THE RELATION OF INSECT TAXONOMY TO MOSQUITO CONTROL *

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Before attempting to outline the relation of insect taxonomy to mosquito control, I should like to make a few generalizations about the scope and objectives of insect taxonomy. I do this because I have the impression that taxonomy is sometimes poorly understood and too narrowly interpreted.

Taxonomy was once defined, by a well-known ecologist, as "that branch of natural science in which the blunders and banalities of the irresponsible and incompetent are perpetuated and respected." It is also looked upon by some workers, presumably taxonomists, as the ultimate in scientific investigations. The truth lies somewhere between these two extremes, we hope. According to my understanding, insect taxonomy is not an end in itself, but a means by which other objectives in entomology may be attained. It is not the entomological equivalent of stamp collecting. It is a method of investigation, useful as an aid in interpreting or clarifying observations, guiding experimental work and control operations, and providing working hypotheses.

Whenever an insect-control problem is encountered, one of the first questions asked about the pest is "What is it?" Taxonomy is directly concerned with that question. Under ideal conditions the answer can be given promptly and without qualification. Too often this cannot be done. Frequently the answer has to be couched in weasel words, something like "This is close to so-and-so, but not the same, and it may be a distinct species." Under such circumstances the taxonomist must rely upon subjective reasoning, knowledge of the group in question and,

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most of all, upon ideas of classification that he hopes are sound. If the classification—i.e., the organized framework upon which the various subspecies, species and genera are arranged—is sound, then the identification, even though not complete, has value, because it correctly reflects the relation of the unknown to known elements. Having established this association, certain deductions can be made. Biology, probable relation to disease, general geographic origin, and other matters pertinent to research or control problems can at least be "guesstimated."

Before proceeding further I should like to discuss what may be called the "economics of insect taxonomy." Most entomological taxonomy is based on a study of the comparative morphology of the insect group under consideration. This does not mean that taxonomists are unaware of the importance of such refinements as culturing, serology, paper chromatography, and so on as means of interpreting relationships or defining specific concepts. I can assure you that most taxonomists utilize these approaches whenever opportunities permit. However, I can also assure you that, until taxonomic entomology is much better supported financially, the basic approach to identifications will continue to be by study of comparative morphology. This is simply a matter of economics and expediency. The identification of an insect by means of comparative morphology takes from a few minutes to a day or so, provided adequate literature and reference collections are available, and costs relatively little. By contrast, the identification (bacteriologists and pathologists call it diagnosis) of disease organisms requires considerable time for culturing, and usually costs much more. Call it analysis, diagnosis, or identification, the results are the same. You pay for the answer to "What is it?" It is fortunate that insect identifications can be accomplished at bargain rates—the economy of entomological operations simply will not support markedly higher costs of service identifications.

Taxonomic entomology has come to be recognized as the official custodian of materials, knowledge, and experience accumulated during the course of our long association with insects. This accumulated knowledge is so extensive that entomologists, no matter how well trained, who are required to operate for extended periods of time "on their own" must call on some central repository of knowledge for assistance in connection with their problems. The relation of taxonomy to mosquito control operations is well illustrated by activities that were carried on during World War II and subsequently.

Early in World War II the Army, Navy, and Public Health Service began clamoring for dozens of nonexistent *medical* entomologists. When it finally became apparent that adequately trained medical entomologists could not be obtained, an intensive training program was initiated. During the period 1942 through midyear 1945, personnel of the U. S. Department of Agriculture instructed 265 officers of the Army, Navy, and Public Health Service in the identification of medically important anthropods. Other agencies and the Armed Services conducted similar training programs. The periods of training varied from a few days to several weeks or months. Even so, these personnel found that they must constantly call upon taxonomic specialists to identify uncommon forms encountered, and to supply data on their biologies, distribution, and relation to diseases. As a result, thousands upon thousands of insects were channeled to Washington for identification, many of them with urgent requests for immediate reports.

