PROCEEDINGS AND PAPERS

of the

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California Mosquito and Vector Control Association, Inc.

January 26 thru January 29, 1992

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CONCORD, CALIFORNIA

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TABLE OF CONTENTS

BIOLOGICAL AND ECOLOGICAL STUDIES

GENERAL

OPERATIONAL CONCERNS

C.M.V.C.A. REPORTS

WILLIAM C. REEVES NEW INVESTIGATOR AWARD

California Mosquito and Vector Control Association, Inc.

Volume 60 **January 26 thru January 29, 1992**

CONFERENCE DEDICATION

DEDICATION OF THE 60TH ANNUAL C.M.V.C.A. CONFERENCE TO

DR. WILLIAM C. REEVES

Richard F. Peters

C.M.V.C.A. Past President
25 Oak Tree Drive
Rancho Mirage, California 92270

The man we honor at this 60th annual conference has been a prominent identity on the vector-borne disease control scene for close to 50 years. Dr. William C. Reeves has devoted a substantial part of those years to areas of prime concern to this association. His research on the encephalitides has provided us with the facts needed to obtain effective control of this public health hazard. His role as perennial chairman of the State Vector Control Advisory Committee has involved him in virtually every important development which has affected the programs of the local agencies within this association. And since the production of a committee usually reflects the quality of its chairman, I want to personally express my fullest appreciation to the committee for the great assistance provided the State of California's Bureau of Vector Control during its evolutionary years; which translates into personal praise for Bill Reeves.

Bill and I were classmates in entomology at U.C., Berkeley. Actually, I preceded him by a year, graduating in 1937 and he in 1938. Yes, Cal had a football team then that went to the Rose Bowl undefeated, including Stanford. I'm sure it won't surprise you to learn that Bill was a top-notch athlete in those days. We played intramural basketball together on the Entomology Department team, which won just about every game even though matched against the larger university departments. Bill and Tommy Aitken were our high scoring forwards, Paul DeBach played center and George Bohart and I caught rebounds and fed them to the front line. One gameday I returned from the dressing room to find Bill giving my twin brother Bob, seated in the bleachers, the word for not suiting up for the game. At that point he became aware that there are two of us. Or one might say re-Peters!

If you know Bill well, you know that he rarely comes in second to anyone when expressing a differing view. In this regard, Professor Ray Smith, chairman of the Entomology Department in the 1960's, once voiced pleasure over believing he had bested Bill who had teased him about having a common name. Ray replied "Smith is not a common name, Bill, it is a popular name." Bill offered no response.

In reality, Bill Reeves is a person who functions with great intensity on everything he undertakes. He is solidly down to earth, or perhaps better stated, down into water in deference to his expertise in culicidology. He has never asked anyone to do something he couldn't or wouldn't do himself (and probably better). He expected something from his staff and students and his expectations have brought out the most in them, to their advantage and to his credit.

In my opinion, his mentor in epidemiology, Dr.

Karl F. Meyer (Director of the George W. Hooper Foundation, U.C. Medical School, San Francisco), provided him during the early stages in his career with a motivation and inspiration which persists to this day. Dr. Meyer was one of a kind, a majestic individual who possessed a penetrating gaze and a dynamic demeanor which commanded respect and captivated audiences, whether one on one or in a filled auditorium. I believe he regarded Bill as a protégé and he evidenced much pride and pleasure in Bill's technical and scientific accomplishments.

Another person deserving conspicuous recognition for Bill's lifetime attainments is a lady whose support, devotion, encouragement, and patience has characterized her relationship with him for 51 years of marriage - Mary Jane Reeves.

Lest you get the impression that Bill is all work and no play, be assured that going fishing lures him whenever his commitments and the seasons permit. One of the pleasures I had during the early years of our careers was visiting his Bakersfield research station and accompanying him in the evening to Helen Lovegreen's restaurant for a choice steak and a piece of her inimitable peanut butter cream pie. I had a reputation for eating in those days, which Bill referred to as gluttony, particularly after I outdid him in the distant past at Jack Kimball's abalone bash at the Orange County District. And fond memories remain of accompanying him at those annual Kern River swims and barbecues put on by Art Geib. As a hobby, Bill raises exquisite orchids, or at least he did until last year's freeze.

It should be mentioned that Bill has been an active participant in the American Society of Tropical Medicine and Hygiene throughout his career and is a Past President of that society.

Your program contains more of Bill Reeves' background, which I trust you have perused. Now, in the interest on getting the conference program underway, as a Past President of this association, I am privileged to dedicate this 60th Annual Conference to you, Dr. William C. Reeves, in recognition of your many significant technical and scientific contributions to the world, your country, your state, and to this association.

KEYNOTE ADDRESS

PERSPECTIVES ON MOSQUITO RESEARCH BY THE UNIVERSITY OF CALIFORNIA - PAST, PRESENT, AND FUTURE

William C. Reeves

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I was honored and challenged when Harmon Clement, your Program Chairman, asked me to present a keynote address on the "Past, Present, and Future of Research at the University of California". Over the past 50 years I have participated in and observed the research and known the pioneers who did it: Quayle, Herms, Gray, Freeborn, Meyer, and Aitken. Since 1938, I attended all but two of your annual conferences and contributed 53 papers to the *Proceedings*. I served on countless committees charged to plan and finance research on control of mosquitoes and the diseases they transmit. So to review the past and present should be relatively easy if I simply can recall it.

My review is divided into four eras: Pioneering, Diversification and Expansion, Present, and Future. I cannot separate the role of the University in research from the contributions made by the California Mosquito and Vector Control Association (CMVCA) and the California Department of Health Services (CDHS). You have been, and I hope will continue to be, close collaborators.

The Pioneering Era, 1905-1940.

In 1904, the Burlingame Improvement Club asked the Department of Entomology, Berkeley, to review the problems salt marsh mosquitoes posed in the development of the area and on the health of their residents. Professor Quayle was assigned the task and the Club allocated $2,000 in 1905 to implement his recommendations. The Burlingame program emphasized physical control, and San Rafael in Marin County developed a program emphasizing oiling. Both programs were a success and provided a basis for the first bulletin on mosquito control issued by the Agricultural Experiment Station.

In 1909, malaria was a highly endemic disease in the Sacramento Valley. Professor Herms of the Berkeley faculty was deputized an Associate Health Officer and given $700 by the Penryn Fruit Company to determine if malaria control was feasible. The project was successful, and based on that research other areas began *Anopheles* control in 1910. From 1910 to 1912, Freeborn, Herms, Gray, and associates made mosquito surveys of California and a malaria survey of central California. In 1915, the California Legislature passed the Mosquito Abatement Act and in 1919, allocated $10,000 to the University for research on mosquito control in the Sacramento Valley. In 1920, the California Mosquito Control Association (CMCA) was formed and in 1921, the first effort at biological control of mosquitoes was attempted by the introduction of *Gambusia*.

Freeborn published the first edition of the *Mosquitoes of California* in 1926, based on the earlier surveys of mosquitoes. He listed 36 species and summarized their habits, distribution, importance as vectors of malaria, and provided keys for identification.

The first annual conference on mosquito research and control was hosted by the Berkeley Department of Entomology in 1930 and included University, health department, and mosquito control personnel.

In that same year, Dr. Meyer and his associates from the Berkeley and San Francisco campuses made a major discovery when they reported the isolation of western equine encephalomyelitis (WEE) virus from the brain of a horse and raised the question whether this virus was transmitted by mosquitoes and caused disease in both equines and humans. By 1940, WEE and St. Louis encephalitis (SLE) viruses had been shown to be the cause of thousands of cases of encephalitis in western states.

Herms and Gray published the first edition of *Mosquito Control* in 1940. This classic book reviewed research, and showed that mosquito control in California was practical and already had gone through significant changes.

In the late 1930s, mosquito control districts requested assistance in the identification of mosquitoes. These agencies and the CDHS had no trained entomologists on their staffs. In 1939 and the early 1940s, Aitken and I developed and presented workshops and keys on mosquito identification as a part of your annual conferences.

We will do well in current and future research to emulate these pioneers. They worked closely with health departments, mosquito control agencies, local communities, and the state legislature to: define mosquito problems; describe mosquito species and their biology; recommend integration of physical, biological and chemical control; and promote legislation to implement control based on the research.

The Diversification and Expansion Era, 1941-1970.

Major changes in the direction of research on mosquitoes and their control occurred in this era. Emphasis shifted from concerns with springtime flooding of the Central Valley and coastal salt marshes to management of pest and vector species in man-made sources such as permanent pastures, rice fields, and urban and rural waste water. The second edition of Herms and Gray's *Mosquito Control* was issued in 1944 and still emphasized the use of oils, arsenicals, fish, and physical modifications of the environment. A single page was devoted to the new war-time miracle insecticide, DDT. In May 1945, I received the first shipment of 100 pounds of DDT from the U.S. Army to determine the effectiveness of residual spraying of domestic habitats in Kern County for encephalitis control. Mosquito control and research then entered a new era optimizing the use of DDT and other hydrocarbon insecticides.

World War II had sensitized the public to the importance of malaria and other vector-borne diseases. Research in California had proven that mosquitoes carried encephalitis viruses. In January 1945, the State Legislature received "A Report on Investigations of the Disease Bearing Mosquito Hazard in California" that represented the concerns of the CSDH, University, and CMCA. The report urged that the control programs and research be broadened to include all disease vectors and that mosquito control be extended geographically. That report predicted the cost of such a program for the state might eventually reach $10 million, far short of the actual budget in 1992 of more than $50 million.

In 1945, the legislature allocated $400,000 to the CDHS for subvention to mosquito control districts and $200,000 to further demonstrate the role of *Culex tarsalis* Coquillett as an encephalitis vector. This was a real shot in the arm for research and mosquito control. There were only 29 small control districts, covering fewer than 5,000 square miles, a population of one million people, and less than $100,000 in local tax support. In a short time, many new districts were formed and old ones extended.

In 1951, Freeborn and Bohart issued the second edition of *Mosquitoes of California* which consisted mostly of revised keys for the identification of 41 species.

An epidemic of malaria occurred in 1952, with 35 cases at Lake Vera derived from a single veteran of the Korean War. An even more urgent event that year was the largest epidemic of encephalitis in the history of the state; 375 WEE and 45 SLE cases. Following this experience, the research findings on encephalitis were published in *Epidemiology of the Arthropod-Borne Encephalitides in Kern County, California, 1943-1952.*

Concurrent to the encephalitis epidemic, mosquitoes were found to be genetically resistant to DDT and subsequently to other organophosphorus insecticides. Extensive research was devoted to this problem. The amazing thing was that within 25 years, we passed through what you might call the "heyday" of chemical insecticide research and use in mosquito control.

To understand the history of this research better, we must backtrack. In 1953, the University had a very small staff concerned with vectors of encephalitis located at the Hooper Foundation and the Kern County Field Station, and Drs. Bohart and Bailey at Davis concerned with taxonomic and biological research. In the early 1950s, the Vector Control Section of the CDHS established the Fresno Field Station in recognition of the need for centralized and integrated research on mosquito biology and control. The program objectives were to develop information directly applicable to mosquito control and to augment the limited University program. Richard Peters and Ralph Barr organized and directed studies of pasture and rice field mosquitoes, alternative uses of insecticides and other approaches to mosquito control that were major contributions.

In February 1965, the University, CDHS, and CMCA prepared yet another report to the legislature on "Proposed Expanded Research and Extension Programs for the Control of Mosquitoes Affecting the Health and Well-Being of Man and Animals". It was to be a collaborative effort. To the surprise of many, in June 1965 the legislature proclaimed that on July 1, all research on mosquitoes was to be transferred to the University. In less than two weeks, a budget of $141,000, a staff of 12 professionals at Fresno and six on subassignment to the University at Berkeley or Davis had been transferred.

Partially promoted by the reallocation of these resources, and supplementation by the University, mosquito research programs were developed on the Riverside, Los Angeles, Davis, and Berkeley campuses. By 1970, no other University and few other agencies had equal research staffs or facilities. The programs encompassed expanded studies on mosquito biology, insecticide development and testing, development of insecticide dispersal equipment, physical alterations of urban and agricultural environments, improved management of excess water and sewage effluents, and the biology and disease relationships of vectors.

The Current Era, 1971-1992.

This is an era that you all know. It began with a big boost in 1973 when the legislature appropriated $300,000 to the University for research on mosquitoes and mosquito-borne diseases. This action was vigorously supported by the CMCA. A series of program coordinators, Mitchell, Loomis, Fontaine and Eldridge, have worked hard to develop a rigorous process for review of research proposals and have prepared annual reports that assured the dissemination of new research findings locally, nationally, and internationally. This program now allocates almost $400,000 annually to research, which is augmented significantly by more than $1 million from the departments for faculty, staff, and facilities. Federal and private grants provide almost $1 million, and your agencies contribute direct funds in excess of $100,000. This more than $2 million in research support is not all that could be used, but is certainly more than the estimated $20,000 available in 1919 or $600,000 in 1945.

In 1978, the third edition of *Mosquitoes of California* was published by Bohart and Washino and included 47 species, improved keys, extensive biological data, and new information on relationships of vectors to viruses and malaria. In 1990, the staff of the Arbovirus Research Unit at Berkeley published *Epidemiology and Control of Mosquito-Borne Arboviruses in California, 1943-1987*. This summarized almost 50 years of research.

I believe one of the most significant developments for the future direction of research by the University may have been in 1977 when you changed your title from the CMCA to the CMVCA. Inclusion of the word "vector" in the title indicated a broadened concern with diseases other than mosquito-borne. This will place new research demands on the University.

Time does not allow me to review in depth the impressive array of research during the present era. It included extensive studies on the conventional chemical pesticides and shifted to development and evaluation of environmentally safe alternatives. During the past several years, the research turned almost entirely in this new direction. The University allocated most of the $400,000 available for 1991-1992 to development and evaluation of biological control agents, better equipment for insecticide dispersal to control adult mosquitoes, management of the environment to minimize mosquito production, and biological studies of major disease vectors. All of these topics will continue to be major concerns in the future.

It is clear that mosquito and vector abatement no longer can be practiced as in the past. In the world of today and tomorrow, the manager, entomologist, and technician in your agencies and the University researcher must be aware of and conform to restrictions imposed by federal and state agencies, the University, and public opinion. A major challenge for researchers will be to keep pace with the control problems you face and still conform to these strictures.

The Future Era.

Now to the most difficult era, "the future role of the University in mosquito research". Clearly, there will be no future research unless there are competent research workers and funds to support them. The University has provided an amazingly diversified group of researchers over the past 90 years. We are now in an era when many researchers are retiring, changing interests, or leaving for other reasons. You can be assured the University will not replace them unless the positions are clearly ear-marked in a budget. When I retired, I was replaced by a very competent physician-epidemiologist concerned with other currently important infectious diseases and international health. Drs. Bohart, Bailey, Loomis, Barr, Work, Dadd, Judson, and others concerned with mosquito research have retired and not been replaced by persons with similar interests. Researchers Washino, Hardy, Milby, Georghiou, Mulla, Schaefer, Womeldorf, and others may not be replaced in the not-too-distant future. The University is not being effectively pressured for continued or increased research on mosquitoes and vector-borne diseases by outside political or interest groups and will abolish such positions during periods of budget crunches or move them to other areas of current academic and research concern.

