Journal of the American Mosquito Control Association, 11(2):284–289, 1995

COMPUTER MODELS: KILLING MOSQUITOES WITH INFORMATION

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ABSTRACT. This paper looks at the relationship between man and mosquitoes from the perspective of coevolution. From this perspective, the primacy of information processing in vector control programs becomes acutely evident. A composite mosquito control program is developed and illustrated to show the benefits derived from incremental increases in information. The use of computer modeling is seen as the next logical step to be taken by vector control personnel to add the next increment of efficiency and effectiveness. This step could well lead to significant reductions or perhaps the elimination of the need for pesticide use. The author encourages the use of computer modeling in teams as the means to learn across disciplines. The feasibility of this approach has been greatly enhanced by the availability of off-the-shelf modeling programs. The author appeals to university and vector control professionals to support students and staff in learning computer modeling techniques.

INTRODUCTION

The argument set forth in this paper is that, from a fundamental perspective, we control mosquitoes with information, not pesticides, and because computers and computer modeling enhance our ability to process information, we can conclude that computer modeling kills mosquitoes.

Humans have been interacting with mosquitoes for millions of years. Each, mosquitoes and humans, has had reciprocal influence upon the other (Fig. 1). It is important for us to recognize that the metaphors we choose to describe our relationship with mosquitoes will dictate the reality that emerges. In fact, ultimately, the metaphors we choose will influence the kinds of strategies that we select for mosquito or vector-borne disease control. Fortunately, we humans, unlike the mosquito, have the advantage of changing our metaphor to obtain a different perspective on the problem. In reality, we have the ability to change our metaphors, but we may not change them often enough to gain maximum advantage.

PESTICIDES AND THE WAR METAPHOR

Metaphors can be subtle. They often insinuate themselves into our brain, influence what we see, and leave us unaware of their presence. I believe a war metaphor has subtly taken over our thinking. It produces images of people pitted against mosquitoes in warfare. The mosquitoes attack with biting and disease and we retaliate with pesticides or mosquito fish (Fig. 2). In this metaphor, pesticides are ammunition. Take away our pesticides and we are disarmed against our enemy—a truly frightening prospect. We could choose another metaphor, however, and we might see pesticides in a much different context.

MOSQUITO CONTROL AS COEVOLUTION

The coevolution metaphor provides a most productive perspective for vector control (Roberts 1989). Coevolution refers to the reciprocal interactions between 2 species as depicted in Fig. 3. We find that the ability of mosquitoes and human beings to gain advantage over one another is dependent upon genes; more specifically upon genetic plasticity. Now here you may recoil to think that we might simply coevolve with mosquitoes through genetic change. In fact, as mentioned previously, this has been going on for millions of years. Thalassemia provides an example. It is a human blood condition where abnormal hemoglobin formation causes a form of anemia and also provides humans with protection against malaria. The gene for thalassemia can be found in more than 20% of humans inhabiting malarious areas (Gazzaniga 1992). Our interaction with mosquitoes has created genetic change in the human population in malarious areas—a high level of thalassemia.

GENES ARE REPLACED BY MEMES OR "GOOD IDEAS"

In the last 40,000 years, with the development of language, however, humans have broken free of gene-dependent coevolution with mosquitoes. We have passed from Darwinian, gene-depen-

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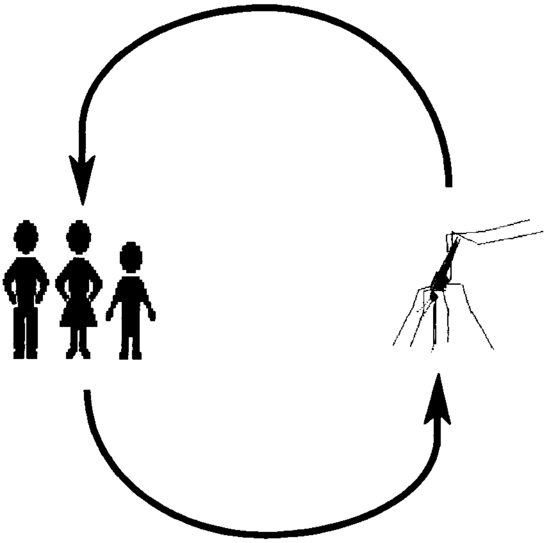
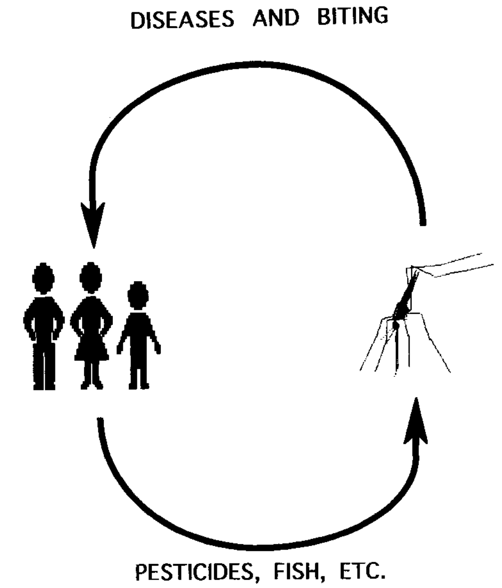