Not all requests came from troops in the field. Prior to June 1942, upon specific request from the Office of the Army Surgeon General, the taxonomic unit of the Department of Agriculture supplied concise, organized data on insects of medical importance occurring in various parts of the world, with special emphasis on malaria vectors. The territory covered included all countries bordering the Mediterranean, Rumania, Arabia, Iraq, Iran, India, Burma, South China, Malaya, the Philippine Islands, Australia, New Zealand, and the islands of the South and Southwest Pacific. Information dealing with insects of the Australian and Oriental regions was also made available, upon request, to the Bureau of Medicine and Surgery, Navy Department. In 1944 an annotated bibliography of the literature dealing with the yellow fever mosquito, covering more than 1,200 published papers, was prepared upon request for the U. S. Public Health Service. U. S. Department of Agriculture taxonomists worked in close cooperation with the Medical Intelligence Branch of the Surgeon General's Office, furnishing whatever information was available on the distribution and habits of various species and their importance as pests or as vectors of human diseases.

You are familiar with the work known as "Global Epidemiology." Investigators engaged in the compilation of parts of this work contacted various agencies for assistance and guidance, and it was inevitable that taxonomists would be called upon. One investigator, whose task was to assemble information on the mosquitoes of South America, spent nearly two years at the U. S. National Museum with Alan Stone and the accumulated files in his custody.

You are also familiar with the theory and practice of selective mosquito control, sometimes referred to as species sanitation. Such practice permits maximum utilization of limited budgets and has an integral part in the establishment of priorities in work. The identification of the species to be controlled is, of course, a prerequisite for a species sanitation approach. As an example of important operations that have depended upon a thorough understanding of the species involved, I mention the solution of malaria transmission in southern Europe through an understanding of the *Anopheles maculipennis* complex, which provided a logical explanation as to why malaria was practically nonexistent in some localities, even though the *Anopheles* population was high, and prevalent in other regions with considerably lower *Anopheles* populations. Another example is the solution of the *Anopheles gambiae* problem in South America, where a knowledge of the species and its habits permitted eradication to proceed on a species basis. There is also the solution of a malaria-transmission problem in Trinidad after identification of the vector as *Anopheles bellator,* a species that breeds in bromeliads high in the trees. There undoubtedly have been many similar operations involving control of pest species.

Any detailed review of the development of knowledge of mosquitoes will reveal the essential part that taxonomists have played in the accumulation and organization of that knowledge. Information so assembled forms the basis for the preparation of mosquito handbooks and guides to their control. In the 1930's the U. S. Department of Agriculture undertook a survey of the mosquito fauna of tidewater Maryland, using light traps as a sampling method. This survey required the identification of over 60 thousand mosquitoes. Without the identifications, the survey would have been meaningless, so far as ideas of species abundance was concerned. The effort devoted to identification probably totaled more man-hours than all other aspects of the work combined.

As an outgrowth of the need felt by military personnel during World War II, there was envisioned in 1950 the preparation of pictorial keys to mosquitoes of medical importance for various regions all over the world. After some preliminary discussion, the job of preparing such keys was delegated to the taxonomic unit of the U. S. Department of Agriculture. Sixty-seven keys were prepared by 1954, and some of them have been published in *Mosquito News.* After completion of this series of keys, their probable use and adequacy was carefully considered, and it was decided to expand their usefulness by adding information on relation of species to diseases, their biology, ecology, and other pertinent information, as well as accounts dealing with other common, though not medically important, mosquitoes occurring in the different regions. That job has now been completed, and a comprehensive work on the mosquitoes of medical importance for the world, including all the pictorial keys, is being published by the Department of Agriculture.

In 1954 Alan Stone and Kenneth L. Knight joined efforts in the preparation of a synoptic catalog of the mosquitoes of the world. Aided by a grant from the Office of Naval Research which permitted hiring of a capable assistant in October, 1955, this work has progressed rapidly, and we hope the project can be completed by mid-year, 1958. This basic reference work will certainly be indispensable to mosquito-control workers all over the world.