We cannot turn to federal resources for support as their internal budgets are constantly decreasing and research grant funding is increasingly competitive. Federal agencies are saying "If California has a problem, let them solve it." This picture is not likely to lead many young scientists into looking for a career in research on mosquitoes or vector-borne diseases.

I think most of you believe in the need for research in support of your programs. I also believe your Association and the California Conference of Directors of Environmental Health must be the pressure groups to convince decision makers in the University that such activities are in the best interests of this state. You should have clout; you represent over 50 community-based programs, serve more than 20 million people, and have an annual budget of well over $50 million from local taxation. You obviously feel the need for research, as you contributed over $300,000 to the University and State Department of Health Services for research and disease surveillance in 1990.

Let me turn now to future research topics. It is time for a fourth edition of *Mosquitoes of California*. This will be a major research undertaking: new species have been found; the taxonomy deserves revision; new identification keys are needed; extensive records are available on species distribution; and the relationships of various species to many viruses are now known. Such a publication will serve a large and expanded audience of mosquito control and public health workers.

As a second problem, each week I review the mosquito light trap records from 32 mosquito control agencies. Populations of vector and pest species continue to be excessive in parts of the Sacramento, Imperial, and Coachella Valleys. This situation persists in spite of extensive research over the past 50 years. In the same period, an extensive network of mosquito control agencies and dedicated workers has developed in these areas and has given maximum cooperation and support to the research effort.

Western equine and St. Louis encephalitis viruses persist in the southeastern region of the state. No major disease outbreak has been recognized in this area and this may reflect the relatively low density of people or an ineffective surveillance for cases. Regardless, the fact is this area may be a source for virus reintroductions into receptive areas of southern and central California where these infections have disappeared. This situation will remain a statewide and not just a local problem until it is resolved.

Many parts of the Sacramento Valley continue to have high populations of both vector and pest mosquitoes. It must be assumed this region will continue to be receptive to reintroduction of encephalitis viruses or malaria.

If funding sources can be found, I recommend the establishment of field stations and research staffs year round in both areas. I will not presume to present details of such research except to say a very critical evaluation must be made of any new approaches to control that offer promise.

As a third problem, there will be a continuing need for research and surveillance on vector-borne diseases. You know the history of western equine and St. Louis encephalitis, malaria, plague, Lyme disease, and many other vector-borne diseases. Some of these diseases are at a low ebb, in part due to vector control; however, this is not a time for complacency. All of these infections, except malaria, are firmly established in a cycle between vectors and wildlife hosts. None will be eradicated in the next 50 years and they must not resurge and become epidemic. Molecular biology will not produce a vaccine or a drug to protect you, and a vaccine or drug will do nothing to decrease the reservoir of infection for these vector-borne diseases. Continued research and surveillance is the only approach to identify the sites where such infections persist and to develop and evaluate ways to minimize the risk of exposure to infection. Vector control will continue to be the most economical approach.

I am currently on a committee of the National Academy of Sciences charged to identify "Emerging Microbial Threats to Health" and to identify avenues of research most promising for prevention and control of epidemics of such diseases. Problems such as the emergence of AIDS, hemorrhagic fevers, and influenza serve as current models. We are having difficulty evaluating the threat of innumerable viruses, bacteria, and parasites that exist in our environment but have not caused epidemics. We have no assurance they cannot change and become highly virulent. Let me give you examples that are close to home. *Culex tarsalis*, the principal vector of encephalitis viruses, frequently are infected with four additional viruses, Turlock, Hart Park, Llano Seco, and Grey Lodge. Snow mosquitoes in the Sierras and salt marsh mosquitoes on the coast are infected with viruses in the California encephalitis complex. Viruses seem to occur whenever and wherever we look for them, and people are exposed whenever they are bitten by these vectors. However, we have been unable to associate these viruses with any disease. In research jargon, we say these are "viruses looking for a disease".

I do not have time to dwell at length on the subject of global warming. There is evidence that major increases in temperature, the level of the ocean, and seasonal patterns of precipitation may occur in the next century. We initiated preliminary studies and found it is practical to research the impact of increased temperatures on vector life tables and vector-virus interactions. It is feasible to extend such studies and to predict the impact of global warming on mosquito populations and diseases. A lack of funding is the major barrier that precludes University interest in such research.

There are many additional future research problems related to interactions of mosquito vector and pest populations to growth of human populations in California that I have not mentioned. We are confronted with the spread of human populations into rural areas, urban congestion, the impacts of population growth on the environment, and assimilation of immigrants from around the world. News media and political bodies rarely concern themselves with the impact of these changes on health and certainly not with their impact on mosquito control. I believe the University can be a base for research and planning to prevent future epidemics of vector-borne diseases and minimize increases of pest species in urbanized environments. Every problem that is anticipated and prevented today is better than being confronted with management of a crisis tomorrow.

In closing, I want to thank you again for asking me to look at the past, present, and future of the University in mosquito research and for dedicating this conference to me. I wish you success in your future endeavors.

WETLANDS SYMPOSIUM

THE INTERRELATIONSHIPS OF AGENCIES HAVING ROLES AND RESPONSIBILITIES INVOLVING WETLANDS

Fred C. Roberts

Symposium Moderator
Alameda County Mosquito Abatement District
23187 Connecticut Street
Hayward, California 94545

PANELISTS

Charles H. Dill	Marin-Sonoma M.A.D., C.M.V.C.A. Environment and Biology Subcommittee Chairman
David Paullin	U.S. Fish and Wildlife Service, Central Valley Joint Habitat Venture Committee
Peter Sorensen	U.S. Fish and Wildlife Service, Division of Habitat Conservation
Edward Smith	California Department of Fish and Game
Richard P. Meyer	Kern Mosquito and Vector Control District
Phil Oshida[1]	U.S. E.P.A., Office of Coastal Wetlands Planning and Protection
Vicki L. Kramer	Contra Costa M.A.D.

MODERATOR'S INTRODUCTORY REMARKS

Today we have seven speakers from seven different agencies representing various points of view on wildlife management and mosquito suppression in wetland habitats. I sincerely welcome each of you. As moderator, I feel the need to perform a meaningful function. I intend to represent the point of view of an "informed" citizen, the most important stakeholder in the wetland issue. Therefore, I must state: I simply want wetlands of maximum ecological and recreational value at minimal costs and with minimal mosquito and vector problems.

I expect my government and my tax dollars to do the job. Wetlands, I realize, are highly complex systems that require a high level of technical knowledge to create and effectively manage. I am highly concerned, not skeptical, not defeated, but highly concerned that the job falls to a group of disparate agencies, enmeshed in a tangle of conflicting laws, seemingly often in competition rather than cooperation, approaching the problem from seemingly incongruent disciplines. Quite frankly, I, representing the role of an informed and interested citizen, am keenly interested in how you will overcome these obstacles to cooperate effectively together and make this work. I look forward to having the speakers prove my fears unfounded.

[1] Article not available at the time of publication.

WETLANDS POLICIES, CONCERNS, AND EXPECTATIONS OF THE CALIFORNIA MOSQUITO AND VECTOR CONTROL ASSOCIATION

Charles H. Dill

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ABSTRACT

For many years when we spoke of our responsibility in wetlands, we were talking about controlling mosquitoes. It is now readily apparent that our responsibilities in these biologically sensitive areas go well beyond the control of one class of organisms. We are as responsible for the overall health of wetland ecosystems as we are for the health and comfort of the human residents of our districts. If we expect our views and concerns for public health to be an integral part of the on-going activities involved in the wetlands issue, then we must show, through our active cooperative participation, that we are sensitive to the needs of wildlife and willingly acknowledge our responsibility for maximizing wildlife values. Only in this way can we expect reciprocity from our colleagues in the resource management agencies and thus end years of frustration due to being excluded from wetlands planning.

The relationship between public health biologists and our colleagues in the wildlife field should not be a contentious one. For too many years it was erroneously believed that our respective goals were mutually exclusive. An examination of existing physical control practices for mosquito control would bear this out. A good example is the replacement of drainage as a control methodology with circulation enhancement practices. Also, for too long, a debate has raged over which is the more important- "wildlife values" or "public health goals". The fact is that they are equal in importance and wetlands design and management criteria must reflect this fact.

We must be biologists first and vector ecologists second. It is essential that we promote the fact that our knowledge of wetlands is a necessary resource that must be utilized for success. Our presence must be evident in all phases of wetlands projects; from conceptual talks to developing an operational management plan for the completed project. By taking a holistic approach in order to end up with the best habitat possible for wildlife, we incorporate those elements of design and management necessary to minimize mosquito problems.

As a profession, we need to be more proactive in selling our expertise in wetlands. We must begin to network with other biological professionals in order to better use all available knowledge. It is time to stop the swing from one extreme stance to another. We must cooperate to bring order to the process and thus provide the greatest possible chance for success. It is time for those in each discipline who are used to taking an adversarial position on wetlands projects to change their thinking. It is a time of change.

Change can be a positive event if we are the architects of the new thinking and not simply reacting to the thoughts of others. Some thirty years ago as the environmental movement began to emerge, it was said that "if you are not part of the solution, you are part of the problem". That is just as valid today as it was then. Be a force in the wetlands movement . . . get involved.

CENTRAL VALLEY HABITAT JOINT VENTURE

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The Central Valley of California is the most important waterfowl wintering area in the Pacific Flyway, supporting about 60 percent of the total population. In pristine times, four million acres of wetlands, mostly surrounded by grasslands and riparian areas, provided ideal wintering and breeding habitat for waterfowl and other wildlife that flourished throughout the region. These wetlands provided a wide variety of benefits including fish rearing and passage, groundwater recharge, and sediment control, among others.

In the Central Valley, 95 percent of the historic wetlands have been lost. Much of this reduction can be attributed to habitat loss (including drainage and intensive agriculture) that has reduced the quantity and quality of wetlands and surrounding upland nesting habitat. Since the mid-1950s, duck populations have shown sporadic fluctuations related to weather and land-use changes. However, in the late 1970s populations started to decline, and by the mid-1980s, fall flights were approximately 30 percent below long-term averages. This loss was greatly accelerated in the 1980s when a severe, prolonged drought in Canadian prairies and the north-central United States aided widespread wetland drainage for agriculture.

Concerned over the decline in duck populations, the United States and Canadian federal governments developed and signed the North American Waterfowl Management Plan (NAWMP) on May 14, 1986. The NAWMP provides a broad framework for waterfowl conservation and management based on populations and habitat goals needed to meet public demand. The NAWMP established a continental breeding population goal of 62 million ducks, including 8.7 million mallards and 6.3 million northern pintails, and a fall flight of 100 million ducks during years of average environmental conditions. These goals are based on average continental duck populations from 1970-1979 in surveyed areas.

Implementation of the NAWMP is the responsibility of designated joint ventures, in which agencies and private organizations collectively pool their resources to solve waterfowl habitat problems. The California Central Valley Habitat Joint Venture (CVHJV) was formally established by a working agreement signed in July, 1988. The CVHJV is guided by an Implementation Board comprised of representatives from the California Water Fowl Association, Defenders of Wildlife, Ducks Unlimited, National Audubon Society, The Nature Conservancy, and The Trust for Public Lands. Ex-officio board members include the U.S. Fish and Wildlife Service (FWS), U.S. Bureau of Land Management (BLM), U.S. Soil Conservation Service (SCS), and the California Department of Fish and Game (CDFG).

The goal of the CVHJV is to "protect, maintain, and restore habitat to increase waterfowl populations to desired levels in the Central Valley of California consistent with other objectives of the NAWMP". Six objectives were developed by the Implementation Board to achieve this goal:

1. Protect 80,000 additional acres of existing wetlands through acquisition of fee-title or perpetual conservation easements.
2. Secure an incremental, firm 402,450 acre-foot water supply that is of suitable quality and is delivered in a timely manner for use by National Wildlife Refuges (NWR's), State Wildlife Areas (WA's), and the Grasslands Resource Conservation District (GRCD).
3. Secure Central Valley Project (CVP) power for NWR's, WA's, GRCD, and other public and private lands dedicated to wetland management.
4. Increase wetland areas by 120,000 acres and protect these wetlands in perpetuity by

acquisition of fee-title or conservation easements.

5. Enhance wetland habitats on 291,555 acres of public and private lands.
6. Enhance waterfowl habitat on 443,000 acres of agricultural lands.

Overall, the CVHJV is targeted for completion by the year 2000. When completed, 80,000 acres of existing wetlands will be protected through perpetual easements or fee-title purchases; 120,000 acres of historic wetlands will be restored and protected; 291,555 acres of existing wetlands will be enhanced; 402,450 acre-feet of water will be secured for existing Central Valley NWR's and WA's; and 443,000 acres of private agricultural land will be enhanced annually for feeding and nesting waterfowl. The estimated capital investment for attaining all objectives is $528.7 million. In addition, meeting the water and power objectives will require new federal legislation.

At objective level, the CVHJV's annual contribution to the continental breeding population will average 490,000 breeding ducks, including 300,000 mallards, and a fall flight of one million ducks. Upon completion of the CVHJV objectives, the Central Valley will support 4.7 million wintering ducks, including 2.8 million pintails. Because they are so dependent on the Central Valley, wintering pintails will be given special attention in the CVHJV.

The CVHJV Implementation Plan will be updated with scheduled NAWMP revisions or as otherwise appropriate. Such updates will occur at least every five years.

WETLANDS POLICIES, CONCERNS, AND EXPECTATIONS OF THE UNITED STATES FISH AND WILDLIFE SERVICE

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Introduction.

The United States Fish and Wildlife Service (USFWS) has been more or less intimately involved in working with various mosquito abatement districts around San Francisco Bay for the last ten years. We currently have an exciting wetlands management plan underway in Alameda County. If time permits, perhaps we can talk about that more during the panel discussion after the featured talks are completed.

This morning I would like to very briefly describe to you the role of the U.S. Fish and Wildlife Service in interagency matters concerning wetlands issues, primarily to give you a quick rundown of the status of some of the different wetland habitats around the state, focussing mainly on northern and central California. I will also talk a little bit about some of the endangered species and other species that are candidates for future Federal listing that occur in these wetland habitats.

Legal Background.

The Division of Habitat Conservation is composed of the old Division of Ecological Services and the Office of Endangered Species and this is probably the most controversial division within the agency. We get involved in reviewing proposed projects that private citizens and other governmental agencies want to get approved through the wetland regulatory process. The process is primarily administered by the United Stated Environmental Protection Agency (EPA) and the United States Army Corps of Engineers.

