VECTOR CONTROL AS COEVOLUTION

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Preamble.

I am a manager of a mosquito abatement district. We managers work real hard. We are always upgrading our programs. It doesn't do any good. The districts do not give us sabbatical leave to prevent burnout. Instead of a sabbatical, I present a paper every decade or so, to step back from the trees to look at the forest. This is such a paper.

Introduction.

I would like to discuss vector control from the point of view of evolutionary theory. The paper will provide no new information. It will, however, focus on areas not usually stressed. Hopefully it will offer a fresh perspective and maybe even some insight. As an aside, I need to warn you that contrary to the teachings of my English teachers, I believe mixing metaphores can be expressive.

The paper is not a scientific paper, but it is somewhat logically driven. The process has led to some suprising conclusions. The premise of the paper suggests that a vector control program, when suppressing a vector population, operates in a manner similar to coevolution. If this is true, then we should expect to learn something by looking at what is known about coevolution.

Coevolution and the Red Queen.

Coevolution is when two or more species interact in a reciprocal fashion. Species A, perhaps a predator, applies selective pressure to species B, its prey, which adapts to avoid predation, causing reciprocal selective pressure on species A. Dawkins (1987), a modern evolutionist, describes the process as an "arms race." It is characterized by escalating, reciprocal adaptations. He considers coevolution to be the major mechanism by which progressiveness is injected into evolution. Both sides will continue to improve their survival advantage as long as neither side gains a decisive advantage (De Angelis et al. 1986). Evolutionsists refer to this as the "Red Queen" effect. The term refers to when Alice, in *Through the Looking Glass*, is holding hands with the Red Queen and running faster and faster, yet staying in the same place.

I would like to extract the salient features of coevolution and use them to test the analogy with vector control. The first test would be to see if two or more organisms are interacting. The second would determine if each side causes selective pressure upon the other, resulting in reciprocal adaptations. The third would ask if there is an increase in complexity on both sides. The final test would determine whether either side gains a long term advantage, or, in other words, whether the "Red Queen" effect is operating.

The Elegant Proof.

In the first test, we ask whether there is an interaction of two species in vector control. On the one side we have a vector population, obviously a species. On the other, we have the vector control organization. One is an organism. One is an organization. Organism, organization; close enough for me. The first test passes.

The second test is not so easy. It asks whether both sides apply selective pressure to the other resulting in adaptations. Looking at the phenomenon of insecticide resistance gives a clear picture here. The vector control organization applies insecticide A. The vector population develops resistance to insecticide A, creating a control failure. The vector control organization adapts by applying insecticide B.

The best reason to use resistance as an example, of course, is that there is ample evidence to suggest this kind of process of reciprocal adaptation is not uncommon (Brown and Pal 1971). It may also be the case that our vector control programs are pressuring the vector population and creating other less evident adaptations. A mosquito population under larviciding pressures may adapt by seeking more cryptic larval habitats, developing pesticide avoidance behavior, increasing autogeny rates, or shifting to alternate hosts for a blood meal.

There are some discrepancies in the analogy with test two. The time frame in which vector control occurs is measured in decades. Evolution occurs in a geologic time frame. How then could it be possible that true evolution could be going on in such a short period of time? The answer lies in the fact that most vectors are r-pests (Conway 1981). They produce great numbers of individuals, preadapted forms, that are widely distributed into the environment. The environment then selects the fittest. From this perspective, the vector population could be viewed as a machine generating hypotheses to be tested. The natural environment operates as the selection system; only those hypotheses that pass the test survive.

It is well known that random mutations of genes supply the basis for change in a species. Mutations create the new ideas for survival if we can be teleological for a moment. But, it is unlikely that mutation is occurring at a significant rate, if at all, in the time frame of vector control (Brown and Pal 1971). Nevertheless, the vector population has possibly stored a heavy load of historical mutations over geologic time. These mutations are distributed in individual prototypes which are generated in great numbers and variety conferring genetic variability to the population. The selective pressures applied by our recently arrived vector control programs are simply changing the environmental test to select individual vectors that have pre-adapted in a geologic time frame.

Another discrepancy is evident in the anology when we realize that a different kind of selection and change is occurring on the vector control side. Our vector control programs acquire characteristics through our rational processes, and they are passed to the future as updated vector control programs. This is a Lamarkian-like evolutionary process that can result in almost instantaneous changes, while the vector population's most elemental changes, mutations, require a geologic time frame. Korzybinski (Postman, 1988) recognized this as an enormous advantage that man has over plants and animals when he described man as a time binder. In spite of discrepancies of time and method of evolution, however, the prevailing relationship between the control organization and the target organism, as demonstrated by the example of insecticide resistance, is that of two sides interacting reciprocally. Test two passes.

Test three asks whether both sides increase in complexity. Again we can use the example of insecticide resistance. Insecticide resistance occurs when individuals in the vector population are selected that possess a physiologic mechanism to detoxify pesticides. The physiological complexity of these individuals is greater than that of those individuals who cannot detoxify the insecticide. The increased complexity is expressed at the population level as the selection process creates a higher frequency of resistant genes in the population. On the vector control side, we have been forced to introduce another pesticide. An obvious increase in complexity of the program. Test three passes!

I would like to digress for a moment on this matter of the complexity of a vector control program. Our agency is currently using computer simulations. They formalize our decision making and quantify the complexity of the decision. Alan Berryman, at our recent AMCA Conference in Seattle, extolled the benefits of bottom up modelling. He felt this approach would lead to practical models that were no more complex than they have to be. He said to start simple and add one change at a time. Each change is then validated or discarded. The validation process, of course, is to test the model in the real world. Does this procedure sound hauntingly similar to evolution? From this perspective, the vector control organization could be viewed as a machine generating hypotheses to be tested, or validated. The "real world" operates as the selection system. Only those hypotheses that pass the test survive.

