists could include the relevant species in their lists.

The second main criterion of selection concerns the systematic status of the species. As nobody can claim an exhaustive knowledge of all Acari, I abandoned some sources which did not mention at least the name of the family accommodating the species studied.

The complete series of the two main acarological journals, *Acarologia* and the *International Journal of Acarology*, constituted the basis of the sources of data. These scientific journals ensure a good randomization of the samples, since they do not specialize in a particular taxonomic group. *Experimental and Applied Acarology* was also consulted, but it contains few description of species. I added elements of my personal library, reprints, books and unpublished theses. Dr. J. Trave, Banyuls, also kindly lent me some reviews concerning the Oribatida. It is obviously not possible to give here the complete list of references used for this bibliographic research.

In order to simplify the contents of the columns for statistical use, I have not mentioned the authors of the selected species. This lack should not be a real problem for specialists. If necessary, the author's names may be easily found in the *Zoological Record*.

*The difficult choice of a classification*

Krantz (1970) wrote in his first Manual of Acarology: "The fragmentary state of knowledge presently existing in the field of acarological systematics makes any attempt at a familial classification of the subclass Acari a difficult task (...) Acarology is, in fact, in a state of systematic turmoil similar to that experienced in the field of entomology nearly a century ago." Twenty five years after these considerations, the problem remains nearly the same!

Following Evans (1992), the division of the Acari in two major groups, Anactinotrichida and Actinotrichida is at present admitted by the majority of acarologists.

The higher classification, especially supercohorts,
remains questionable however, and covers different taxonomic levels. Just compare, for instance, Krantz (1970, 1978) Niedbala (1980) Evans (1992) Karg, 1993, etc. But, statistically speaking, the different levels of populations and samples, must be gathered into the same type of categories, so the vague limits of these higher taxonomic levels have to be eliminated (these levels are nevertheless recorded in the original version of the database). This is why I regrouped Acari in six groups of equivalent level (order or suborder) as indicated in figure 1. Oribatida were sometimes divided in two groups, Inferores and Superior, in order to mathematically demonstrate their peculiar taxonomic characteristics, i.e. the “upgrading” of their taxonomic levels (see below).

I then selected the superfamilies as the immediate lower taxonomic level. The subfamilies and the subgenera were not taken in account in the present analysis, but they are listed in the original version.

Except in Oribatida, superfamilies usually constitute rather good, well-defined taxa. I used the manuals of Krantz (1978) and Evans (1992) and some recent reviews (for instance Kaliszewski et al., 1995 for Tarsonemida), without serious difficulties. On the other hand, the classification of Oribatida varies greatly, depending on the authors, their nomenclature and their morphological criteria. Some systems do not even recognize the suprafamilial level. Because a statistical analysis needs a precise hierarchy of samples and sub-samples, I finally chose arbitrarily to follow the classification proposed by Krantz (1978) for this group, whatever may be its drawbacks and qualities may be.

Inevitable biases.

In such a systematic list, one encounters three main types of bias: species of economic importance, habits of specialists, and synonymies.

For instance, the phytopenalistic Tetranychoidea, obviously benefit from their impact in agrosystems. With 245 recorded species, they are three times better represented than Tydeoidea—only 84 species—although these small free-living mites are very abundant in soil. Similar biases are encountered in all other groups which present an economical impact, being pests or predators used for biological control.

The case of Tarsonemida shows a more complex situation. Members of the family Tarsonemidae are important as phytoparasites or parasitoids of xylophagous insects. But, with 197 listed species, they appear to be poorly represented compared to Scutacaroida (525 items), a superfamil which yet offers little applied interest. This is partly due to my own interest in Scutacaridae (bias caused by the specialist’s topic), but perhaps also to the abundance of descriptions of new species. Scutacaroida in fact show very easily discernible specific criteria, so that the description are short and rapid, favouring a certain “stakanovism” (bias due to the specialist’s habits).