Under the Fish and Wildlife Coordination Act, the Service has authority to make recommendations and comment on impacts of proposed projects for the purpose of insuring that there are no adverse impacts to wetlands or endangered species over the long term. The second legislation that the Service operates under is the Endangered Species Act, which was authorized by Congress in 1973. Since its inception, this Act has resulted in the listing of close to 500 endangered species in the United States. At this time a sizeable percentage of those endangered species, probably 50% or greater, occur in the wetland habitats. The same is true in California with probably more than 60% of the listed endangered species in the state occurring in wetland habitats. To determine whether a species is threatened or endangered it has to meet one of the following criteria under Section 4 of the Act:

1. Present or threatened habitat destruction.
2. Over-utilization from scientific, commercial, or other purposes.
3. Disease or predation.
4. Inadequacy of existing regulatory mechanisms.
5. Other natural or manmade factors that have diminished populations to the extent that they require protection.

As you can see, this last criterium is very general in nature, making it a kind of catchall category under which a great many species can qualify as threatened or endangered.

I will briefly summarize at this point some of the different kinds of wetlands and the associated listed endangered species as they occur in central and northern California.

Seasonal Wetlands.

The first, seasonal wetlands, are widely distributed in coastal foothill habitats as well as on valley floors. Some of the threatened or endangered species that occur in seasonal wetlands include the California red-legged frog (a candidate endangered species currently being reviewed by the Service), the California tiger salamander, the San Francisco garter snake (which is restricted to San Mateo County), and the western pond turtle (which appears in seasonal wetland as well as riparian wetland habitats).

Riparian Woodlands.

Riparian habitats, probably more than any other kind of wetland habitat, have suffered larger historical losses to the point that now close to 98% of the state's historical riparian wetland habitats have been lost. So with most of that occurring in the Central Valley, the Service is embarking on a number of listing activities that will get us involved to a much a greater extent with mosquito control agencies and other segments of the public. The valley elderberry longhorn beetle is one of the few listed endangered species in riparian habitats in central and northern California; others include the California freshwater shrimp, which occurs in the north coastal counties around San Francisco Bay. The Service is also reviewing the status of the western pond turtle, the riparian brush rabbit and the San Joaquin Valley wood rat. These last two species are known only from one remaining population along the Stanislaus River in southern San Joaquin Valley.

Vernal Pools.

Vernal pools are common throughout the valley floor of the Central Valley. I'm not sure if there's much of a mosquito problem associated with vernal pools. I haven't heard of any if there is. But the Service is currently involved in developing proposals for listing four species of fairy shrimp plus a tadpole shrimp. We are also reviewing the status of California tiger salamanders and numerous plants. Eight or nine species of endemic plants will be proposed for listing in the near future as a result of a lawsuit brought about by the California Native Plant Society against the Service. Two of the few listed species that occur in vernal pools at this time are the delta green ground beetle and Solano grass, which occur in Solano County.

Alkaline Sinks.

Alkaline sinks and alkaline wetlands are prevalent throughout the San Joaquin Valley and probably the only listed endangered species that occurs in those types of habitats would be the palmate-bracted bird's beak, an annual wildflower. To a certain extent the tiger salamander probably also occurs in this habitat.

Emergent Wetlands.

As far as emergent wetlands go, cattails and bulrush, the Service is concerned about the large losses in the statewide population of tri-colored blackbirds and is reviewing the status of that species. The giant garter snake was recently proposed for listing as endangered at the end of December. Its primary habitat type is emergent freshwater wetlands in valley floor habitats throughout the Central Valley. It is one of the larger species of garter snakes, exceeding four and one half to five feet in length. Reflective of the historic loss of emergent marsh, most of the remaining populations are restricted to rice production zones throughout the valley. Fortunately for the snake, it has adapted to these modified habitats provided in agricultural areas.

Estuarine Marshes.

The last type of wetland that I will talk about is the coastal estuary systems, San Francisco Bay being the primary focus of our office in Sacramento. Since the 1850s, these wetlands have been diked off primarily for salt production, urbanization, and flood control purposes. The tidal marshes are now very much restricted to narrow bands around the edges of the salt ponds. As a result of this massive habitat loss, the Service listed the salt marsh harvest mouse and the California clapper rail as endangered in the early 1970s. The diked-off areas are the main mosquito problems around San Francisco Bay and that is the type of habitat that we in the Service, the East Bay Regional Park District, the California Department of Fish and Game, Alameda County Flood Control District, and the various mosquito abatement districts are closely coordinating together on to resolve hydrologic problems. We are attempting to get these diked-off areas to function more naturally in a way that will benefit both the control of mosquitoes as well as endangered species and other kinds of wildlife.

Tidal marshes, and to a certain extent diked baylands, provide high waterfowl and shorebird habitat values. In the dry season, these diked baylands often times are not real impressive but nonetheless provide critical habitat values during the winter

Disking of seasonal wetlands has occurred in the past as a way to solve soil dessication and cracking problems. That is at the heart of the issues we are trying to resolve between endangered species protection and mosquito control. The salt marsh harvest mouse, which was endemic to the tidal marshes, has also colonized many of the diked baylands throughout the Bay. This is one of the primary driving forces behind a coalition of agencies working to come up with improved management schemes in the diked salt marsh areas.

Mitigation Concepts.

I think the most commonly cited statistics are that historically there was between four and five million acres of wetlands in the state. Today, it is around 300,000, roughly a 90-92% loss. The primary loss of these habitats are caused by urbanization and agriculture. The Army Corps of Engineers is doing a good job around the Francisco Bay of protecting the remaining wetland habitats. It is often said that mitigation is an acceptable form of replacement of losses for new proposed projects, but in a comprehensive review of the literature, it has been determined that very few mitigation projects have been required over the past regulatory era. It is only within the last ten years that there has been a dramatic increase in the number of mitigation projects documented in agency files. The Fish and Wildlife Service and most other agencies stress ideas and concepts to be worked into mitigation plans. These include perpetual protection of the set-aside areas along with associated operation and maintenance costs that are used to fund and manage the set-aside areas. Wherever possible, mitigated wetlands should be contiguous with other existing wetlands. They should be compatible with adjacent land uses, and in cases of vernal pools and certain other situations, adequate watersheds need to be preserved to insure proper hydrologic balances so that the value of the wetland can be maintained. In addition, adequate buffers are critical from the wildlife standpoint to insure that encroaching disturbances do not eliminate some of the more important and sensitive wildlife values in these areas. In that regard, fencing would be an important tool. We consistently that mosquito abatement considerations are worked into the design so that problems are not exacerbated in the future. We also recommend that firebreaks be situated on the outside of these preserves or at least on the outward edges to minimize the amount of intrusion and degradation of the natural value. Plans for stormwater runoff are designed to maintain the integrity of water quality. We try to avoid disturbances due to recreational activities to maintain wildlife habitat values, although in the face of increasing urbanization, it is becoming more difficult to achieve.

In this era of high technology, computers, and the advent of GIS systems, the nature of planning is becoming increasingly more sophisticated. We believe these tools will help to avoid losses of wetlands and increase the benefits of mitigation.

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WETLANDS POLICIES, CONCERNS, AND EXPECTATIONS OF THE CALIFORNIA DEPARTMENT OF FISH AND GAME

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This morning I would like to present the California Department of Fish and Game's (CDFG) perspective on wetlands and mosquito control. Some of these things I will be saying in the very beginning are things that you have heard before but are important enough to warrant reiteration. Historically, there were about four million acres of wetlands in California. Today, only 300,000 wetland acres remain. Recently, the citizens of California have made it clear that they appreciate the wildlife values of wetlands and wish to see more of this habitat in this state in the future.

In the late 1970s State Senate Concurrent Resolution 28 was passed which directed the Department of Fish and Game to create 150,000 acres of new wetlands by the year 2000. Numerous initiatives have since been approved by voters, including Propositions 19, 70, and 99, which provided funds for the State to acquire property for the purpose of recreating wetlands.

The Department of Fish and Game is also partner, along with the U.S. Fish and Wildlife Service and numerous other public and private organizations, in the Joint Venture North American Waterfowl Plan. So, we really have been directed very strongly to create more wetlands and to enhance the wetlands that we have. Recent acquisitions in the Central Valley include the 8,500 acre upper Butte Sink Wildlife Area in Glenn and Butte Counties, the 3,000 acre Yolo Bypass Wildlife Area in Yolo County, the 5,500 acre North Grasslands Wildlife Area in Merced County, as well as substantial additions to the Los Banos Wildlife Area in Merced County and the Mendota Wildlife Area in Fresno County.

Managing wetlands in the wildlife areas involves many diverse concerns, methods, and considerations. We begin flooding on most of these areas in late August or early September and usually the flooding is complete by mid-October. Most flooded areas are maintained until April or May when they are drained to allow native waterfowl food plants to germinate. Irrigation of these food crops usually occurs during the summer period and, in most cases, we are talking about one or two quick irrigations. Semi-permanent wetlands, which represent a small percentage of the total wetlands, must remain flooded from March to August to provide brood water for waterfowl and summer habitat for a variety of species of wetland wildlife.

That scenario may sound like a prescription for producing mosquitoes. And like the rancher that grows alfalfa or permanent pasture, some mosquitoes surely will be produced as a result. However, with the help of local mosquito abatement districts, I believe we have the ability to keep the mosquito populations at minimum levels. A case in point is Mendota Wildlife Area where over 8,000 acres of this 12,100 acre wildlife area are in seasonal and semi-permanent wetlands. We recognize the mosquito producing potential of our management and have done the following to reduce mosquito production:

1. We provide the local mosquito abatement district personnel with a weekly water map which describes among other things areas that are being flooded and those that are being drained.
2. We try to make our irrigations as quick as possible so that water doesn't stand in the summer period for a long time.
3. We strive to prevent unnecessary pond fluctuations.
4. We have provided mosquitofish ponds for the District to use.
5. We contract each year with the local mosquito abatement district to apply chemical and

biological materials to control mosquito populations. And we do that with some real concern. We have had examples where we have found dead wildlife. I remember a rookery that had dead young herons in it; I felt reasonably sure that the applications of chemicals were the cause.

Recent research has indicated the importance of invertebrates as food items for waterfowl and other birds, particularly at the chick stage. Consequently, in the last few years we have requested that *Bacillus thuringiensis* var. *israelensis* (*Bti*), a specific biological agent, be used during the spring and summer period when we have found that an insect diet is so important to wildlife. These treatments are more expensive than conventional chemicals but we feel they are necessary to maximize wildlife production on our wetlands. Additional methods of biological control are certainly needed. Mosquitofish have been used with some success on a lot of wetlands on state lands. Hopefully, other avenues will be found in the future.

In conclusion, the key to managing mosquito problems successfully is for the wildlife agencies and the mosquito abatement districts to develop close working relationships. And that can only be done if we all make a concerted effort to understand each other's programs and problems.

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RESIDENTIAL ENCROACHMENT ON WETLANDS

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Introduction.

The California Mosquito and Vector Control Association (CMVCA) is currently in the process of finalizing a wetlands policy statement that will outline the Association's role in wetlands development, management, and vector control. One major component of the policy deals with the fact that wetlands support the production of mosquitoes and other vectors of human disease and discomfort. Therefore, it is essential that the Association and member vector control agencies secure their role in wetlands development in response to the potential health risks presented by blood feeding arthropods that colonize wetlands environs. This paper briefly summarizes some of the conflicts and their impact on vector control operations that are created as urban and residential developments progressively encroach on wetlands.

Overview.

The continued human population growth and inevitable urbanization of California has created land usage conflicts between developers and conservationists. Urban expansion also has placed many Californians at risk by locating residents in environs where there is a high probability for arthropod-borne (e.g., mosquito) disease transmission or periodic attack by large numbers of nuisance vectors (Reeves 1990). As vector control agencies, we have the direct responsibility of protecting the public from arthropod-borne diseases and arthropod sources of discomfort. Problems arise when vector control agencies are caught in situations where there is a mutual demand for public protection, but to provide that protection with minimal environmental impact. This major conflict has been created as a result of public perception and political activism. Briefly, residents of rural housing developments have chosen to live in a "country" setting in close contact with "nature" where they can enjoy the benefits of that life style. At the same time, those same individuals are by nature very sensitive to the discomforts presented by "biting insects" and will subsequently demand their control, but with minimal environmental impact. This situation presents a paradox to mosquito and vector control agencies in providing effective vector abatement without disrupting the ecology of "natural" breeding areas (e.g., wetlands) (Fig. 1).

With the currently existing regulations on vector control activities in environmentally sensitive areas, the proposed scenario for accommodating both desirable options is operationally untenable. In which case, there is no practical way to provide effective vector control without some undesirable impact on the environs that support vector production. Even low impact source reduction operations such as ditching a marsh can have a profound effect on that environ by dramatically changing vegetation patterns and attendant ecological relationships.

Current abatement operations on wetlands are incumbered by existing laws and regulations that directly protect wildlife and sensitive habitat types. As a consequence, effective protection from vector attack and/or disease transmission cannot be afforded to residents that live within vector dispersal range of wetlands sources. The lack of our ability to provide effective protection from vectors in the current context can be attributed to two major factors that deter abatement efficacy, 1) physiographical disposition of the wetlands environ and 2) cultural disapproval of abatement activities. Principal physiographical components that affect abatement efforts include vegetation profiles coupled with water quality, impoundment status, and lack of access to implement control operations. Cultural disapproval factors include activism in wildlife protection among environmental groups and wildlife management agencies, material label and application restrictions, and public opinion. Continued reinforcement of these "barriers" can

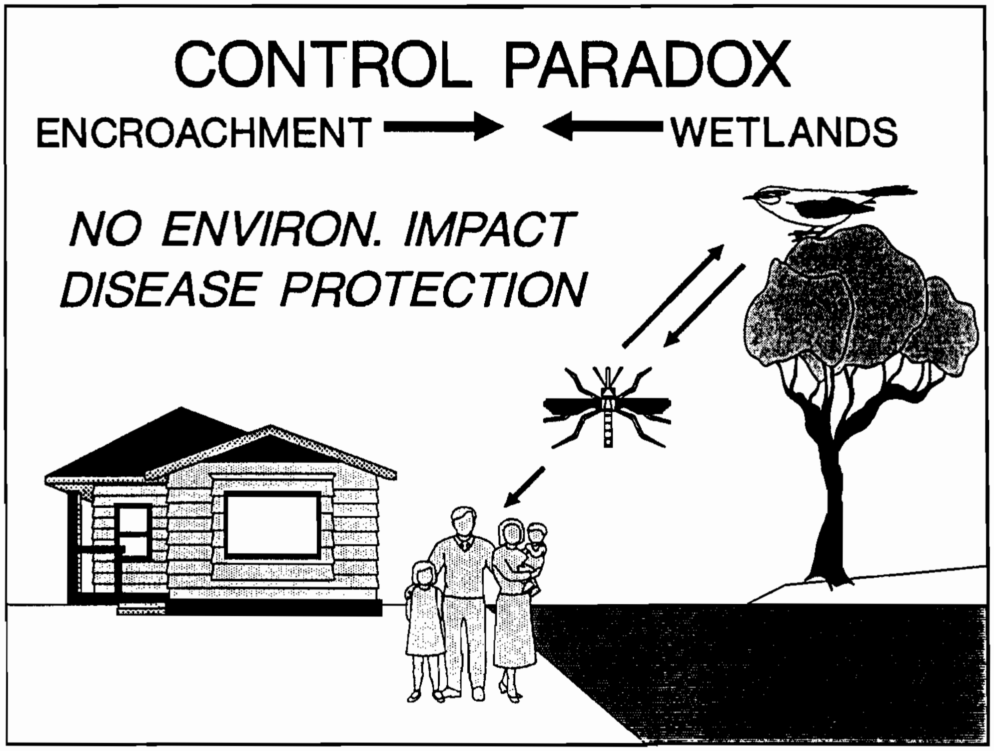

Figure 1. Depiction of the vector control paradox where wetlands are encroached upon by residential developments.

