The Current Status of Mosquito Systematics[1]

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In an article by Marston Bates (1950) entitled, "The Lady Lives on Blood," the author stated, "The most recent complete list of mosquitoes of the world was published in 1932, and at that time 1,400 different kinds were known. I once calculated that an average of 40 supposedly new kinds have been described every year since 1932, which would bring the total well above the 2,000 mark. But many of the new kinds turn out to be mistakes, the new name becoming a synonym of some older name, so that 2,000 is probably a safe estimate for the known kinds of mosquitoes in the world." He further notes a total of 121 species for North America.

Bates' estimate, made 30 years ago, has not turned out to be very safe; even his calculated 40 new species per year has proved conservative. According to the new Catalog of the Mosquitoes of the World by Knight and Stone (1977), and the 1978 Supplement to this catalog by Knight, which updates our knowledge through December, 1977, there are now well over 3,000 described mosquito species; specifically a total of 3,244 species, subspecies and varieties. This averages out to 46 new taxa a year since 1950. The number of species reported for North America has now passed the 160 mark.

To some, this impressive total may indicate that mosquito taxonomy will soon be reaching a point where a peakout and decline must occur. Eventually, this will be inevitable, but in my opinion, is not apt to occur very soon. Modern systematics means much more than simply describing taxa and recognizing the diversity of life. In its broadest sense it includes all relationships between kinds including ecological, distributional, behavioral and phylogenetic. Our progress in describing new mosquito taxa has been good, but on the other aspects of systematics the overall progress would have to be considered poor.

We know a detailed ecology and behavior for only a relatively few species. The concept of the ecological niche in mosquitoes has hardly been touched, and the interrelationships which exist between the larvae and adults of sympatric species have not received enough attention.

The distribution of mosquito species presents another major deficiency in our knowledge of mosquito systematics. The importance of this is not always

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appreciated. There are those who object to the inclusion of distributional records in published journals, believing that such information takes up space that could be used for more important information. I do not agree with this opinion. Distributional information is vital to our knowledge of mosquito systematics and the epidemiology of mosquito-borne diseases. This knowledge was certainly appreciated by Alfred Russel Wallace (1876), who wrote, "It thus comes to be admitted that a knowledge of the exact area occupied by a species or a group is a real portion of its natural history, of as much importance as its habits, its structures, or its affinities; and that we can never arrive at any trustworthy conclusions as to how the present state of the organic world was brought about, until we have ascertained with some accuracy the general laws of the distribution of living things over the earth's surface."

In his book, The Natural History of Mosquitoes, Marston Bates (1949) had this to say about mosquito distribution. "It is particularly true for mosquitoes that a map showing the distribution of various species is apt to reflect the distribution of the collector's more than the distribution of the animals."

There is no doubt that our knowledge of mosquito distribution has greatly improved in the past 25 years. Particularly outstanding has been the expansion of our knowledge of the New World species through the work of John Belkin and his associates in the Mosquitoes of Middle America project and the excellent work performed by U. S. National Museum personnel on the Southeast Asian Mosquitoes.

Unfortunately, in the area we would least expect major deficiencies in our knowledge of mosquito distribution, North America, there are still major gaps. Large areas still exist in this region where the mosquito fauna is not well known. Since 1955, when Carpenter and La Casse reported 143 species for North America, the rate of new species described, resurrected or new records reported, has increased at the rate of nearly one per year; the total now exceeding 160. Yet the number of U. S. states and Canadian provinces which have publications with up-to-date keys to species and distributional data, number less than one dozen.

An outstanding publication on the Mosquitoes of Canada (Wood, Dang and Ellis, 1979) (reviewed elsewhere in this issue) has just appeared and greatly updates our knowledge of the 74 species reported from that area. A new publication of the AMCA, now in preparation, Identification and Geographic Distribution of the Mosquitoes of North America: North of Mexico, by Richard Darsie and Ronald Ward, should be available in 1980. This profusely illustrated publication will update Carpenter and La Casse and used in conjunction with that book, which has now been reprinted for the second time, should prove extremely useful. Hopefully, it will stimulate mosquito workers in various states to undertake more detailed surveys of their fauna.

Two state publications have recently appeared, the Mosquitoes of California by Bohart and Washino (1978), and the Mosquitoes of New York, Part I, the Genus

Aedes Mergen by Means (1979). Both publications are of high quality with very useful keys, profuse figures and much biological information.

State and regional publications on mosquitoes are valuable and extremely useful to studies in mosquito biology and control in the particular areas involved and each can contribute valuable information to the overall picture of mosquito biology and distribution.

However, the major problems which presently exist in mosquito systematics, concerning dispersal and evolution, can only be solved by comprehensive studies of all mosquito stages on a world-wide basis.