Another serious problem concerns synonymies, which are mainly caused by the occurrence of phentotypic polymorphisms, especially in phoretic forms (Lindquist & Walter, 1989, Athias-Binche, 1994). For instance, in Scutacaroida and Pygmephoroidea, phoretic females possess a thickened leg I bearing a strong claw, while this claw is reduced or absent in the sedentary phenotype (Kaliszewski et al., 1995). But, the presence of a claw was, until recently, a subgeneric character. This induced a plethora of synonymies, many species being described under two different names according to their phenotypes. As pointed out by the review of Lindquist & Walter (1988), such bimorphism exists in other groups of mites. Furthermore, since polymorphisms are only detected in laboratory cultures, a critical review of synonymies will take a long time. Synonymies also exists in Acaridida: many species have been documented as a hypopus under a different genus name than that of the other life-stages.

Technical features of the database

The original data were registered using the word processor Microsoft WORD 5.5 for PC (text version). This software is useful for its rapid copy and search functions, even in case of very long files. The command sort (alphanumeric or numeric order) is also very useful. The data are listed in a tabular format, allowing transfer to mathematical software. The data were registered under the WORD form “filename-.DOC”, but they may be readily translated into ASCII characters for any further transfers. As an example, for the statistical part of the present paper, I
easily exported the data from WORD to Quattro PRO 5.0 (Borland International Inc.) for PC DOS (math version).

The database is available at the author's address on a 3.5” DS/HD disk at the price of 20 US $ or 100 FF (post free). In addition, it may be sent free of charge in exchange for any computerized PC compatible data concerning mites: bibliography, sizes, ecology, systematics, population dynamics and genetics, pathogeny, etc. The disks are not write-protected, this permits copying, modifications, additions, etc. Due to the length of the file, contrarily to the disk version, the paper support, which is much too long (about 200 A4 pages) and heavy for reasonable postal charges and paper cost, is not available except for a comparable exchange (book, thesis, etc.). Besides, as the database is regularly updated, a paper version rapidly becomes outdated.

Features entered on computer

The database consists of 7 columns of taxa and selected features (Table 1): body length of adults, length of eggs, clutch size, sexuality and ecological features. Entries for sexuality, arrhenotoky or thelytoky follow the review of Norton et al. (1993) and papers which clearly mentioned the type of reproduction. In other cases, species are assumed to be bisexual. The ecological features concern habitats and parasitic or phoretic ways of life (Table 2). Soil, which constitutes the original, ancient habitat of mites is of interest in indicating conservative groups. The characteristics may be combined. For instance “dung, ph” (Table 1) describes a species as phoretic on dung-inhabiting adult insects, mostly synanthropic flies, which usually feed on the host’s progeny. The complex “wood, ph” suggests a comparable relationship with xylophagous beetles. When a group is ecologically homogeneous, a line may specify its main features, as indicated for Demodicidae in table 2.

Obviously, not all of these six columns may be completely filled in. For instance, the number of eggs is not known in Opilioacaroidea (Table 1). The absence of male body-length is frequent. Usually, this does not mean that males do not exist, but that they are scarcer than females, especially in arrhenotokous forms, which commonly exhibit a skewed sex-ratio. Sometimes, males are also neglected by some authors, notably in the case of hardly-discernible secondary sexual characters. This situation is particularly frequent among Oribatida.

APPLICATIONS FOR STATISTICAL BIOSYSTEMATICS

What does statistical biosystematics mean?

Systematics aims at arranging the different taxonomic levels, with the best possible phylogenetic affinities. Statistics are mainly used for the analysis and comparison of series of numerical data, or samples. Suppose that we consider each taxonomic category as so many statistical samples, containing sub-samples, i.e. the immediately lower systematic level. Thus, it becomes possible to treat pure systematic data mathematically. Each item is represented by the number 1, for instance, the Opilioacaroidea comprise 1 family, 5 genera and 14 species (Tabl. 2). One can then calculate the classic parameters: mean, variance, standard deviation and the usual tests of significance of comparisons among groups of data.
TABLE 2: Database, some examples. F, M: adult body length of females and males (μm); E: widest diameter of the egg (μm); C: clutch, number of eggs per female during her life; S: sexuality, arrhenotoky or thelytoky; EC: ecological features explained in Table 1.

**Statistical significance of the data**

The present database does not pretend to take a census of all the known species of Acari. Such a project might be possible in the future, with the emergence of new international electronic networks.