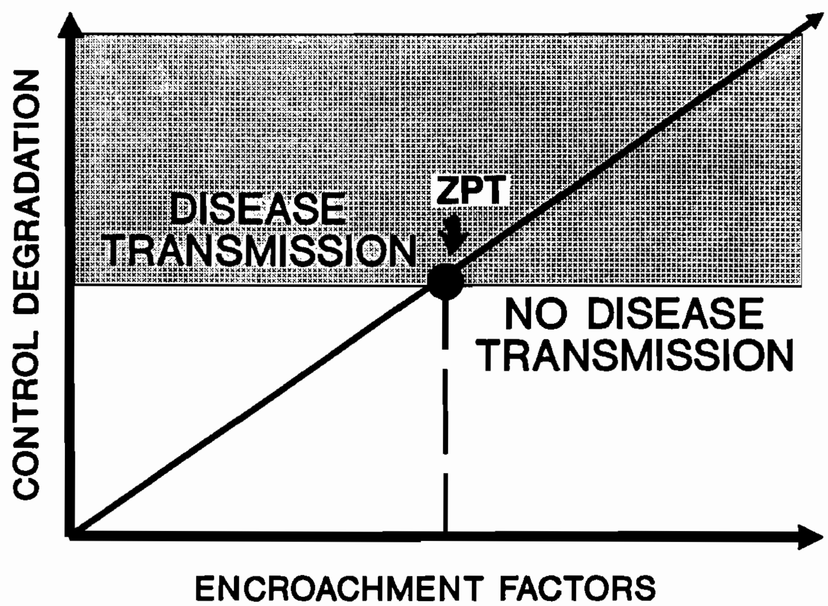

Figure 2. Effects of increasing encroachment factors on vector control degradation. Zero protection threshold (ZPT) point indicates where vector-borne disease protection is no longer feasible.

proceed to a Zero Protection Threshold (ZPT) point where control efficacy is so thoroughly degraded that vector control agencies no longer will have the capacity to protect the public from vector-borne disease transmission or inundating attack rates (Fig. 2).

Selected Regional Conflicts.

The potential for residential encroachment conflicts are widespread in California and should be of greatest concern to the residents of 1) central and southern coastal communities, 2) Central Valley, and 3) interior desert valleys of southern California.

Coastal encroachment conflicts deal primarily with the production of nuisance levels of salt marsh *Aedes* and locally abundant populations of *Culex*. With the exception of some coastal communities situated on the western fringe of the Los Angeles basin, there has never been a history of mosquito-borne encephalitis associated with coastal environs. However, the recent discovery of a California Encephalitis (CE) group virus in *Aedes squamiger* (Coquillett) (Eldridge et al. 1992) may change the perception of coastal areas as being non-encephalitic. A change in the vector status of *Ae. squamiger* will certainly affect wetlands management versus mosquito abatement activities in coastal communities plagued by that species.

The Central Valley of California has a well documented history of mosquito-borne outbreaks of encephalitis and human malaria (Reeves 1990). Urban and residential developments are currently expanding into Valley wetlands that support encephalitis transmission by *Culex tarsalis* Coquillett and *Aedes melanimon* Dyar and autochthonous malaria transmission by *Anopheles freeborni* Aitken and *Anopheles punctipennis* Say. Therefore, encroachment factors in association with a reduction in effective abatement services will seriously impact our ability to adequately protect Central Valley residents from these mosquito-borne diseases.

A similar "Valley" scenario is likely in the greater Los Angeles basin for developments bordering small tracts of wetlands in the uplands and valleys north and east of Los Angeles. Recent outbreaks of St. Louis encephalitis in the region were supported by limited *Culex* breeding in a surprisingly small number of sources (Reisen et al. 1991). Thus, small tracts of wetlands that are colonized by *Culex* in heavily urbanized environs have the potential of fostering the epidemic transmission of mosquito-borne encephalitides when the proper conditions prevail.

Residential encroachment on wetlands in the interior desert valleys of southern California presents a unique problem related to tourism. Retirees from Canada and the northern continental United States caravan to desert areas to winter in the mild climate. Some recreational vehicle (RV) parks that have been established to accommodate the hoards of "snow birds" are situated close to existing wetlands that are focally very active for both western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) viruses (Reisen et al. 1992). The elderly status of most RV park residents would put them at risk to infection with SLE. Also, of particular concern would be the potential of WEE transmission to younger residents in the event of a late spring in the north and early spring in the desert; in which case, the usual northern exodus would be delayed at the time when vernal WEE transmission would be anticipated.

Urban and Residential Factors.

Resources presented by urban environs that are situated near wetlands can enhance vector survival, reproductive success, and subsequent vector potential in encephalitis endemic areas.

For example, mosquitoes that invade a typical urban neighborhood from nearby wetlands breeding sources enter a well maintained environment of irrigated landscaping and man made shelters (e.g., woodpiles, sheds, etc.), abundant carbohydrate (e.g., ornamental blossoms and fruits) and host resources (e.g., resident wild birds, domestic pets, and humans), and access to breeding sources (e.g., abandoned swimming pools, ornamental ponds, etc.) These conditions can significantly increase vector and or nuisance potential by enhancing conditions that favor increased daily survival and reproductive success. Therefore, in some scenarios, it is feasible that encephalitis outbreaks can be linked to the interaction of wetlands mosquito production and urbanization where urban environs offer mosquitoes more in the way of resources that support enzootic disease transmission than nearby wetlands environs.

Kern River Scenario.

An unexpected epidemic of St. Louis encephalitis occurred in Kern County during the late summer and early fall of 1989. St. Louis encephalitis virus that was initially detected on the west side of the San Joaquin Valley spread rapidly eastward along the Kern River flood plain and eventually throughout the service area of the Kern Mosquito and Vector Control District (KMVCD) within a period of 4-6 weeks (Reisen et al. 1991).

Data obtained in previous studies by Reisen et al. (1990) indicated that residents living in housing tracts in juxtaposition of the Kern River channel in southwest Bakersfield are particularly vulnerable to contacting mosquito-borne encephalitides. During the 1989 outbreak, pools of *Cx. tarsalis* and *Culex quinquefasciatus* Say collected from new housing developments bordering the Kern River in the southwest area were highly positive for SLE (Emmons et al. 1991, Reisen et al. 1990). The KMVCD currently has unrestricted access to abate mosquitoes that breed in the Kern River environ. However, the river supports three endangered vertebrate species and seasonal wetlands during above normal rainfall years. Restricting KMVCD abatement activities in the river environ during a wet year could lead to conditions that result in encephalitis outbreaks similar to the outbreak that occurred in 1989. This probable scenario is quite disturbing and clearly illustrates public health problems that can arise as a consequence of the "paradox" and land usage conflicts.

Conclusions.

Tenable resolution of the paradox and associated conflicts will necessitate adjustments in public and environmental perceptions. Vector-supporting environs, particularly wetlands, that are juxtaposed to urban and periurban developments cannot be maintained without restructuring maintenance regimens that previously promoted the production of vectors. Wetlands management strategies will have to include mechanisms for impounding water in a manner that minimizes vector production, or if "biorational" methods of control are used, they will have to be self-sustaining and/or supplemented with more conventional control methods in emergency situations. This effort will require considerable interagency cooperation if wetlands are to be maintained and/or mitigated in populated areas.

References.

Eldridge, B.F., G.C. Lanzaro, G.L. Campbell, W.C. Reeves and J.L. Hardy. 1992. Occurrence and evolutionary significance of California encephalitis virus in the California salt marsh mosquito, *Aedes squamiger* (Diptera: Culicidae). J. Med. Entomol. (in press).

Emmons, R.W., D.V. Dondero, M.M. Milby, L.T. Hui, R.A. Murray, J.E. Tueller, F. Ennik, B.A. Wilson, L. Pitstick, J.L. Hardy, S.B. Presser, W.C. Reeves, L. Barrett and M.S. Ascher. 1991. Surveillance for arthropod-borne viral activity and disease in California during 1989. Proc. Calif. Mosq. Vector Control Assoc. 58:1-11.

Reeves, W.C. 1990. Epidemiology and control of mosquito-borne arboviruses in California, 1943-1987. Calif. Mosq. Vector Control Assoc., Sacramento, CA 508 pp.

Reisen, W.K., J.L. Hardy, W.C. Reeves, S.B. Presser, M.M. Milby and R.P. Meyer. 1990. Persistence of mosquito-borne viruses in Kern County, California, 1983-1988. Amer. J. Trop. Med. Hyg. 43:90-145.

Reisen, W.K., M.M. Milby, R.P. Meyer, A.R. Pfuntner, J. Spoehel, J.E. Hazelrigg, and J.P. Webb, Jr. 1991. Mark-release-recapture studies with *Culex* mosquitoes (Diptera: Culicidae) in southern California. J. Med. Entomol. 28:357-371.

Reisen, W.K., J.L. Hardy, S.B. Presser, M.M. Milby, R.P. Meyer, S.L. Durso, M.J. Wargo and E. Gordon. 1992. Mosquito and arbovirus ecology in southeastern California, 1986-1990. J. Med. Entomol. 29(3):512-524.

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REDUCTION OF SALT MARSH MOSQUITOES BY ENHANCING TIDAL ACTION

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Salt marsh mosquitoes, such as *Aedes dorsalis* (Meigen) and *Aedes squamiger* (Coquillett), have been a chronic problem in the San Francisco Bay area. In fact, the first mosquito abatement districts in California were formed in Marin and San Mateo Counties in 1915 and 1916, respectively, in response to these pestiferous mosquitoes. In 1926, Contra Costa Mosquito Abatement District was formed to address the problem of mosquitoes generated in the extensive marshes along the Sacramento-San Joaquin River Delta and San Francisco Bay.

There are currently about 6,000 acres of marsh in Contra Costa County, most of which have been altered or impacted by human activity. For instance, the marshes have been diked with the spoils from the 1906 San Francisco earthquake, duck clubs have been created, water control structures have been installed, and from about 1930 to 1978, mosquito abatement added miles of ditches to "dewater" the marsh and eliminate mosquito breeding. After the passage of Proposition 13 in 1978, the staff at Contra Costa Mosquito Abatement was drastically cut and ditching projects were virtually discontinued.

During the last several years, mosquito problems in the marshes of Contra Costa County have intensified. The ditches previously created for mosquito reduction are not alleviating the problem. In fact, the marshes with the most extensive ditch networks often generate the most mosquitoes. This is because the number, size and arrangement of these ditches were not determined in relation to marsh geomorphology and tidal hydrology, and thus water is not effectively conveyed throughout the marsh. For instance, the ditches increased the tidal capacity, or size, of the drainage networks without increasing the quantity of water entering the system. Thus, during a tidal influx, too much water was diverted to the ditches and not enough was available to maintain the upper reaches of natural channels. Portions of these upper channels have therefore filled in, creating isolated potholes of water which breed mosquitoes.

Mosquito problems are compounded by the desiccation of the organic marshland soils between the ditches and natural channels, which causes the soils to oxidize and subside. Consequently, the areas between the waterways are the lowest areas of the landscape, and mosquitoes are produced when water collects behind the spoil lines of ditches and the banks of natural channels. In addition, water control structures put in by mosquito abatement and other agencies have overly restricted tidal action, creating marshes with only limited tidal circulation.

In 1990, Contra Costa Mosquito Abatement District began a collaborative project with researchers from the Department of Geography, University of California at Berkeley, to develop guidelines to reduce salt marsh mosquitoes by enhancing tidal action. The draft guidelines, completed in June, 1991, provide a step-by-step methodology for designing a drainage network that allows the daily high tides to flood and then ebb from the marsh, thereby minimizing the amount of standing water available for mosquito development. The drainage design would be based on the geomorphology and tidal hydrology of the marsh, and should therefore provide a comprehensive, long-term approach to marsh mosquito reduction. The restoration of full tidal action to a marsh should also enhance the quality of that marsh for wildlife.

We next selected a 70 acre pilot project site to test the applicability of the guidelines and to assess fully the impact of enhanced tidal action on mosquito production and marsh quality. The site,

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located just north of Concord on U.S. Navy property, was selected because it has recurrent mosquito problems and because it's isolated hydrologically from the surrounding marsh. That is, it is bordered to the north by the Sacramento-San Joaquin River Delta, to the west and south by Hastings Slough, and to the east by a large, man-made channel. The drainage network within the pilot project site could therefore be manipulated without influencing other local marshlands. The site is criss-crossed with ditches created by mosquito abatement several decades ago, and there is only one major natural channel, which almost bisects the marsh. Prior to our enhancement project, the only major tidal source for the entire 70 acre marsh was through the mouth of this natural channel, where flow was restricted by a 36" culvert.

We'll now outline the procedure we used in the design and implementation of the pilot project, and our plans for evaluating the project's success. We began by closely monitoring the distribution and abundance of *Ae. dorsalis* larvae by inspecting the marsh and establishing a series of 59 monitoring stations in the poorly drained areas where there was mosquito production. Some stations were contiguous, whereas others were isolated low spots. Five dips were taken at each station after each of the seven tidal cycles between May and October, 1991, that were high enough (>6 ft) to inundate the stations. Only fourth instar larvae were sampled so that larvae would be exposed to approximately the same attrition period during each tide cycle. Average mosquito densities for each tide cycle ranged from about 0.5 to almost 8 larvae per dip (Fig. 1). The seasonal average was 3.6 larvae per dip (range 0.0-52.8 larvae/dip). The proportion of monitoring stations that were inundated and had larvae varied among the cycles, with the highest tides resulting in mosquito production at the most stations (Fig. 1). Marsh mosquito production is therefore a function of larval densities and the number and size of breeding sites.