HUMANS VERSUS MOSQUITOES

Fig. 1. The metaphors we choose to describe the reciprocal relationship between humans and mosquitoes dictate the "reality" we see and ultimately influence the kinds of strategies we select for mosquito or vector-borne disease control.



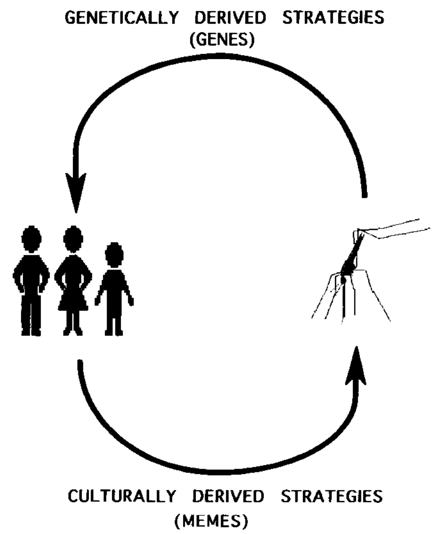
MOSQUITOES AND HUMANS AT WAR

Fig. 2. A war metaphor depicts mosquitoes and humans at war. Disease and pest-biting by mosquitoes is pitted against pecticides, fish, or other "munitions" of man.

dent, evolution to cultural or meme-dependent evolution (Bonner 1980:185–186). Memes have replaced genes in human evolution. Memes are ideas, beliefs, customs, or lessons that propagate themselves from brain to brain in humans primarily by way of language (Dawkins 1976:203–215). By using memes to coevolve, we are able to respond rapidly to mosquitoes, rather than depend upon the slow process of mutation, selection, and genetic drift to confer an adaptation upon us.

OUR AMMUNITION AGAINST MOSQUITOES BECOMES INFORMATION

It is important to recognize that the fundamental currency of the interaction between mosquitoes and humans in the coevolution metaphor is information. In Darwinian evolution, the information is transmitted by genes, whereas in cultural evolution, information is transmitted by memes. We may have a "good idea" (meme) to use DDT. The "good idea" (information) has prescribed human behaviors to use pesticide, say DDT, against mosquitoes. The use of DDT may



MOSQUITOES AND HUMANS COEVOLVING

Fig. 3. Mosquitoes and humans seen in the "coevolution metaphor". Mosquito genes are pitted against memes or "good ideas" of man.

Table 1. An illustration of a hypothetical control program evolving towards using less pesticides by the infusion of information.

Control program	Information	Amount sprayed	Efficiency effectiveness	Environmental impact
Area-wide spray	Mosquitoes seen biting	800 mi.^{2} weekly	−/0	Disaster
Spray all water	Larvae are in water	80 mi.^{2} weekly	−/0	Negative impact
Spray larvae	Larvae recognized	8 mi.^{2} when detected	0/+	Reduced impact
Spray species	Species identified	2 mi.^{2}	+/+	Reduced impact
Spray no./dip	Know larval densities	1 mi.^{2} at a threshold	+/+	Very low impact
Spray based on natural mortality	Know natural mortality	0.5 mi.^{2}	+/+	Very very low impact
Spray based on systems dynamics	Know wetlands systems dynamics	0.2 mi.^{2}	+/+	Extremely low impact
Manage wetlands holistically	Predict and create dynamics	Emergencies only	+/+	Enhances wetlands

select for a population of mosquitoes with a resistant gene. A resistant gene in mosquitoes has information encoded in DNA that prescribes a biochemical response to DDT to render it harmless. By shifting the metaphor from warfare to coevolution, we have changed our view of the currency of the interaction between man and mosquitoes from "ammunition" to "information".