The updated file (November 1995) comprises 7832 different species, of which 3020 are anactinotrichids and 4812 actinotrichids. I listed 23 superfamilies in Anactinotrichida, grouping 76 families and 454 genera. Actinotrichida assemble 77 superfamilies, 239 families and 1310 genera. These simple numbers demonstrate a well known fact in acarology, i.e. the higher taxonomic diversity of the Actinotrichida. Now, the computerization will allow us to quantify this. The high numbers of data (n > 30, except for anactinotrichid superfamilies) within each taxonomic sample, superfamilies, families, genera and species, ensure a good statistical significance: the samples (data) give a reasonable estimate of the population (see for instance SCHERRER, 1984), here the total known species of mites.

**RESULTS**

**Superfamilies, families, genera**

The distribution of the 100 superfamilies of Acarina (Fig. 1) indicates the dominance of Oribatida, which total 45 items. It is to be noticed that the sub-groups Oribatida Inferiores and Superiores accommodate an equivalent number of superfamilies (22 and 23 respectively). If one considers that the number of superfamilies reflects the diversity of a group, Oribatida could be supposed to be the most varied taxon. On the other hand, with only 7 items, Tarsonemida might be a more homogeneous group. This was systematically proven as documented by KALISZEWSKI et al. (1995): these minute mites actually constitute a relatively highly derived group of Actinotrichida. This seems to be confirmed by their low number of families (Fig. 1). Anactinotrichida, and more certainly Actinedida, are perhaps heterogeneous, in view of their number of families. Oribatida exhibit the highest number of families (101), but the familial richness is lower in the Oribatida Inferiores.

Considering now the number of genera (Fig. 2), the tendency of lesser diversity continues in Oribatida Inferiores, the number of which is half that of the Superiores group. At the generic level, one can observe an inversion of the prevalence of Oribatida: with a total of 342 genera, they now occupy only the third rank after Actinedida and Anactinotrichida and only slightly exceed Acarida. This allows us to foresee a question regarding the level of the systematic criteria adopted by the experts of the group. As for the higher levels, Tarsonemida appear homogeneous,
while Anactinotrichida and Actinedida remain more diversified.

The distribution of the families within the superfamilies of Anactinotrichida (Fig. 3) immediately reveals the favourite group of the author, i.e. Uropodoidea. However, as will be seen below, this may reflect a true morphological, and thus systematic, diversity. Among the other Anactinotrichida, Dermanyssoida, which groups many parasites, appears to be the most diversified superfamily. In a general manner, the groups comprising mostly free-living forms are less rich, as for the set Zerconoida to Veigaoida. In Actinedida (Fig. 4), the high number of families belonging to Pachynathoidea and Hydra-
carina, usually recognized as homogeneous groups, may suggest an over-estimation of the systematic criteria. On the other hand, the high number of cheyletid families reveals the heterogeneity of the group, which includes parasites of questionable affinities. Tarsonemida are characterized by a low number of families, never exceeding three items (Fig. 5). Among Acaridida (Fig. 6), it is to be noticed that the parasitic families are more numerous, especially feather mites and Psoroptoidea. It seems that the morphological modifications for parasitism and host/parasite specificity constitute the reason of such diversification. However, in the case of Analgoidea, the high scientific productivity of experts might be the cause. Note that Acaroidea, largely described at the hypopial stage, appear to be clearly underestimated. Oribatida Inferiores are obviously remarkable for the high number of monofamilial superfamilies (Fig. 7). The Superiores group seems to be more diversified, but one can still count 10 monofamilial superfamilies (Fig. 8).
In Anactinotrichida, it appears that the “primitive” superfamilies (from Opiloacaroidea to Thinozerconoidae) contain fewer genera than the other Anactinotrichida (Fig. 9). This is evident for specialists, who know that the ecological niches or biogeographic distribution of these groups are rather narrow (ATHIAS-BINCHE, 1982; EVANS, 1992). Uropodoidea appears once more to accommodate the highest number of items. As suggested above, superfamilies containing phoretic or parasitic forms also present a rather high diversity, particularly Laelapoidea.