In addition to documenting the abundance and distribution of *Aedes dorsalis* larvae, we needed to generate a topographic map of the marsh surface to assure the design of an efficient tidal drainage system. We tried several types of survey equipment, including simple laser levels and total station

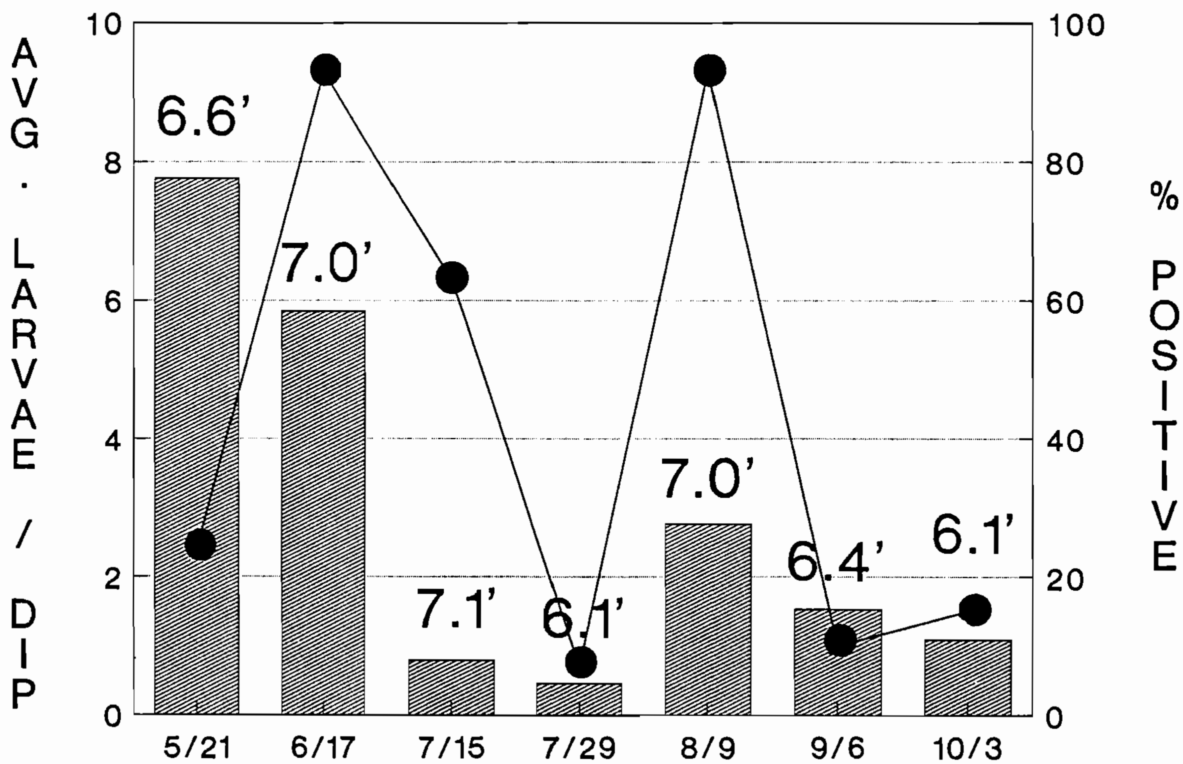

Figure 1. West Navy Marsh mosquito densities (bars), maximum tidal heights as predicted for the Golden Gate (above bars), and percent of stations inundated and with larvae (line), 1991.

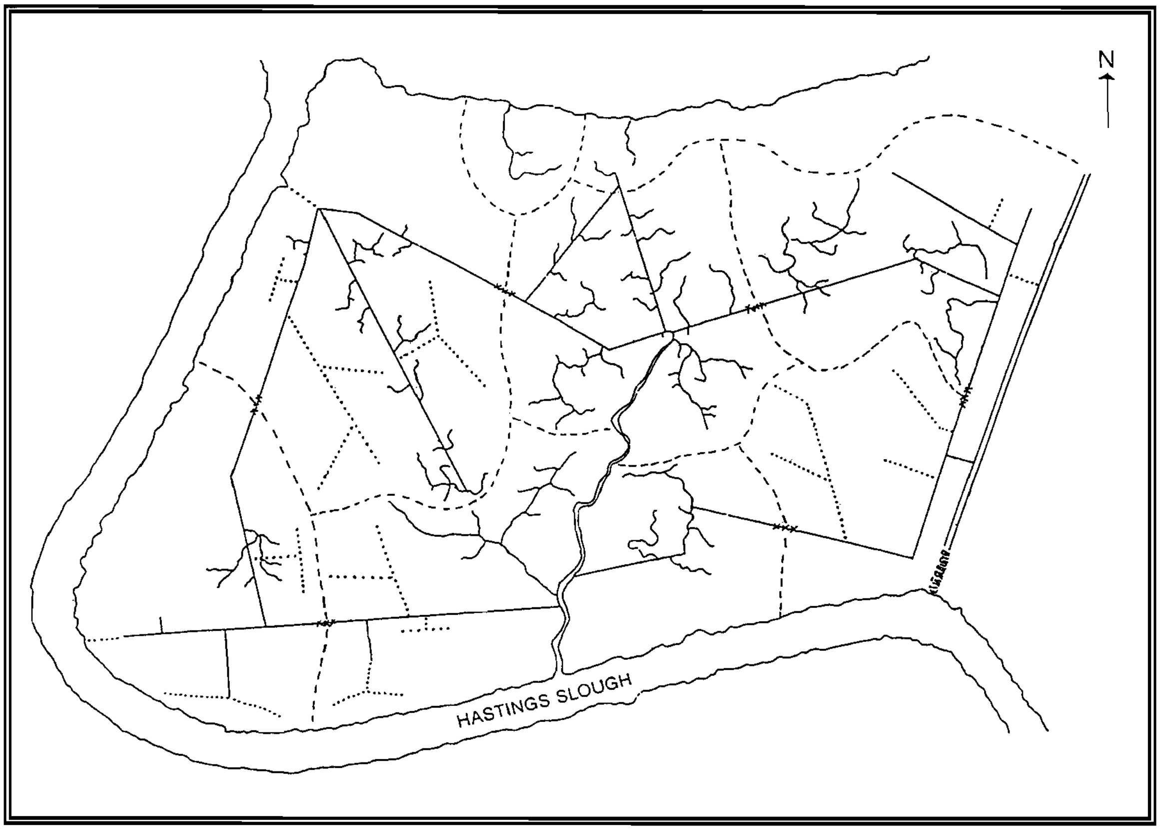

Figure 2. West Navy Marsh enhancement plan indicating new ditches (...........), existing ditches (——), drainage divides (-----), and eliminated ditches (xxx).

instruments. The potential benefits of total station instrumentation include computer-based data collection, storage, and analysis for cartography. Both hardware and software problems were encountered, however, and most elevations were determined by leveling with simple laser levels. Tidal elevations were established by the "Alternate Method" of tidal datum reckoning (Swanson 1974) based upon local National Oceanic and Atmospheric Administration (NOAA) benchmarks.

We determined the approximate location of drainage divides, or high areas on the marsh, and used these divides to delineate seven independent drainage subsystems (Fig. 2). To provide a tidal source for each drainage subsystem, the perimeter levee of the site was breached in three places, thereby converting the marsh from limited to full tidal action.

We found that many of the existing ditches crossed the drainage divides, so the plan included filling in 8-foot sections of these ditches at the divides with excavated marsh soil. The number and location of new ditches extending into mosquito sources were determined in relation to marsh topography. Each existing or proposed ditch or channel was assigned a code number, and its exact dimensions calculated using empirical formulas derived from studies of natural regional tidal marsh geomorphology (Collins et al. 1986, Collins et al. 1987, Haltiner and Williams 1987). These formulas involved several variables, such as the area of the drainage basin and marsh elevation. It was critical that the depth and width of the ditches be adequate to effectively convey water to and from all regions of the marsh during each tidal cycle.

We expect the restoration of tidal action to benefit wildlife by enhancing the vigor and complexity of the marsh vegetation. To document the impact of the pilot project on the marsh plant community, we acquired an infrared photograph of the site, took the photo to the field, correlated the colors on the photo with the marsh vegetation types, and generated a vegetation map. The predominant marsh plants were pickleweed (*Salicornia virginica*) and peppergrass (*Lepidium latifolium*). Mosquito densities were highest in pickleweed, which provides a very protected habitat for mosquito larvae. We will be documenting changes in the plant community over the next several years by purchasing subsequent infrared photographs, available through the Army Corps of Engineers. We also measured pickleweed vigor by randomly measuring the height and percent coverage of the plant in 96 quarter meter quadrants. The least vigorous pickleweed was found in the most poorly drained areas of the marsh, which sometimes had no vegetation at all. We'll compare those data with measurements taken subsequent to project completion.

We began implementation of the pilot project plan on the first of November, 1991. We carefully flagged the location of new ditches, using different colored flags to represent particular ditches. The field crew then correlated ditch number and flag color with ditch dimensions. We used an excavator with a two foot wide bucket to create new ditches and enlarge some of the existing ditches. The new ditches ranged from about 1-4 feet in depth, and 2-12 feet in width; the widest ditches were those that breached the levees. Spoils were mounded in piles on alternating sides of the ditch and were widely spaced so that water would not become trapped behind them. We expect that these spoil piles will be slowly eroded by rain and tide, but that in the interim, they will be colonized by upland plant species, providing upland escape habitat for wildlife.

The project took six weeks to complete, and included digging 4,000 feet of new ditches, enlarging 2,500 feet of existing ditches, filling in six ditch segments at drainage divides, creating three levee breaks, and removing the 36" culvert restricting flow into the natural channel bisecting the marsh. The costs of approximately $7,000 for equipment rental and materials and $24,000 for in-house labor were covered, in part, through a contract with the U.S. Navy. We expect this project to be cost effective in the long run because the number of routine inspections and larvicidal treatments should be drastically reduced.

Since the excavation work has been completed, the amount of water entering the drainage system, flooding the marsh plain, and draining back into the channels has greatly increased, leaving little standing water between high tides. Extensive reconnaissance during April, 1992, revealed rapid sedimentation on the marsh surface, the elimination of ground fissures, substantial new plant growth in excess of previous conditions, abundant waterfowl and shorebirds previously unseen at the site, and no mosquito larvae.

The impact of the project on mosquito numbers will continue to be evaluated by repeating, for the next several years, the intensive surveillance program described above. To determine whether any reductions in mosquito densities are due to enhanced tidal action, rather than other physical or biological factors, numbers of *Ae. dorsalis* in the marsh surrounding the pilot project site have also been documented, and larval densities there will continue to be monitored. We expect to see a significant reduction in mosquito numbers in 1992 but also expect that the system will have to be refined through the years, by, for instance, extending small ditches into remaining or newly evolved mosquito sources.

Substantial changes in marsh geomorphology and ecology will probably occur over the next 5 years, and equilibrium conditions might be achieved in about ten years. We expect to see the marsh surface continue to build up in response to greater supplies of suspended sediments, especially in low-lying areas which serve as sediment traps. The salinity and moisture gradients of the soil will change and, in general, the system will begin to acquire the characteristics of a fully tidal, unaltered marsh. Ecological conditions will therefore be enhanced for species of plants and animals that are endemic to the tidal wetlands of the region.

If this pilot project proves to be successful in reducing mosquito densities while enhancing the quality of the marsh ecosystem, as we expect it will, then similar source reduction projects will be designed for other marshes in Contra Costa County.

Acknowledgments.

We thank the Contra Costa Mosquito Abatement District's Vector Control Inspectors who made completion of this project possible. The input and assistance of Craig Downs, Stephen Perkins, and Carlos Sanabria were greatly appreciated.

References.

Collins, J.N., L.B. Leopold, and V.H. Resh. 1986. The influence of mosquito control ditches on the geomorphology of tidal marshes in the San Francisco Bay Area: Evolution of salt marsh mosquito habitat. Proc. Calif. Mosq. Vector

Control Assoc. 54:91-95.
Collins, L.M., J.N. Collins, and L.B. Leopold. 1987. Geomorphic processes of an estuarine marsh: Preliminary results and hypotheses, pp. 1049-1072. *In*: V. Gardiner (ed.), International Geomorphology 1986 Part I. John Wiley and Sons, Ltd., London.
Haltiner, J. and P.B. Williams. 1987. Hydraulic design in salt marsh restoration, pp. 293-299. *In*: J.A. Kusler and G. Brooks (eds.), Wetland Hydrology, Proceedings of National Wetland Symposium, Chicago, IL. Association State Wetland Managers, Inc., Berne, NY.
Swanson, R.L. 1974. Variability of Tidal Datums and Accuracy in Determining Datums From Short Series of Observations. NOAA Tech. Report NOS 64., U.S. Dept. of Commerce.

THE INTERRELATIONSHIPS OF AGENCIES HAVING ROLES AND RESPONSIBILITIES INVOLVING WETLANDS

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MODERATOR'S SUMMARY REMARKS

In summarizing, I am just picking some of the key points; and I apologize in advance for what I leave out that was important.

Mr. Dill, representing the CMVCA, was the first speaker and I think what he said in essence was that we are vector biologists and we want to be respected as professional biologists. He was asking for the vector control community to be accepted as part of the wetlands coalition.

Mr. Paullin, representing the U.S. Fish and Wildlife Service's interests in the Central Valley Habitat Joint Venture Committee, indicated that we have a serious problem with the wetlands situation. Ninety-two percent of California wetlands have disappeared, and the wildlife populations are in a downward spiral. What we are required to do in California immediately is focus on 120,000 acres of wetlands to be restored in the Central Valley; a critical wildlife area.

Mr. Smith, from the California Department of Fish and Game, told us that Propositions 19, 17, and 99 indicate that California citizens want these wetlands. He presented a very promising picture of the relationship between wildlife personnel and vector control. He said he works effectively with mosquito abatement personnel; and if I heard it right, California Department of Fish and Game is willing to pay for the use of *Bti*.

Mr. Sorensen of the U.S. Fish and Wildlife Service, speaking from the perspective of endangered species, told us that over 60% of the endangered species are found in wetland habitats. He raised an interesting issue you might think about. Are there mosquito problems in the vernal pools? Talk to Pete, he wants that information. He also described water management in mosquito control as a promising solution to some wetlands problems.

Richard Meyer, of Kern Mosquito and Vector Control District, spoke about a paradox where residences encroach on wetlands, and the result can be mosquito-borne disease. The proximity of wetlands and residences creates the basic conflict between wildlife interest and disease control. He created a bleak scenario when he talked about "zero protection threshold". A new concept, and I think it needs to be looked at very carefully.

Phil Oshida, from the U.S. Environmental Protection Agency (EPA), told us about the voluminous input that the EPA receives. He questioned whether or not we are really talking about a paradox. He informed us that EPA is trying to resolve the public and environmental health conflict. One of the really significant things that was said, I felt, and some of us here can attest to it, is that he feels that vector control is seen too late in the planning and permit processes. He suggests that we move one step back and get involved in the planning process. We, in mosquito control, can only concur with that I am sure. Phil was concerned about the wetlands manual and the potential reduction of wetland jurisdiction ranging from 20-80%, a serious concern for the EPA.

Vicki Kramer, Contra Costa Mosquito Abatement District, must have been a breath of fresh air for Pete primarily because she didn't talk about conflict or paradox. She talked about mosquito control in a wetlands where they focussed on geomorphology and hydrology as a means for mosquito control as well as marsh enhancement. She described a highly scientific approach sensitive to the environment and to mosquito control. The approach seemed to suggest there is no paradox; there is no conflict.