Mosquitoes, like other forms of animal life, have evolved from primitive types which have become dispersed, and by adaptive radiation have speciated as they have exploited available niches throughout the world. Thus, mosquitoes exist today as groups or complexes of closely to distantly related species, all isolated in some way, whether found in the same localities or separated by thousands of miles. What is needed are modern detailed taxonomic studies and revisions of these species groups. To do this one needs to know what characteristics unite the members, what characters can be used to separate the individual species in the complex, and where the members of the group occur on cosmopolitan basis. None of this information is necessarily easy to come by. As an illustration, let me refer to some of the research I am currently involved in with the northern *Ochlerotatus Aedes* mosquitoes. There are close to 200 species in this cosmopolitan subgenus. About 20 of them are holarctic, occurring across the northern hemisphere from North America to northern Europe. These northern *Aedes* include several species groups among which the *excrucians, punctor* and *communis* complexes contain most of the species. For the past two summers I have been in Sweden, studying these northern *Aedes* with Dr. Christine Dahl, of the Department of Entomology, at the University, of Uppsala, Sweden. We were particularly interested in comparing new and old world representatives of the *excrucians* complex. After comparing data and making a relatively superficial examination of new and old world representatives it soon became apparent, that what we have been calling *Aedes excrucians* Walker, is a group of several related species. Some of these may turn out to be synonyms. Some will probably prove to be undescribed. Some appear to be species which have been described in both Europe and North America, each with a different name. As yet, we do not know how many species will eventually be involved. It will take some time to straighten out the *excrucians* complex, but it would be impossible to accomplish without comparing specimens on both continents, as well as the literature from both regions.

The tools now available to the mosquito systematist in solving taxonomic problems include a multiplicity of disciplines, the importance of which will be noted later.

Morphological characters have always been and still continue to be the most extensively used in classical mosquito taxonomy, because they are the easiest to observe and use. Such characters also tell us a great deal about

mosquito biology and evolutionary relationships, particularly if we make some attempt to distinguish between apomorphic (derived) and plesiomorphic (primitive) characters.

Yet even morphological characters have not been adequately exploited for any stage of mosquito development. A number of workers have shown how the chorionic structure of the egg can vary between species. Mattingly, in a series of twenty-nine papers in Mosquito Systematics (See Harbach and Knight, 1978), has demonstrated the remarkable diversity of egg structure in many genera, subgenera and species of mosquitoes. Still the eggs of only a relatively small number of the world's species of mosquitoes have been described.

The complete chaetotaxy of pupae and larvae was meticulously worked out and reported by Belkin in a series of papers published during the fifties (See Knight and Laffoon, 1971). Many workers have since demonstrated the usefulness of this data in mosquito taxonomy, yet the complete larval and pupal chaetotaxy is known for only a small number of the world's mosquitoes.

Too often in the past, mosquito classification has been based solely on adult stages, male or female, and too little upon the immature stages. The value of using all stages in taxonomic revisions was beautifully illustrated by Zavortink (1979) in his revision of the genus *Trichoprosopon*. By studying the adult female, male terminalia and the immature states he determined that this genus was actually composed of 50 species and four phyletic lines (genera) instead of the recognized 29 species belonging to a single genus.

Many morphological structures and techniques for examining those structures are still not being adequately exploited.

The scanning electron microscope is a good example of an extremely valuable tool, which has not been sufficiently utilized in mosquito taxonomy.

In a recent paper, Dahl (1978) reported on the use of the scanning microscope to examine the epicuticular patterns in mosquito larvae. In this paper, Dr. Dahl made scanning studies of portions of the head capsule, siphon and anal saddle, of six *Aedes* species. Her studies showed specific differences between all six species and she suggested this technique could possibly be used to distinguish species groups. Dr. Dahl and I have also made scanning studies of the micro structure of the mosquito wing. Although our studies are preliminary the results indicate that distinctive generic differences do occur.

Another insufficiently used character is the tarsal claw. This character has been used primarily in the separation of *Aedes* species. Indeed, it may be one of the best characters we have to separate *Aedes* females.

It is difficult to use, however, for most species because the differences which involve the length and angle of the main claw and the length and shape of the tooth are often very subtle, and to be accurately assessed the claws must be mounted in a completely flat position and examined under high magnification. Other complications are that the claws may vary slightly from

pro to meso to meta thoracic leg and the two claws on same tarsal segment are rarely identical.

In addition, no one has established the range of variation which occurs within populations of the same species.

The claw is still a promising taxonomic character and Dahl will report in a forthcoming paper on the development of a tarsal claw index which can measure subtle differences between claws. Her data also indicates that this index may also be useful taxonomically in studying the tarsal claws of genera, other than *Aedes*.

Thus far, I have mentioned only ecology, distribution and morphology as tools to provide taxonomic characters. Obviously many other disciplines can and must provide information if we are ever to have a truly meaningful concept of what constitutes a mosquito taxa, or what constitutes satisfactory phylogenies.

Broadly, these include studies related to genetics, physiology, biochemistry, behavior, epidemiology and numerical taxonomy. A recent paper by Faran (1979) stresses the importance of an integrated approach in solving problems in mosquito systematics, and the necessity of interaction and cooperation among investigators in different disciplines to achieve these objectives.

As editor of *Mosquito Systematics*, I intend to sollicit papers from time to time from specialists in the various disciplines noted above. Hopefully, these papers will give us added insights and a better overall understanding of other studies and approaches which contribute essential information to a more complete understanding of our favorite science.

What then is the current status of our favorite science? It is viable and exciting with many productive contributors, but we still have a very long way to go.

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