Among Actinedida (Fig. 10), Cheyletoidea—a heterogeneous group including (more or less artificially?) many parasitic forms—concomitantly exhibit the highest number of genera. Note the striking difference in the so-called “primitive” Endeostigmata (= Pachygnathoidea + Nematальногоidea) between the genera/family and superfamily number, a phenomenon also encountered in Oribatida. On the other
hand, one can observe some changes from figure 4 in
Caeculoidea, Raphignathoidea and Hydracarina,
which now present a significantly lower generic rich­
ness.
Within Tarsonemida, Tarsonemoida clearly
appears to be the most diversified group (Fig. 11). In
fact, this superfamly accommodates the largest eco­
logical spectrum of habitats, ranging from phytopha­
gous forms to parasitoids and insect parasites, while
the other superfamilies are mostly phoretically asso­
ciated with animals, mainly insects, and more specifi­cally with mammals in the genus Pygmeophorus (KALI­
ZSEWSKI et al., 1995).
As shown above among Acaridida, the generic
richness is usually higher in superfamilies containing
parasitic forms (mainly the set from Canestrinioidea
to Psoroptoidea; Fig. 12).
Oribatida Inferiores are clearly characterized by
the notable proportion of mono- and bi-generic
superfamilies (Fig. 13). The richness of the Oribatida

Fig. 13: Oribatida Inferiores, number of genera within superfamilies.
Fig. 14: Oribatida Superiores, number of genera within superfamilies.
Fig. 15: Number of recorded species within the six main groups of Acarina.
Fig. 16: Anactinotrichida, number of recorded species within superfamilies.
Superiores seems well marked in the less “primitive”
groups (from Ceratozetoeida to Galumnoidea, Fig. 14).

Species

Concerning the number of species per group
(Fig. 15), one can see that Anactinotrichida possess
the higher specific diversity. This may result from the
broad ecological spectrum of this group, comprising,
among others, planticolous, commensal, phoretic
and parasitic forms.

Actinedida, as stated above, is a heterogeneous
group. This group verified by its relatively high specific
richness. The fact that Tarsonemida are, without
doubt, the smallest mites may explain their richness.
This also reflects their large ecological range, especially
in Tarsonemoidea. The number of acaridid species seems to be underestimated, in view of their
ecological biodiversity. This observation may be due
in part to many species only being described at the
hypopial stage. As quoted above, the number of ori­
batid species appears remarkably low compared to
the recorded superfamilies.

In Anactinotrichida, Uropodoidea present the
highest specific richness (Fig. 16). This may be due to
recent surveys in tropical areas, where this group
certainly exhibits its highest diversity. As the specialists of this cohort also present a high productivity in
terms of descriptions of new species, this conjunction
may explain such a richness. On the other hand, in
order to illustrate the influence of an applied interest
on the number of described species, I treated the
family Phytoseiidae separately—accommodated
within Ascodioidea by KARG (1993), but elevated to
the superfamily level by KRANTZ (1978) and EVANS
(1992). Without doubt, these planticolous mites,
which are predators of phytoparasites, mainly Tetra­
ychoidea, obviously benefit from their interest as
predators in biological control. This constitutes an
evident bias, as stated above.

Among Actinedida, as we have seen, the specific
richness of the Endeostigmata is actually rather low
(Fig. 17). Non edaphic forms—the marine Halaca­
roidea and the fresh-water Hydracarina—seem to
be either very diversified, or arouse the interest of
specialists. On the other hand, the high number of
Cheyletoidea once more reflects the heterogeneity
of this taxon. Not surprisingly, the phytophagous
Eriophyidae and Tetranychidae—mites of economic
importance—contain a high number of described species.

In Tarsonemida, the prevalence of the Scutacaroi­
dea is remarkable, despite the limited applied interest
of this group (Fig 18). This is partly due to my own
interest in Scutacaridae, but perhaps also to the grea­
ter abundance of descriptions of new species in the
literature. Scutacaridae in fact present very easily
discernible specific characters, mainly the size and
shape of idiosomal setae, so that their description is
short and rapid. An other serious problem is due to
possible synonymies. The two other dominant groups
of Tarsonemida effectively exhibit a broad ecological
spectrum, which seems to be reflected by their specific
richness. However, in Pygmephoroidea, adult female
bimorphism leads us to expect synonymies.

Despite the under-estimation of Acaridida which
have conserved the hypopial stage, the parasitic forms
appear to be prevalent (Fig. 19). The dominance of
parasitic taxa may also be due to the abundance of
the literature, especially concerning the feather mites,
or to truly higher ecological biodiversity, such as in
Psoroptoidea. Applied aspects may also play a role,
as in the insect-parasitizing canestrinids for instance.