So, again taking the viewpoint of an informed citizen, after hearing all of this I think we have taken the first step. I think the agencies have established a dialogue. They are saying we need to be working together more closely. I picked up a hint that there is something lacking, however, and if I were to say what it is most basically, I would say that it is a high environment of trust. I think that is going to be essential in the future if we are going to be able to work together effectively. Before I open it up for questions, let me give you a couple of examples of why I think that. You are going to hear some things when I give these examples that are the real world we are dealing with. It can change.

In an atmosphere of high trust, when we consider those from other disciplines as colleagues, they are partners and we act in collaboration; we are inclusive, we bring them into our discussions. When we act in an atmosphere of low trust, we look at them as interlopers, as impediments to progress; we attempt to act unilaterally. In a high trust atmosphere, we can work in cooperation and use informal approaches. In a low trust atmosphere, we invoke laws and we stonewall. In high trust environment, we can develop win/win situations. I believe that is what Vicki was talking about. We can develop synergistic solutions. In low trust environments, we end up with win/lose or lose/lose situations. In low trust atmospheres, compromise is the best possible expected result. I do not think compromise is effective in designing and managing complex wetlands.

I believe that a high trust environment is vital to the process. I would like to suggest that the next step we take in getting together should be orientated toward developing that high trust environment.

QUESTIONS AND ANSWERS

I would like to open it up for questions from the audience to anyone on the panel. Are there any questions?

QUESTION: How are we going to get involved at the city level in city planning?

ANSWER (PHIL OSHIDA): The way we are trying to do it is we are trying to work at more of a landscape, a watershed level, because the problem is, I think, that the federal wetlands program only goes up to the edge of the wetland. You are not city planners. You cannot put something just outside of a wetland. There is no regulation. That is the problem that we are having. We can only say what does not go in the wetlands. We cannot say what goes next to the wetland. That is why we are taking sort of the watershed approach. We are trying to work with County Supervisors, Planning Departments, the other wildlife agencies, and vector control agencies for what is best for the watershed. We try to incorporate some of those buffer zones that you talk about and we, like the wildlife agencies, like also. We do not have something that says by authority of such and such we can say what goes on. We are trying to do it cooperatively and right now we are working on that trust. And it is going to be hard but I think everybody understands the problems of wetlands, but we also realize that California has increasing population growth.

QUESTION: First, I'd like to say how much I appreciated Vicki Kramer's talk. I thought that was a real fine example of mosquito and vector control districts working to solve a mosquito problem and recognizing the importance of a wetland to other segments of the population and wetland managers. I hope that there more examples of that in the future. I would like to ask a question of the wetland managers. What degree do you see recognition on a local level by wetland managers and agency personnel of the importance of mosquito control? How widespread is it? What steps have you taken or you feel need to be taken to increase that recognition? I feel that there has been more recognition out there than has been indicated.

ANSWER (DAVID PAULLIN): I can give two examples, both very positive. I think our first outreach to the mosquito control folks in Sacramento was about a year ago. There was a meeting with a lot of wetland and mosquito abatement people just exchanging information. As an upshot of that meeting, we now have an ongoing dialogue and contact with the Sacramento/Yolo Vector Control District on two projects, Stonelake and Yolo Bypass. We have monthly meetings with what we call the Yolo Basin Working Group over in

Davis. Alan Hubbard, Stan Wright, and Dave Brown come all the time. I mean they are there every month. Sometimes not all three of them, but every month there is a least one of those folks there. They are giving us information on wetland design. We are telling them about the needs of wildlife, and we are now getting together and discussing how do you massage those needs and make it work.

The other project is down in south Sacramento County in Stonelake. There is a lot of information being shared and a lot of concerns being raised about that very issue. In the Elk Grove area, a big urbanization area, you have a lot of people moving right out next to this wetland and wildlife refuge. There is one case in point where the outreach went both ways. It is in the offing. We have not really gotten too far with it, but we have had contact with San Joaquin Mosquito Abatement District folks about getting involved in the Delta. I think that dialogue has been very positive. We just have not gotten the project far enough down the road in the Delta yet that we can talk about a particular case.

ANSWER (PHIL OSHIDA): As I mentioned, our particular planning group has not been around terribly long. We have had one major planning project that has been going on in Arizona. I did not mention it today. The other ones I mentioned in San Diego County are maybe in their fourth month of development. Other agencies have been working there for awhile. So, I guess the message I will take back for the people in my staff is to make sure that the vector control people are involved or at least notified and probably push them to make sure they are involved. We talked a little bit with Janet Ortiz of the San Diego Vector Control District about the project in San Diego. So, at least we have started. But I cannot say that it is something we have been doing for a long time. It is something that we will try to get better at.

I'd just like to say that most, if not all of the Central Valley wildlife area statewide, had a budget item that is for mosquito abatement. We pay for those services. I think the moderator is correct that in many cases that the level of trust has not been good. Perhaps, there has been stonewalling on our part. I think there is the area we really need to work more diligently on in the future. To work cooperatively like I think we have not been doing. Try to work with the field people to understand more about mosquitoes and for them to understand more about wetland management so we can do a better job and the dollars will accomplish more.

SURVEILLANCE FOR ARTHROPOD-BORNE VIRAL ACTIVITY AND DISEASE IN CALIFORNIA DURING 1991

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This brief report summarizes arboviral surveillance activities during 1991 and is the 22nd report to the California Mosquito and Vector Control Association (CMVCA) since 1969. The surveillance program involves cooperative efforts by many groups and individuals from local mosquito control agencies; the Arbovirus Research Program at the University of California at Berkeley; the California Mosquito and Vector Control Association; the CMVCA Research Foundation; county and local public health departments; the California Department of Food and Agriculture (CDFA); physicians and veterinarians throughout California; and three branches of the California Department of Health Services (CDHS)- the Infectious Disease Branch, the Environmental Management Branch (EMB), and the Viral and Rickettsial Disease Laboratory (VRDL) of the Division of Laboratories.

Announcements about the program and 30 weekly bulletins (April 11-November 29) were distributed widely during the season to provide detailed surveillance data. Many recipients now receive these via facsimile transmission (FAX), and eventually all recipients of the bulletin should have FAX equipment to receive reports as quickly as possible. Information is also available on the CMVCA's MosquitoNet computer system. In addition to the weekly bulletins, positive findings were telephoned immediately to the agency which submitted the mosquito pools or sentinel chicken sera.

Clinical and laboratory surveillance for human and equine cases of encephalitis, meningoencephalitis and meningitis detected only one case of St. Louis encephalitis (SLE) acquired in California: a 39-year old man from Valinda, Los Angeles County, with onset 10/11/91 and place of exposure most probably the Santa Fe Dam

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Recreational Park and flood control basin near Irwindale, where 14 of 15 sentinel chickens seroconverted to SLE virus during September. There were no confirmed cases of western equine encephalomyelitis (WEE) in equines or humans in California.

Two additional cases of SLE were detected in California residents, but infections were contracted outside of California. One case was a 21-year old male on active duty in the U.S. Army, who arrived on 10/1/91 at Ft. Irwin, near Barstow, San Bernardino County. He became acutely ill on 10/2/91 with encephalitis and was hospitalized on 10/4/91 at March Air Force Base in Riverside County. He had been training at Ft. Bliss, McGregor Range, Otero County, New Mexico from June until he returned to Fort Irwin. The site of infection was most likely the field training area in New Mexico. Serum samples were submitted to the VRDL by the Riverside County Public Health Laboratory and SLE was confirmed serologically.

The second case, reported to the Infectious Disease Branch by the San Diego County Public Health Department, was a 44-year old man from Solano Beach, who became ill 9/11/91 and was found positive for SLE viral antibodies by a private laboratory. He had travelled during August 24-31 in the areas of Prescott, Winslow, and Monument Valley in Arizona, and was most likely infected in an area east of Winslow.

Tests were done by the VRDL on 4,589 mosquito pools, containing 184,770 mosquitoes (Table 1). The majority of the pools were submitted from Los Angeles, Riverside, Kern, and Orange Counties. *Culex tarsalis* Coquillett made up 47.8% of the pools, *Culex pipiens* Linnaeus complex 42.2%, and *Culex stigmatosoma* Dyar, *Aedes melanimon* Dyar and other species the remainder. Only eight viral isolations were made by the VRDL, all from sites in Los Angeles County (Table 2). These included one SLE and seven WEE viral strains. Viral tests in the VRDL program are now limited to SLE, WEE and California encephalitis (CEV) group viruses. Additional mosquito pools from the lower deserts of southeastern California and Kern County were tested by the U.C. Berkeley Arbovirus Researach Laboratory (Table 3).

Sentinel chicken flocks were located at 102 sites covering most enzootic areas of the state. Serum samples were collected and tested monthly for SLE and WEE viral antibodies from May through November by the VRDL, and during the winter period for selected flocks by the U.C. Berkeley Arbovirus Laboratory (Tables 4 and 5). No viral activity was detected in northern California. Seroconversions occurred from June onwards in southern California (Imperial Valley, Coachella Valley, Needles in San Bernardino County, Irwindale and Long Beach in Los Angeles County).

An even larger surveillance program will be conducted during the 1992 season, since the cyclic occurrence of viral activity continues to be unpredictable and there is an annual possibility of an epidemic.

Acknowledgements.

We thank Robert Kang for special assistance in the testing of mosquito pools and chicken sera. We are also grateful for the help of many other staff members of the Viral and Rickettsial Disease Laboratory, Environmental Management Branch and Infectious Disease Branch of the California State Department of Health Services; the Arbovirus Field Station and the Arbovirus Research Unit, School of Public Health, University of California, Berkeley; participating local mosquito control agencies; local health departments; the California Department of Food and Agriculture; and physicians and veterinarians who submitted specimens from suspect clinical cases. We especially thank the California Mosquito and Vector Control Association for support needed for laboratory tests.

Table 1. Number of mosquitoes and pools tested in the VRDL for WEE, SLE, and CE viruses during 1991.

County	*Cx. tarsalis*		*Cx. pipiens* complex		*Cx. stigmatosoma*		*Ae. melanimon*		Other Species		Totals	
	mosq.	pools	mosq.	pools	mosq.	pools	mosq.	pools	mosq.	pools	mosq.	pools
Fresno	71	2	361	9							432	11
Imperial	3780	83	181	5					915	20	4876	108
Inyo	380	9					492	12			872	21
Kern	14194	307					5264	116			19458	423
Lake	842	17					106	3			948	20
Los Angeles	25966	669	32786	881	1568	70					60320	1620
Merced	195	6	187	4			79	2			461	12
Orange	7899	225	25760	656							33659	881
Placer	35	2									35	2
Riverside	14845	334	12248	279	6602	170					33695	783
Sacramento	5103	109			20	1					5123	110
San Bernardino	3590	91	360	16	681	22					4631	129
San Diego	6544	162	1027	21	173	5					7744	188
Shasta	135	5									135	5
Sonoma	98	3	20	1	17	2					135	6
Stanislaus	2301	50	1617	37			1350	30			5268	117
Sutter	1999	45									1999	45
Tulare	1478	31	1132	24							2610	55
Ventura	1024	23	227	5	117	3					1368	31
Yolo	474	10									474	10
Yuba	527	12									527	12
Totals	91480	2195	75906	1938	9178	273	7291	163	915	20	184770	4589

Table 2. Mosquito pools found positive for SLE and WEE viruses by the VRDL in 1991.

Dist	#	Species	Date	Place	Co	Long	Lat	Collector	Mosq	Pool	WEE	SLE
LACO	197	*Cx. stigmato*	09/23/91	Pomona	L.A.	11745	3405	Brisco	41	1	0	1
LOSA	355	*Cx. pipiens*	09/24/91	Torrance	L.A.	11820	3350	Pierson	50	1	1	0
LOSA	356	*Cx. pipiens*	09/24/91	Torrance	L.A.	11820	3350	Pierson	50	1	1	0
LOSA	363	*Cx. tarsalis*	09/24/91	Torrance	L.A.	11820	3350	Pierson	40	1	1	0
LOSA	364	*Cx. pipiens*	09/24/91	Torrance	L.A.	11820	3350	Pierson	50	1	1	0
LOSA	371	*Cx. tarsalis*	09/25/91	Encinal Canyon	L.A.	11840	3410	Pierson	50	1	1	0
LOSA	372	*Cx. tarsalis*	09/25/91	Encinal Canyon	L.A.	11840	3410	Pierson	22	1	1	0
LOSA	379	*Cx. tarsalis*	09/25/91	Malibu	L.A.	11840	3400	Pierson	22	1	1	0
								Totals	325	8	7	1

Table 3. Mosquito pools tested by the Arbovirus Research Laboratory in 1991. Positive findings included 4 SLE and 15 WEE virus isolates from the Coachella Valley, and 40 SLE and 58 WEE virus isolates from the Imperial Valley.*

Agency	Total Mosquitoes (Pools)	*Culex tarsalis*	*Culex quinquefasciatus*	*Culex erythrothorax*	*Culiseta inornata*	*Aedes melanimon*
CHLV	26,864 (625)	25,932 (593) 4 SLE 15 WEE	888 (31)	0	44 (1)	0
IMPR	15,682 (355)	15,482 (351) 40 SLE 58 WEE	0	200 (4)	0	0
KERN	1,855 (47)	308 (13)	0	0	0	1,547 (34)
Totals	44,401 (1,027)	41,722 (957) 44 SLE 73 WEE	888 (31)	200 (4)	44 (1)	1,547 (34)

* A complete list is available from the Arbovirus Research Unit, School of Public Health, U.C. Berkeley.