AN EXAMPLE OF INFORMATION KILLING MOSQUITOES

In spite of the above, it may seem to be stretching it a bit to put forth the idea that we are killing mosquitoes with information. A more practical way to illustrate this idea is to focus on the evolution of a typical mosquito control program. For that purpose, I have created a "composite" mosquito control district; a hypothetical agency that is controlling mosquitoes. Let us assume it has some 800 mi.^{2} of territory within which it protects more than a million inhabitants against the pain and suffering caused by mosquitoes. Such an agency might start with simple and expedient approaches to mosquito control and, over time, evolve more complex, sophisticated approaches. Table 1 illustrates important features and consequences of the evolving control program. The program may start with an area-wide spray program and then, through additions of information, the program evolves toward using less and less pesticides. The table shows that a program that begins with area-wide spraying can reduce pesticide use by approximately 90% by spraying only over water. That 90% reduction in pesticides is attributed to the information (knowledge) that mosquito larvae are found in water. The table illustrates that the control program continues to reduce the amount of pesticides used by adding increasing increments of information about where, what, and how many mosquitoes there are, and whether they will be controlled naturally. By moving down column 2 (information) and column 3 (amount sprayed) in Table 1, one can find a clear inverse relationship between information and pesticide usage. By looking down columns 2 and 4 (efficiency/effectiveness), one can see that there is a positive correlation between information and killing mosquitoes.

Lest you think that this kind of hypothetical control program is a pipe dream, I refer you to an example of an agency that took just the first 4 steps described in Table 1 and was able to dramatically reduce pesticide use and increase effectiveness (Roberts 1971). In 1964, in this real-life agency, more than 4,000 lb of insecticide was used in area-wide treatment (adulticiding). In 1970, after the infusion of information about what, where, and when larvae were present in aquatic habitats, insecticide use was reduced to a few hundred pounds and mosquito control improved.

One should also note that in Table 1, the reduction of pesticides used in the program (column 3) reduces environmental impact. This is dramatically shown in the case of an actual agency where area-wide spraying had created a scale infestation in the urban forest by selectively killing the predators and parasites of scale insects. The transition to mosquito larviciding and the halting of adulticiding allowed natural predators to return to the urban forest and control the scale insects naturally (Roberts et al. 1973).

MAXIMIZING INFORMATION PROCESSING TO MAXIMIZE MOSQUITO CONTROL

If we agree that increasing increments of information can reduce the amount of pesticides used and increase the effectiveness of killing mosquitoes, then must we not conclude that information kills mosquitoes? So then, to reduce or eliminate mosquitoes altogether in our control programs, we need only collect and process information to know the following:

1. Where all of the hundreds or thousands of aquatic habitats are in our jurisdictions.
2. Whether the aquatic habitats produce mosquitoes.
3. If they do, when, what species, and under what conditions.
4. What numbers at each source represent a threshold number to be treated with larvicide.
5. What predators exist at each source; when, where, and in what numbers; and when and whether they provide effective control of mosquitoes.
6. What impact larviciding has on populations of mosquitoes, predators, wildlife, endangered species, the wetland system, the public, and anything else important.
7. What management decisions such as flooding, drawdown, and vegetation types, have on the wetland system, and on and on . . . .

The above is only expressed to show that a dizzying amount of information is necessary if we are to make effective treatment decisions in complex wetlands. Here is where computers enter the picture. Returning to our evolutionary perspective, we realize that information processing in humans has evolved from genes to brains. In fact, one information processing machine, the genome, has spawned another, the brain (Bonner 1980: 30). Today we are at the beginning of another enormous evolutionary breakthrough as the human brain spawns the computer. In our coevolution with mosquitoes, the computer provides an enormous advantage to humans by providing an exponential increase in information processing power.

Computers offer immediate and practical value to agencies accomplishing mosquito and vector control (Roberts 1990). One very powerful approach, computer simulations, has not yet found common usage in mosquito or vector control agencies. The major reason that is the case may be because computer modelers create an esoteric barrier to understanding computer modeling with mathematics, computer programming language, jargon, complex flowcharts, and an inscrutable all-knowing air (Meadows and Robinson 1985:414–434). This no longer needs to be the case. Today we have powerful off-the-shelf computer modeling programs that require no knowledge of computer programming and minimal knowledge of mathematics (Roberts and Page 1992). We can do computer modeling inhouse with our own staff.

PRACTICAL USES OF COMPUTER MODELING

I believe there are 2 practical pathways to harnessing the power of computer simulations in vector control. One would primarily be aimed at helping to predict when and where the inspection and treatment of mosquitoes or other vectors would be necessary (Roberts 1990). The other use of computer modeling would be as a learning tool and a means to create effective conversations across disciplines (e.g., mosquito control and wildlife experts) (Roberts and Page 1992).