It might logically be asked, "If this job takes only three years, why wasn't it done long ago?" The facts of the matter are that the catalog will not have been prepared in three years. Alan Stone spent a great deal of time during the 25 years prior to 1955 preparing a card index to the mosquito literature. Nearly all of this was done on personal time—i.e., outside of official hours—and both Stone and Knight have continued this project largely as an extra-curricular activity. Add to this the information accumulated by earlier workers, and the official time of technical literature abstractors employed by the U. S. Department of Agriculture who have materially aided in this work, and you begin to appreciate the immensity of the task of organizing part of our existing knowledge of a relatively small group of insects.

I alluded previously to the possibility of making deductions about mosquito biology on the basis of a knowledge of the taxonomy of the group. Deductions such as I had in mind might be made like this. For a number of years investigators in the Far East, notably Japan, have been trying to find how *Culex tritaeniorhynchus* passes the winter months. Because this species is believed to be the principal if not the only vector of Japanese B encephalitis in Japan, details of its life cycle could be important in the control of the pest and thus in lowering the disease rate. Taxonomically, *tritaeniorhynchus* is assigned to the typical subgenus *Culex,* all known members of which overwinter in the adult stage in temperate regions. It follows that *tritaeniorhynchus* should conform to this overwintering pattern, although to date the most intensive searches have failed to reveal any overwintering stages of the species in Japan. By a similar line of reasoning other South East Asia species of the subgenus *Culex* are considered prime suspects as vectors of Japanese B encephalitis or closely related neurotrophic viruses.

Attempts to predict the pattern of future relations between insect taxonomy and mosquito control are naturally largely speculative, and highly colored by past experiences. Almost certainly future taxonomic research on problems related to mosquitoes and mosquito control will continue along the same general lines as it has in the past. We hope that these investigations will permit us to answer questions as they arise, but it is apparent that we cannot always anticipate what the needs may be.

The normal movements of human populations in their search for living space periodically bring large segments of humanity in contact with regions favored by mosquitoes. Extension of irrigation practices in the Western United States in recent years has resulted in mosquito problems where none existed before. We have also experienced increased demands and pressure from wildlife interests for preservation of large areas for recreation and wildlife reserves. It is reasonable to believe that these trends will continue, and bring demands for more and better mosquito control. New methods of attacking the problem will surely be sought and, in the seeking, taxonomic entomology will be called upon to render assistance.

For example, consider the chain of events that might occur if biological control of mosquitoes is thoroughly investigated. The natural enemies already present must be studied and their importance assessed. Other regions of the world must be scrutinized for worthwhile predators that might be introduced. The ecology, habits, and biotic potential of both predators and prey must be carefully studied. All these processes will require identification of insect material, and one step in particular—i.e., the world-wide search for useful enemies of mosquitoes—is likely to be guided from the very beginning by information assembled by taxonomists.

Or assume that, as a means of control, a change in the ecology of mosquito-breeding areas is contemplated. Again extensive surveys and studies requiring taxonomic assistance will be necessary.

Two comparatively recent developments may have a profound effect on future mosquito control methods. These are the resistance of insects to insecticides, and the insecticide-residue problem. If chemicals become ineffective, or hazardous to humans, domestic animals, or wildlife, the tendency to seek other methods of control will be accelerated. We hope that taxonomic entomology can keep pace with the demands for information that will be imposed upon it by these new approaches, whatever they may be. If budgets become even less adequate in proportion to the mosquito-control problems at hand, even further refinements of the species sanitation approach appear inevitable. Ventures into little-known regions of the world will necessitate working with relatively unknown faunas, for even a group of insects as well studied as the mosquitoes is still poorly known in some regions. In the solution of all these problems taxonomists will play an important part.

Finally I should like to refer to that most important contribution that taxonomy makes to applied entomology—namely, the supplying of a means of organizing and communicating knowledge about insects. A. B. Gahan (Proc. Ent. Soc. Wash. 25(3):73) stated the situation concisely in 1923. I quote. "Objects without names cannot well be talked of or written about; without descriptions they cannot be identified, and such knowledge as may have accumulated regarding them is sealed; unclassified, their relationships are unknown and the possibilities of deduction are destroyed. In short, without the fundamental work of the taxonomist the great mine of entomological literature would not exist, and the accumulation of knowledge would be largely limited to what one could personally observe and remember."