small, rectangular solids separating pond.

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THE COYOTE HILLS MARSH MODEL, CONCEPTUAL FRAMEWORK AND DIRECTIONS OF RESEARCH

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The Coyote Hills freshwater model is a computer-operated, simulation model being developed to integrate the two seemingly opposite management objectives of mosquito control and wildlife management of a freshwater marsh. The marsh is managed by naturalists of the East Bay Regional Park District to introduce students and citizens to the rich variety of flora and fauna associated with the marsh. Unfortunately, the marsh also produces a rich variety of mosquitoes.

In past years the Alameda County Mosquito Abatement District has accomplished mosquito control primarily by planting mosquitofish. Although relatively high populations of mosquitoes of the species *Aedes squamiger*, *Culex tarsalis*, *Cx. erythrothorax*, *Anopheles* spp. and *Culiseta inornata* have, at times, been monitored at the site, pesticides have only been applied on rare occasions to control the winter salt marsh mosquitoes, *Aedes squamiger*. These mosquitoes became necessary to control because they were strong fliers invading distant residential areas. The other mosquitoes, for the most part, have been unnecessary to control because the park is located some distance from residential areas. This may change, however, since plans have been made to create residential housing adjacent to the park, thus portending increased public demand for mosquito control on the marsh.

The Coyote Hills freshwater model, in its broadest sense, is a beginning effort to bring together the two factions of wildlife and mosquito management, and to increase their understanding of the dynamics of the marsh. Hopefully, the increased understanding will lead to development of a marsh management system that will allow an ecologically rich freshwater marsh to exist adjacent to, and in harmony with, a residential development. In its most specific sense, the model may eventually be used to assist in making specific decisions concerning the course of action to be taken to control mosquitoes in a manner compatible with the wildlife management objectives of the marsh.

The first version of the Coyote Hills freshwater model was developed by a team of six scientists led by Dr. James Schooley of California State University at Hayward. It was presented by Dr. Schooley at a workshop on Systems Modelling sponsored by the Northern Chapter of the Society of Vector Ecologists. A thorough description of this first version was presented by Dr. Schooley at last years' C.M.V.C.A. conference (Schooley et al. 1982).

CONCEPTUAL FRAMEWORK.–The essence of the model is the relationship between the population of *Anopheles* spp. and its predators, primarily mosquitofish, *Gambusia affinis*. The effectiveness of predation by *Gambusia* is affected by the biomass of pondweed, *Potamogeton pectinatus*. As pondweed increases in biomass during the growing season it provides an increasingly effective refuge for the *Anopheles* larvae. The initial level of *Anopheles* larvae, and mosquitofish are required inputs to the model and must be accurately determined by field sampling. The biomass of pondweed is a function of the depth the water will be held in the marsh throughout the growing season and is determined by an equation found in the literature.

The mathematical core of the model is a difference equation which determines the level of Anopheline larvae. The equation includes the components of predation by *Gambusia* and the interference of predation by pondweed. During the operation of the model, the difference equation calculates the number of Anopheline larvae to add or subtract from the population in a given period of time, in this case one day. The computer calculates the level of Anopheline larvae for each day. Difference equations are particularly suited to operation

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by a computer because the computer can run many iterations in just a few seconds.

DIRECTIONS OF RESEARCH.–The model in many ways acts as blueprint by vividly illustrating the research needs. The first steps in operating the model requires the user to provide input. The accuracy of the input will undoubtedly have an affect upon the validity of the results. For this reason, some of the initial research efforts have been aimed at developing effective methods to assess the populations of *Anopheles* spp., mosquitofish and pondweed, and developing a method to measure average depth of the marsh. Obviously one cannot expect the model to provide valid results until effective sampling techniques have been developed to measure these parameters.

During the development of the mathematics of the model, it became evident that the literature would not provide all of the necessary information. Numerous assumptions had to be made based upon the best estimates of the team. Assumptions were made about growth rates of *Anopheles* spp., the predation rates of *Gambusia*, and the phenology of pondweed at Coyote Hills, just to name a few. It became quite clear that many of these assumptions would need to undergo laboratory and/or field testing.

The first version of the model may well be simplistic and leave out important invertebrate and vertebrate predators of *Anopheles* spp. Indeed, the model may leave out any number of important physical or biological components. For this reason, a general assessment of the biological and physical components of the marsh has also been deemed important.

On June 18, 1982 a number of interested scientists met to review the model and identify the research needs. The resultant research work load was divided into general categories and the researchers chose areas within which they could accomplish their research. In this way it was hoped that researchers would be able to pursue a productive avenue of research without duplicating the efforts of other researchers working on the model. The following two papers are reports by principal researchers on their research projects.

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