The easiest way to create a computer simulation model for purposes of prediction would be to build from the bottom up; from the simple to the more complex. A simple model of a mosquito source could be updated daily by field data and, when operated, the model would simulate oviposition, growth, and emergence of mosquitoes to provide valuable information about when a source should or should not be inspected (Roberts 1990). This approach focuses on obtaining information to support program (inspection and treatment) decisions. A top-down approach all too often loses focus and incorporates complexity in the model that is unnecessary and makes validation of the model exceedingly difficult.

Perhaps the most valuable use of computer modeling today may be as a tool for learning. Off-the-shelf simulation programs provide mosquito and vector control agencies the power of computer simulations without the formidable learning curve. In-house teams could build simulation models of wetlands that may offer predictive value, but undoubtedly would enhance learning. This kind of approach supports systems thinking rather than linear thinking (Senge 1990). In a multidisciplinary setting, simulation modeling could be used as a means to bridge the gap between disciplines and thus foster multidisciplinary collaboration (Roberts and Page 1992).

Figure 4 is an example of the "front end" of

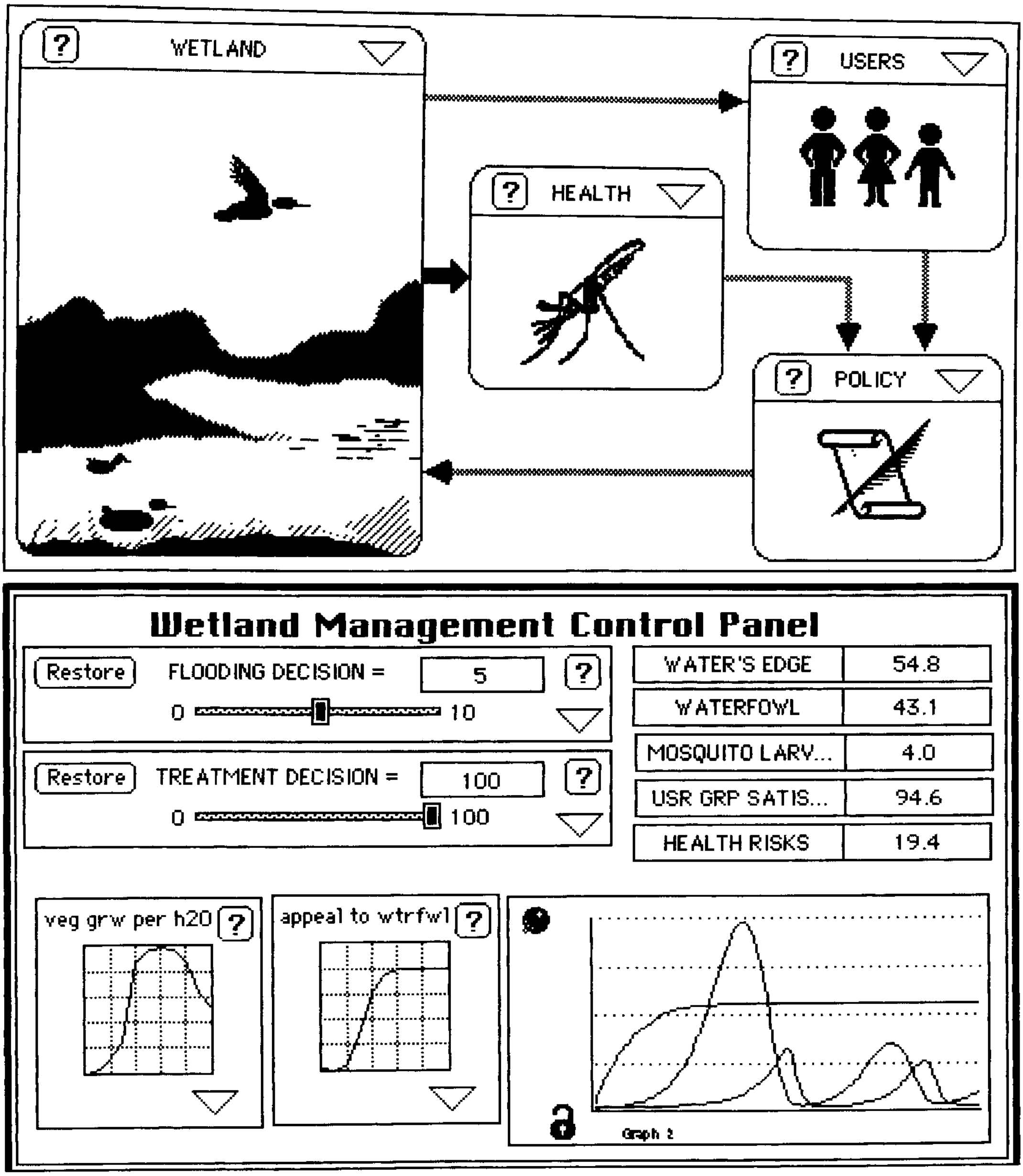


Fig. 4. An example of a "front end" of a wetland simulation model built by a multidisciplinary team. The modeling was done on "user friendly" modeling software.

a computer simulation of a wetland that has been created by a multidisciplinary team of wildlife and vector control experts. The model represents the "mental model" of the team that put it together. It provides an opportunity to test their mental models about how a wetland works. Specifically, they simulate policies of