Table 4. SLE seropositive chickens/number tested (percent positive), Northern California, 1991

Flock Location	Number SLE positive/number tested (percent positive)							
	Apr 15- Apr 17	May 13- May 22	Jun 10- Jun 14	Jul 8- Jul 23	Aug 5- Aug 12	Aug 30- Sep 9	Sep 30- Oct 2	Oct 28-
			Northern California					
Shasta, Pine Grove MAD	.	0/15	dead					
Shasta, Cottonwood	.	0/10	0/10	0/9	0/10	0/10	0/10	0/8
Shasta, Anderson	.	0/10	0/10	0/9	0/10	0/10	0/10	0/9
Tehama, MAD Office	.	0/15	0/15	0/15	0/15	0/15	0/15	
Butte, Chico	.	0/12	0/11	.	0/11	0/11	0/11	
Butte, Honcut	.	0/15	0/12	.	0/12	0/12	0/11	
Butte, Gray Lodge	.	0/15	0/14	.	0/14	0/14	0/14	
Glenn, Willows	.	0/15	0/15	0/15	0/15	0/15	0/15	
Coluse, Reading Oil	.	0/15	0/15	0/14	0/14	0/14	0/14	
S-Yuba, P.V. Ranch	.	0/15	0/15	0/15	0/14	0/14	0/14	
S-Yuba, Dean's	.	0/15	0/15	0/13	0/13	0/11	0/11	
S-Yuba, Barker	.	0/15	0/15	0/15	0/15	0/15	0/14	
Sac-Yolo, Merritt	.	0/14	0/14	0/14	0/14	0/14	0/14	
Sac-Yolo, Natomas	.	0/15	0/15	0/13	0/13	0/13	0/13	
Sac-Yolo, Elk Grove	.	0/15	0/15	0/12	0/12	0/12	0/12	
Marin-Sonoma, W. Santa Rosa	.	0/10	0/10	0/10	0/10	0/9	0/10	
Marin-Sonoma, Eldridge	.	0/10	0/10	0/9	0/10	0/10	0/10	
Lake, MAD Office	.	0/15	0/15	0/15	0/15	0/15	0/15	
Solano, Grizzley Island	.	0/20	0/20	0/20	0/20	0/20	0/19	
Santa Clara, San Jose	.	0/15	0/15	stolen				
Monterey, Castroville	.	0/14	0/15	0/15	0/15	0/15	0/15	
No. Calif. total	.	0/295	0/276	0/213	0/252	0/249	0/247	0/17
			San Joaquin Valley					
San Joaquin, Thornton	.	0/14	0/14	0/10	0/11	0/11	0/10	
San Joaquin, Escalon	.	0/15	0/15	0/11	0/11	0/12	0/9	
Eastside, Oakdale	.	0/14	0/15	0/15	0/15	0/13	0/15	
Turlock, Modesto	.	0/15	0/15	0/5	0/4	0/4	0/4	
Turlock, Vitorie	.	0/15	0/14	0/9	0/9	0/9	0/9	
Merced, Gustine	.	0/15	0/15	dead				
Merced, Veldhaus	.	0/15	0/15	0/15	0/14	0/15	0/15	
Madera, Madera	.	0/15	0/15	0/14	0/14	0/14	0/14	
Fresno W'side, Mendota Ref.	.	0/15	0/15	0/8	0/8	0/8	0/7	
Consolidated, Friant Rd.	.	0/15	0/15	0/15	0/15	0/15	0/14	
Kings, MAD Office, Hanford	.	0/15	0/15	0/15	0/15	0/15	0/15	
Delta, Kingsburg GC	.	0/10	0/9	0/8	0/8	0/8	0/8	
Delta, Goshen	.	0/9	0/9	0/9	0/9	0/9	0/9	
Delta, Woodlake	.	0/9	0/9	0/8	0/8	0/8	0/8	
Delta, Visalia	.	0/9	0/9	0/9	0/9	0/9	0/8	
Delta, Rocky Pt., Porterville	.	0/10	0/10	0/10	0/9	0/9	0/9	
Delta, Linsley	.	0/10	0/10	0/10	0/10	0/10	0/10	
Tulare, MAD Office	.	0/15	0/15	0/8	0/8	0/8	0/8	0/8
Delano, Teviston	.	0/15	0/15	0/13	0/13	0/13	0/13	
West Side, Belridge	.	0/15	0/14	0/14	0/14	0/13	0/13	
West Side, Maricopa	.	0/15	0/15	0/15	0/15	0/15	0/15	
Kern, Wildlife Refuge	0/19	0/19	0/19	0/17	0/19	0/18	0/17	
Kern, River Bottom	0/20	0/20	0/20	0/17	0/18	0/18	0/18	
Kern, John Dale	0/20	0/20	0/19	0/19	0/18	0/18	0/18	
Kern, 9 miniflocks	0/83	0/83	0/81	0/64	0/87	0/85	0/85	
San Joaquin total	0/142	0/422	0/417	0/338	0/361	0/357	0/351	0/8

Table 5. Seropositive chickens/number tested (percent positive), Southern California, 1991

Flock Location — Number SLE positive/number tested (percent positive)

Flock Location	Apr 29-May 2	May 21-May 31	Jun 24-Jun 29	Jul 22-Jul 30	Aug 19-Aug 30	Sep 16-Sep 25	Oct 14-Oct 21	Nov 11-Nov 26
Goleta, Gray's Ranch	0/10	0/9	0/10	0/10	0/10	0/10	0/10	
Ventura, Fillmore Hatchery,Oxnard	0/10	0/10	0/10	0/10	0/10	0/10	0/10	
Ventura,Hill Canyon,Thousand Oaks	0/10	0/10	0/10	0/10	0/10	0/10	0/10	
Ventura, Simi Valley	0/10	0/10	0/10	0/10	0/10	0/10	0/10	
Long Beach, Shoreline RV	0/20	0/15	0/15	0/15	0/15	0/15	0/15	1S/15(7)
Long Beach, El Dorado Park	0/20	0/15	0/15	0/15	0/15	0/15	0/15	0/15
Los Angeles, (LOSA),La Brea	0/15	0/15	0/15	0/15	0/15	0/15	0/15	
Los Angeles, (LOSA), Hidden Hills	.	0/15	0/15	0/15	0/15	0/15	0/15	
Los Angeles (LACO), Irwindale	0/15	0/15	0/15	0/15	0/15	13S/15(87)	14S/20(70)	14S/20(70)
Los Angeles (LACO), Pomona	0/15	0/15	0/15	0/14	0/14	0/14	0/14	0/14
Los Angeles (LACO), Altadena	.	0/15	0/15	0/15	0/15	0/15	0/15	0/14
Los Angeles (SOUE), Sepulveda	0/15	0/15	0/15	0/15	0/15	0/15	0/13	
Los Angeles (SOUE), Harbor Lake	0/15	0/13	0/15	0/14	0/15	0/13	0/13	
Los Angeles (ANTV), Lancaster	0/15	0/15	0/15	0/15	0/15	0/15	0/15	
Orange, Duck Club	0/23	0/15	0/15	0/14	0/15	0/15	0/15	
Orange, Buena Park, 3 miniflocks	0/14	0/14	0/14	0/14	0/13	0/14	0/14	
San Bernardino, Flood Control	0/10	0/15	0/14	0/15	0/15	0/15	0/15	
San Bernardino, Needles	0/17	0/20	0/21	0/20	0/17	1S/17(6)	1S/17(6)	1S/16(6)
West Valley, Chino, Tuenissen	0/15	0/14	0/14	0/14	0/14	0/13	0/14	
Northwest, Corona	0/15	0/14	0/15	0/14	0/13	0/14	0/14	0/14
Coachella Valley, Indio*	0/19	0/19	0/19	0/19	4W/17(24)	9W/16(56)e	4W/18(22)k	1W/20(5)
Coachella Valley, Mecca*	0/20	0/20	5W/20(25)a	2W/20(10)	6W/20(30) 2S/20(10)	11W/20(55)g 9S/20(45)g	3W/23(13)m 5S/23(22)m	0/21q 1S/21(5)q
Coachella Valley, Thermal*	0/20	0/20	0/20	1W/20(5)	3W/20(15)	4W/20(20)f	1W/20(5)l	0/19
CHLV, Mecca, 12 miniflocks*	0/120	0/121	3W/120(3)	9W/124(7)b 3S/124(2)	45W/117(38) 15S/117(13)	52W/114(46)h 51S/114(45)h	9W/144(6)n 31S/144(22)n	3W/132(2)r 12S/132(9)r
Imperial, Drew Rd., Seeley*	0/20	0/20	0/20	2S/20(10)	16S/21(76)c 15W/21(71)	17S/20(85)i 17W/20(85)i	6S/25(24)o 6W/25(24)o	2S/19(11) 0/19
Imperial, Seeley, 6 miniflocks*	0/60	0/56	1S/58(2)	5S/60(8)	31S/65(48)d 28W/65(43)	45S/56(80)j 43W/56(77)j	18S/80(23)p 16W/80(20)p	9S/62(15)s 0/62s
Imperial, Palo Verde	.	0/15	0/16	0/19	0/17	0/19	.	0/14
San Diego, Tijuana River	0/14	0/14	0/14	0/14	0/14	0/14	0/14	
San Diego, Lakeside	0/14	0/14	0/14	0/15	0/15	0/15	0/15	
San Diego, Guajome Park	0/14	0/12	0/13	0/13	0/13	0/13	0/13	
So. Calif. total	0/565	0/590	8W/597 1S/597	12W/603 9S/603	89W/595 59S/595	136W/582 136S/582	39W/631 79S/631	
	Apr 29	May 20	Jun 17	Jul 22	Aug 19	Sep 18	Oct 21	Nov 12
Nevada, Fallon, Macari	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/19
Nevada, Fallon, N. Bdwy	0/19	0/20	0/20	0/17	0/17	0/17	0/17	0/17

* These flocks bled Mar 5-6 and Apr 1-3; all neg.
a. 5 WEE-pos. chickens replaced after June bleeding.
b. 3 WEE-pos. chickens replaced after July bleeding.
c. 1 SLE-pos. chicken replaced after August bleeding.
d. 5 SLE-pos. chickens replaced after August bleeding.
e. 4 WEE-pos. chickens replaced after Sept. bleeding.
f. 3 WEE-pos. chickens replaced after Sept. bleeding.
g. 8 WEE- and 5 SLE-pos. chickens replaced after Sept. bleeding.
h. 44 WEE- and 32 SLE-pos. chickens replaced after Sept. bleeding.
i. 12 WEE- and 11 SLE-pos. chickens replaced after Sept. bleeding.
j. 24 WEE- and 24 SLE-pos. chickens replaced after Sept. bleeding.
k. 3 WEE-pos. and 1 neg. chicken replaced after Oct. bleeding.
l. 1 WEE-pos. chicken replaced after Oct. bleeding.
m. 3 WEE- and 4 SLE-pos. chickens replaced after Oct. bleeding.
n. 7 WEE- and 17 SLE-pos. chickens replaced after Oct. bleeding.
o. 6 WEE- and 6 SLE-pos. chickens replaced after Oct. bleeding.
p. 16 WEE- and 14 SLE-pos. chickens replaced after Oct. bleeding.
q. 1 SLE-pos. chicken replaced after Nov. bleeding.
r. 1 WEE- and 10 SLE-pos. chickens replaced after Nov. bleeding.
s. 1 SLE-pos. chicken replaced after Nov. bleeding.

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ARTHROPOD-BORNE ENCEPHALITIS VIRUS SURVEILLANCE IN LOS ANGELES COUNTY, CALIFORNIA DURING 1991

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ABSTRACT

In 1991 arthropod-borne encephalitis virus surveillance in Los Angeles County was interesting in several respects. Despite the fact that sera from 14 of 15 (93%) chickens from a sentinel flock in the San Gabriel Valley developed antibodies to St. Louis encephalitis (SLE) virus, and a case of SLE occurred in an individual exposed to mosquitoes from that area, no virus was isolated from 171 pools of *Culex tarsalis* collected from the vicinity. Conversely, although SLE virus was isolated from a single pool of *Culex stigmatosoma* collected approximately 18 km southeast of the first site, no antibodies to SLE virus were detected in sera from the sentinel chicken flock located there. These two episodes marked the first detection of arthropod-borne virus in the San Gabriel Valley since 1986.

Introduction.

The first recorded epidemic of St. Louis encephalitis (SLE) in Los Angeles County occurred in 1984 with 16 serologically confirmed cases and one reported death (Monath and Tsai 1987). Only six cases were reported during the next seven years, although SLE virus has either been isolated from mosquitoes, or antibodies to the virus have been found in sera from sentinel chicken flocks in Los Angeles County each year since 1985 (Los Angeles County Department of Health Services data). Here we describe the events surrounding the detection of SLE virus in Los Angeles County during 1991.

SLE Virus Detection.

On September 27, 1991, the Los Angeles County Department of Health Services (DHS) was notified by the California State Viral and Rickettsial Diseases Laboratory (VRDL) that 13 of 15 sera samples collected on September 17 from sentinel chickens located in Irwindale, California contained antibodies to SLE virus (an additional serum sample collected from one other bird at this same site on October 16 also contained antibodies to SLE virus). The sentinel chicken flock is located at the Santa Fe Dam Recreational Area in the San Gabriel Valley adjacent to spreading grounds of the San Gabriel River.

On September 24, an increase was observed in the number of *Culex tarsalis* Coquillett adults taken from a New Jersey trap at the recreational area. During Weeks 38 through 41 of 1991, 193 *Cx. tarsalis* were collected; only one was collected during the same period in 1990. In addition, adult *Cx. tarsalis* were collected at rates of 240, 1785, and 1000 per trap on September 25, October 1, and 2, respectively, using CDC CO_2-baited traps.

A large amount of standing water was impounded behind the dam at the recreational area during this time. Adulticide (resmethrin) was applied as an ultralow volume non-thermal fog during the early evening and early morning hours of

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October 2, 7, 9, and 15. Adult *Cx. tarsalis* populations decreased steadily from 1,000 females per trap collected on October 3 to 3.9 females per trap collected on October 16, an overall reduction of greater than 99 percent.

A single case of SLE was reported in a 39-year old male on October 11. He had spent the day at the recreational area on September 27. The patient was comatose from October 14-22, discharged from the hospital on October 30, and is slowly but steadily recovering.

Hospitals and county health centers in the San Gabriel Valley were contacted by mail and encouraged to report increases in the number of cases of aseptic meningitis and encephalitis, and to submit sera to the Los Angeles County Public Health Laboratory for testing. No additional cases were reported.

Discussion.

This was the first evidence since 1986 that SLE virus was present in the mosquito population of the San Gabriel Valley. Several factors contributed to the presence of SLE virus at the recreational area.

In July 1991, the Los Angeles County Department of Public Works began releasing water from the Colorado River (USG-3) to recharge aquifers in the San Gabriel Valley. This process is performed routinely as water becomes available, due to the extensive depletion of ground water which supplies over 200 wells situated in the San Gabriel Valley.

Recharging the aquifers requires the slow release of clear water into the San Gabriel River, which directs the flow to a series of spreading grounds. Since the release of water is regulated to correspond with predetermined percolation rates, there is a generally minimal risk for creating mosquito breeding areas.

While water was being released from USG-3 in 1991, a pilot project was in operation to remove sediment that had accumulated behind a dam which is located in the San Gabriel Mountains northeast of the recreational area. The process involved draining the water from the reservoir approximately to the level of the sediment, followed by an intensified release of water from a second reservoir situated just above the first. The intended action was to sluice the sediment behind the first dam downstream where it would be allowed to settle evenly and away from spreading grounds, facilitating collection and subsequent removal.

Because water was released simultaneously from both sources, some of the water used to sluice sediment combined with the clear water from USG-3. If water containing a high percentage of sediments is released onto the spreading grounds, the percolation process is severely compromised. Since the dam at the recreational area is the last barrier before these spreading grounds, water was permitted to accumulate behind the dam to allow sedimentation to occur. Consistently warm temperatures in August and September that were typical of the area, and the nutrient-rich water, which remained stationary for at least two weeks, contributed to the sudden and dramatic increase in the mosquito population.

Temperatures in August and September from South Gate (the closest location with available temperature data) were compared for 1984 (when the last epidemic of SLE occurred in Los Angeles County), 1986 (the last year SLE virus was detected in the San Gabriel Valley), 1988 (a year when no cases of SLE were reported in Los Angeles County), and 1991. Although September, 1984 was unusually warm, i.e., 20 consecutive days with a minimum temperature $\geq 21^{\circ}$ C, higher temperatures did not correlate with increased mosquito populations or the presence of SLE virus in the San Gabriel Valley during the other years.