As presumed above, Oribatida Inferiores are
clearly characterized by a very low specific richness,
with the notable exception of the Phthiracaroida
(Fig. 20). The specific richness is higher in Oribatida
Superiores, but it only exceeds 100 items in Oribatu­
loidea (Fig. 21).

A PRELIMINARY EXAMPLE
OF STATISTICAL BIOSYSTEMATICS

The procedure presented above shows some
tendencies concerning the relative number of taxa
and their significance. These numbers may depend on
the systematic habits of specialists or on a real taxo­
nomic and/or ecological biodiversity. This purely des­
criptive step may be followed by a more analytical
study.

One might start with the ratios of the number of
genera per family and number of species per superfa-
family. This allows us to quantify the statistical distribution and the taxonomic diversity of each taxon.

Considering the ratio of the number of genera per family (number of genera in each family/total number of families in the group), one can immediately notice that Oribatida exhibit clearly the lowest ratio (Table 3). At the other extreme, Acaridida possess the highest generic richness. These differences may be tested by usual statistics of comparison (ANOVA, χ², non-parametric methods, etc.). Table 3 indicates that mean statistical parameters of the genera/family rates testify to a perceptible difference between the major groups of mites. The variation coefficient (VC = 100 SD/m) expresses the homogeneity of the distribution of the genera within families. Here, these coefficients, which slightly exceed 100%, indicate a normal, Gaussian distribution of the genera, rendering a normal taxonomic distribution.

Concerning the species/superfamily rates (number of species in each superfamily/total number of super-
families in the group), Oribatida present yet again the lowest mean (Table 4). Except for Actinedida and Acaridida, the distribution of the species within superfamilies is heterogeneous, as indicated by the variation coefficient. This means that, within each group, some superfamilies are very rich while, on the contrary, others are very poor in species. The significance of these observations may differ according to the taxonomy and ecology of each higher taxon and will be analysed in further papers.

<table>
<thead>
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<th>GEN/FAM</th>
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<th>SD</th>
<th>VC</th>
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<td>91.6</td>
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Table 3: Ratio genera/family (GEN/FAM) in the six main groups of Acarina and ANOVA. SD standard deviation; vc: variation coefficient (100 SD/m).

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</table>

Table 4: Ratio species/superfamily (SP/SUPERFAM) in the six main groups of Acarina. Same abbreviations as for table 3.

DISCUSSION

The most obvious result of this preliminary statistical analysis of taxonomic data concerns the exceptional status of Oribatida. As already stated by Krantz (1970), the plethora of morphological characters available for comparative studies, leads to a tendency to “upgrade” the classification of the group, so that species often become monotypic genera, and genera are elevated to the family level, etc. This trend is perfectly demonstrated by the statistical treatment: their specific richness is abnormally low. As Oribatida constitute a rather conservative ecological group, one may conclude that this reflects the “upgrading” pointed out by Krantz, combined however with a certain high morphological diversity.

In the other groups, one can note that the statistical parameters reflect a remarkable mathematical homogeneity. The mean number of genera per family, ranging from 6 to 10, and the number of species per superfamily, going from 78 to 150, reveal a common trend in the distribution of the different taxa studied. Thus, the present paper, despite constituting a simple preliminary analysis of statistical biosystematics, lets us accept the premise of a mathematical organization of the different taxonomic levels. This, combined with the analysis of body sizes, would allow the elaboration of predictive mathematical models of the expected population, i.e. the real number of mite taxa of in the biosphere.

This contribution also allows the detection of a correlation between taxonomic richness and morphological or ecological biodiversity. Further research, combining taxa and ecological features, should lead to mathematical models. Among other questions, it will be interesting to establish a link between a parasitic way of life and specific richness. Theoretically, as a parasite is obliged to adapt to a specific host, its niche width should be much narrower than that of a free-living form. As a consequence of the host/parasite specificity, one would expect a higher specific richness.

The present paper represents a simple preliminary example of the possibilities of a database. Of course, such a global analysis may disappoint specialists. It
can obviously be improved but, as the present database is open to the scientific community, future users will certainly find new and fascinating avenues of research and theories. Mathematical treatments of simple taxonomic data open a series of many other interesting perspectives concerning acarine biodiversity. Of course, further quantitative analysis of the combination of systematic, dimensional and ecological data will broaden the spectrum of our knowledge of the general biodiversity of Acari.

REFERENCES