flooding, drawdown, and insecticide applications and watch the predicted consequences of their actions on waterfowl, mosquitoes, user-group satisfaction, health risks, and other variables. Figure 5 shows the kind of output that is produced. Computer modeling, and the learning it generates, moves towards attaining the last 2 items of information needed in the second column of Table 1 to approach the total elimination of pesticide use.

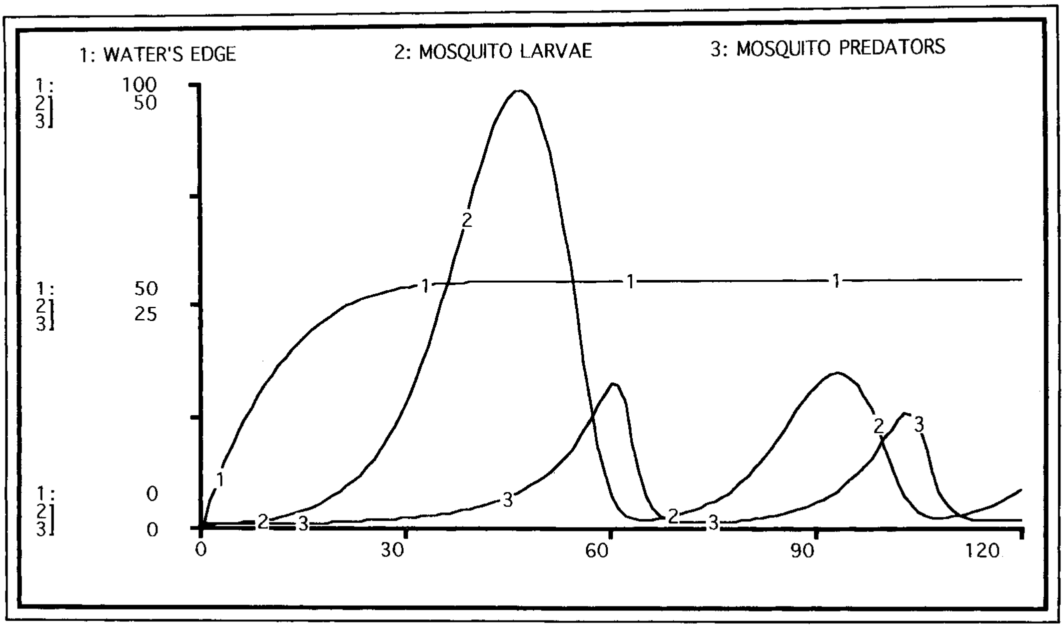


Fig. 5. An example of output from a wetland simulation model designed to test alternative management policies.

CONCLUSIONS

The next significant increase in efficiency and effectiveness (and the next significant reduction of pesticide use) in mosquito and vector control can occur by way of efficient use of computers and computer modeling. Each agency would have a computer modeler whose job it is to design computer support systems while enhancing organizational and individual learning through open, collaborative, model building. However, I cannot visualize where the computer modelers are going to come from unless there are some dramatic changes:

I appeal to those of you who have influence in universities to support computer modeling and systems thinking classes for all disciplines.

I appeal to managers of mosquito and vector control agencies to recognize that information and knowledge lead to efficiency and effectiveness, and therefore to support employees in developing computer and modeling skills.

I appeal to professional staff (young and not so young) of mosquito and vector control agencies to be willing to learn computer modeling and/or join modeling teams.

In the meantime, as our President John Mulrennan has said, the train is leaving, leading us into the 21st century. I believe we better have some "open" and "collaborative" computer modelers on board.

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