The final test may be made by simply asking if all of you in the audience are holding hands with the Red Queen. Are you working harder and harder and not making any progress? Yes, I know that some of the changes we make are associated with safety, environmental, or efficiency considerations, but could some of the changes be adjustments to adaptations made by the vector population? I need only gently remind you of the 60s and 70s when the term "insecticide treadmill" was used so often to describe our programs. The term of course is the infamous "Red Queen" in disquise.

Case closed! Test four has passed.

Darkness Descends on Vector Control.

If we accept the logic of the preceding argument, then must we not also accept the following?

Unless we know the adaptive capacity of a vector population, and whether our control efforts exceed that capacity, we are doomed to ever increasing demands to upgrade our program while gaining no significant long term control benefits from the changes. We are doomed to running in place with the Red Queen.

Oh what darkness has descended upon vector control.

Science to the Rescue.

There is hope of course. A review of the scientific literature shows that scientists in our field, as well as other fields, are working on the problem. Charles Taylor (1986) is approaching the problem from our point of view. He has investigated, by way of computer simulations, whether using several insecticides at once creates a survival hurdle too high for a population to develop resistance. He has chosen the term "survival hurdle" to describe a quantity of control effort in relation to the ability of the vector population to survive.

Geneticists are also looking at the problem. The ability of a population to survive is a function of its genetic composition. Evolutionary change, is at the basic level, a change in gene frequency distribution. Geneticists are developing techniques that will enable them to determine the amount of genetic variation present in populations of vectors (Cockburn and Seawright, 1988). These scientists appear to be moving toward a time when we will be able to determine an "adaptive capacity" of the population. The very practical and timely work of Dr. Georghiou and other researchers (1989) at the University of California at Riverside deals specifically with providing us with the tools to determine gene frequencies for insecticide resistance in vector populations.

Evolutionists are currently looking at the same problem from their perspective. A term "ecological load" has been developed and mathematically defined (Stenseth, 1985). The term is related to the concept of "survival hurdle." The magnitude of the ecological load on a species determines its probability of survival or extinction.

Wildlife biologists, coming from the opposite point of view, that of species preservation, have developed another related mathematical concept called "minimum viable population size" (Reed et al. 1986). The tool would be used to determine how large a population would have to be able to maintain sufficient genetic variability over time to insure survival.

This most cursory review of the literature has indicated that wildlife biologists, evolutionists as well as vector biologists, in spite of their different perspectives and objectives, are all interested in developing the tools to measure the "adaptive capacity" of a population to environmental change. It appears that the advancing field of population genetics holds the key. Some wildlife biologists have made a direct plea to population geneticists to study the problem (Reed et al. 1986). I feel that we should do the same. We should make every effort to support and understand their work.

By requesting so much of geneticists and other scientists, we place a tremendous demand on science; but science is a unique and powerful process. The late Heinz Pagels expressed it well when he likened the scientific process to a selective system. He believed that scientific ideas, because of their vulnerability to failure imposed by the actual order of nature, are subject to a unique, self-imposed selective pressure. From this perspective, scientists collectively could be viewed as a machine generating hypotheses to be tested. The scientific process, linked to nature, operates as the selective system. Only those hypotheses that pass survive.

Conclusions.

I believe the paper has shown the existence of a significant correspondence between coevolution and the process of vector control. I believe it leads to these conclusions:

1. Our programs may suffer from the "Red Queen" effect, exhibiting ever increasing complexity while gaining little or no long term advantage over the vector population.

2. It is incumbent upon us to learn more about the "adaptive capacity" of the vector population.

3. We need a means to measure our control effort in relation to the "survival hurdle" that we impose on the target population.

4. We need to encourage and support the efforts of population geneticists and other researchers to pursue these matters.

5. Wildlife biologists could benefit from as well as contribute to similar research.

6. We may also benefit from the research by utilizing information about the "adaptive capacity" of wildlife species to design control programs with less adverse impact on wildlife.

7. Most vector populations have at least one significant advantage over us. They can afford, by virtue of their high reproductive rate and genetic diversity, to create many "cheap" survival models to be tested in the environment. We cannot afford this kind of approach.

8. We have our own advantages in our struggle with vector populations:

   A. We, as time binders, have time on our side. By making many changes in a short period of time, we are robbing the vector population of a geologic time frame. There is, therefore, little time for mutations, the basic mechanism of change. The vector population must depend upon historical mutations stored as genetic variability in the population. In the near future we may be able to determine the "adaptive capacity" that their store of mutations represents, and use the information in designing our control programs.

B. The control agency has an enormous advantage over the vectors by evolving through Lamarkian methods. The characteristics of the programs are "acquired" through rational processes and passed to the future. The vector population is limited to bottom-up, small incremental changes while the control agency can make large top-down or bottom-up changes. We are limited only by the extent of our knowledge, resources, and creativity.

C. Finally, we have science on our side. Science is a most powerful selective system. Pagels (1988) believed that the power of science is derived from the fact that the selective process is ultimately linked to natural order.

The conference which we now attend is an arm of science. We are here to exchange ideas and to discuss new technology. We are able to select those approaches and tools that are most appropriate for our individual programs. From this perspective, we speakers at the conference are part of a CMVCA machine, generating hypotheses to be tested. You, the audience, operate as a selective system. Those hypotheses that pass your test will survive.

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