Although 93% of the chickens in the Irwindale sentinel flock had antibodies to SLE virus, no virus was isolated from any of the 171 mosquito pools (one pool = 50 mosquitoes) collected from the area for testing. Although approximately 85% of the females that were dissected randomly at the State VRDL before testing were parous, most were not multiparous. Since the likelihood of acquiring an infection with SLE virus increases with the number of feedings (Smith 1987), the absence of multiparous individuals may explain the absence of virus in these mosquitoes.

Of equal interest was the fact that a pool of *Culex stigmatosoma* Dyar collected on the campus of the California State Polytechnic University at Pomona contained SLE virus, and no antibodies were present in sera from the sentinel flock at the same site, though evidence suggesting numerous feedings by mosquitoes existed, i.e., egg rafts in the watering apparatus and many replete females resting on the walls of the coop. This is especially interesting since *Cx. stigmatosoma* is an efficient vector of SLE virus in the laboratory (Hardy et al. 1986).

During years prior to 1991 in which cases of SLE were reported in Los Angeles County, antibodies to SLE virus from sentinel chicken flocks have at best been detected in the same month that the cases occurred. When the mean of the elapsed time between obtaining sera from birds and the appearance of results in the weekly surveillance bulletin is compared by year, results appeared in 1991 significantly more rapidly than in previous years.

Since the results of tests on sera were received in a timely manner, efforts to control mosquito populations were conducted expediently. The single reported case was exposed on the same day that sentinel chicken sera were reported positive for antibodies to SLE virus. We would like to think that the dramatic reduction in the adult mosquito population reduced the potential for human illness. It also appears from the observations at Irwindale and Pomona that the detection of antibodies in a sentinel flock does not necessarily coincide with the detection of virus in the local mosquito population, and vice versa.

During 1990, no antibodies to SLE virus were observed in the flock at the recreational area in Irwindale. The largest number of sera from a sentinel flock in Los Angeles County found positive for antibodies to SLE virus during a single year was six (three in each of August and September, 1988 from Encino). It is unclear what hȁppens to sentinel flocks in Los Angeles County prior to epidemics of SLE. Flocks have only been present in Los Angeles County since 1985, the year after the only large outbreak of human illness on record. In Florida, sera from virtually 100% of the sentinel flocks contained antibodies to SLE virus in the autumn prior to the epidemic of 1990 (Anonymous 1990). Although the environmental conditions of the San Gabriel Valley undoubtedly differ from those of Florida, it will be of interest to conduct surveillance in the Irwindale area in 1992.

Two types of disease surveillance are used by the Los Angeles County Department of Health Services. Passive surveillance enlists the volunteer reporting of communicable disease by health care professionals. Active surveillance involves the inquiry on a regular basis about the incidence of specific diseases.

There are continuing problems with the passive system that is used to report human cases of SLE. Infection with SLE virus can produce signs that are consistent with aseptic meningitis. Since individual cases are not investigated, and serology is rarely done, the number of cases of aseptic meningitis attributable to infection with SLE virus is unknown.

Cases of encephalitis are required to be reported to the health department. Despite its severe nature, in a comparison of 1986 data, only 10% of the cases of encephalitis described on hospital discharge summaries were reported to the health department. Thus, if one case was reported in 1991, other cases may have occurred. Active surveillance for arthropod-borne encephalitis may be an effective tool for detecting cases.

Conclusions.

The presence of SLE virus in the San Gabriel Valley of Los Angeles County during 1991 appeared to be correlated with a large amount of standing water at the Santa Fe Dam Recreational Area in Irwindale. The presence of antibodies to SLE virus in sera from the sentinel flock was reported in an expedient manner; since control measures were implemented five days after the only reported human case was exposed, and a rapid decrease in the adult *Cx. tarsalis* population was observed, it is likely that additional cases of SLE were prevented.

Communication between local mosquito abatement districts and county agencies, e.g., health departments and departments of public works, is essential for the implementation of surveillance and control of human illness and vector populations. It is always difficult to prove the success of control measures in preventing human disease. It is clear, however, that an integrated surveillance system where information is obtained in an expedient manner will allow the best possible efforts at control to be made.

References.

Anonymous. 1990. Arboviral surveillance- United States, 1990. Centers for Disease Control Morbidity Mortality Weekly Report 39:593-598.

Hardy, J.L., S.B. Presser, R.P. Meyer, W.K. Reisen, L.D. Kramer and A.V. Vorndam. 1986. Comparison of a 1984 Los Angeles strain of SLE virus with earlier California strains of SLE virus: mouse virulence, chicken viremogenic, RNA oligonucleotide and vector competence characteristics. Proc. Calif. Mosq. Vector Control Assoc. 53:10-15.

Monath, T.P. and T.F. Tsai. 1987. St. Louis encephalitis: lessons from the last decade.

Amer. J. Trop. Med. Hyg. 37 (Suppl.):40S-59S.
Smith, C.E.G. 1987. Factors influencing the transmission of western equine encephalomyelitis virus between its vertebrate maintenance hosts and from them to humans. Amer. J. Trop. Med. Hyg. 37 (Suppl.):33S-39S.

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1991 MOSQUITO-BORNE ENCEPHALITIS SURVEILLANCE IN WESTERN LOS ANGELES COUNTY

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ABSTRACT

Mosquitoes were collected using CO_2-baited and oviposition traps. A total of 20,952 adult female mosquitoes in 491 pools of *Culex quinquefasciatus* (367 pools), *Culex tarsalis* (117), and *Culex stigmatosoma* (7) were tested for viral activity. Seven pools, all collected in September, tested positive for western equine encephalomyelitis (WEE) virus. One hundred and thirteen feral bird sera were also tested. Two house sparrows and one black bird, all bled in September, seroconverted for Saint Louis encephalitis (SLE) antibodies. This WEE and SLE viral activity was detected during an eight-day period in mid-September when average daily ambient temperatures exceeded 75° F. Monthly blood samples (obtained between May, 1991, and January, 1992) from two sentinel chicken flocks tested negative for WEE and SLE activity.

Introduction.

Surveillance for vector-borne western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) viruses has become a necessity in urban Southern California following the 1984 Saint Louis encephalitis epidemic which resulted in sixteen serologically confirmed cases (1 fatality) in Los Angeles County and five cases in Orange County.

Prevention of human or equine infection depends on early detection of viral activity. Although isolation of viruses from mosquitoes and seroconversion of sentinel chicken are effective tools of viral detection, they may not provide the early warning necessary to prevent a concurrent human or equine infection. A feral or a peridomestic bird serology program may offer that early warning system (Gruwell et al. 1987, Webb et al. 1990).

Materials and Methods.

Mosquito Collection Program: Mosquitoes were collected during May-November, 1991, at random locations and at locations of known mosquito activity using one CO_2-baited trap and one *Culex quinquefasciatus* Say-specific oviposition trap. Following collections of *Culex tarsalis* Coquillett or *Culex stigmatosoma* Dyar, additional CO_2-baited traps were set out. If *Cx. quinquefasciatus* were collected, then follow-up trapping was done with oviposition traps. Usage of oviposition traps ensured collections of mainly gravid female *Cx. quinquefasciatus* (Reiter 1983) and provided nearly homogenous collections thus reducing the probability of inserting a specimen of a different species into a pool of *Cx. quinquefasciatus*. Mosquito collections were also made near sentinel chicken flocks and feral bird traps.

Trapped mosquitoes were anesthetized with triethylamine (TEA), sorted to species and sex, and pooled into freezer vials. The vials were stored on dry ice and shipments to the California Department of Health Services, Viral Rickettsial Disease Laboratory (VRDL) were done weekly.

Feral Bird Bleeding Program: The feral/peridomestic bird bleeding program was implemented in mid-September, 1991. Two modified Australian Crow traps were used with one trap located at the La Brea Tar Pits, adjacent to a chicken flock, and the other placed at the Chevron Refinery, in the city of El Segundo, where significant numbers of *Cx. tarsalis* have previously been collected. Trapped birds were tagged, bled and released. Disposable, 26 gauge syringes were used to extract approximately 0.1 cc of blood from the birds' jugular vein. Following centrifugation, the sera were decanted into test tubes holding 0.9 cc bovine solution. The sera were then taken to Orange County Vector Control District where they were analyzed with HIA tests by Carrie Fogarty.

Sentinel Chicken Program: Two flocks of fifteen sentinel chickens each were set up. One flock was placed at the La Brea Tar Pits where SLE seroconversions have occurred in prior years. *Culex tarsalis* mosquitoes breed in the oily tar pits and, occasionally, some mosquitoes escape the suppression program. Additionally, a vast network of underground flood control drains can flood the area with large populations of *Cx. quinquefasciatus*. The second flock was placed at the headquarters of the Las Virgenes Water District in Calabasas.

The chickens were bled monthly from April, 1991, through January, 1992. Disposable, 22 gauge needles fitted to vacutainers were used to extract approximately 3.0-5.0 cc of blood from the birds' jugular vein. The sera were allowed to clot at room temperature for 24 hours prior to centrifugation as per the State Department of Health Services, Environmental Management Branch's 1991 "Revised Protocol for Sentinel Chicken Serum Submission". The sera were tested by the VRDL.

Results and Discussion.

Mosquito Collection Program: The mosquito collection program yielded 20,952 mosquitoes submitted as 491 pools. The species breakdown was: 16,146 *Cx. quinquefasciatus* (367 pools), 4,674 *Cx. tarsalis* (117 pools), and 132 *Cx. stigmatosoma* (7 pools). Mosquitoes were collected from May to November, 1991 (Fig. 1).

Western equine encephalomyelitis virus isolations were made from three pools of *Cx. quinquefasciatus* and one pool of *Cx. tarsalis* collected in the highly urbanized city of Torrance on September 24, 1991, and from three pools of *Cx. tarsalis* collected in a rural community of Malibu on September 25 (Table 1). A significant number of pools, some from those same localities, were collected the week before and the week after the positive collections (Fig. 2) but tested negative. Although the window of activity was very brief, the two identified foci of WEE activity were 36 miles apart suggesting that the activity affected a large area.

Feral Bird Bleeding Program: We began bleeding feral/peridomestic birds on the 15th of September. A total of one hundred and one bird sera was obtained from the La Brea Tar Pits location. The species breakdown was 33 house sparrows (*Passer domesticus*), 59 house finches (*Carpodacus mexicanus*), 1 black bird (probably *Euphagus cyanocephalus*) and 8 rock doves (*Columba livia*). Two house sparrows and the single black bird seroconverted for SLE antibodies. They were bled on September 18, 20, and 23, respectively (Table 1). The titers were 1:20, 1:20,

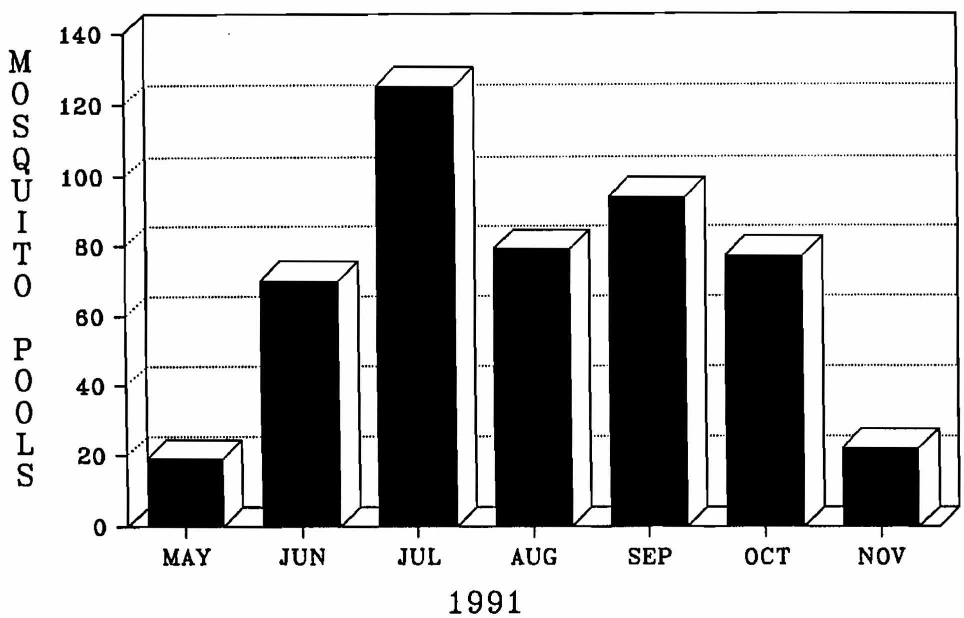

Figure 1. Number of mosquito pools tested monthly for WEE and SLE viruses during 1991.

Table 1. WEE and SLE virus activity in western L.A. County during 1991.

Date	Location	ID Number	Species	No.	Virus
MOSQUITO POOL ISOLATIONS					
09/24/91	Torrance	LOSA-355	*Cx. quinquefasciatus*	50	WEE
09/24/91	Torrance	LOSA-356	*Cx. quinquefasciatus*	50	WEE
09/24/91	Torrance	LOSA-363	*Cx. tarsalis*	40	WEE
09/24/91	Torrance	LOSA-364	*Cx. quinquefasciatus*	50	WEE
09/25/91	Malibu	LOSA-371	*Cx. tarsalis*	50	WEE
09/25/91	Malibu	LOSA-372	*Cx. tarsalis*	22	WEE
09/25/91	Malibu	LOSA-379	*Cx. tarsalis*	33	WEE
FERAL BIRD SEROCONVERSIONS					
09/18/91	La Brea Tar Pit	WBLOSA-12	House sparrow	1	SLE
09/20/91	La Brea Tar Pit	WBLOSA-18	House sparrow	1	SLE
09/23/91	La Brea Tar Pit	WBLOSA-25	Black bird	1	SLE

and 1:40, respectively. We trapped and bled peridomestic birds through November 13, however no additional viral activity was detected (Fig. 3).

Nine spotted doves (*Streptopelia chinensis*) from the El Segundo location were bled between October 14 and November 13, but no viral activity was detected at that location.

Although the overall sampling period was short and the total sampling pool small (113 birds), the results indicate that the period of detected SLE activity did coincide with the WEE activity found in the mosquitoes.

Sentinel Chicken Program: All chicken sera (255 samples total) tested negative for both WEE and SLE.

Mosquito collections at the chicken flock locations yielded small numbers of mosquitoes. At the La Brea Tar Pits location, we collected a total of 224 *Cx. quinquefasciatus* mosquitoes (7 pools). One pool of eighteen *Cx. quinquefasciatus* collected on September 26, during the peak time of viral activity, tested negative. If meteorological and virological conditions were favorable for transmission of SLE virus from the birds to the sentinel chickens, the small number of mosquitoes infesting that location possibly did not provide the

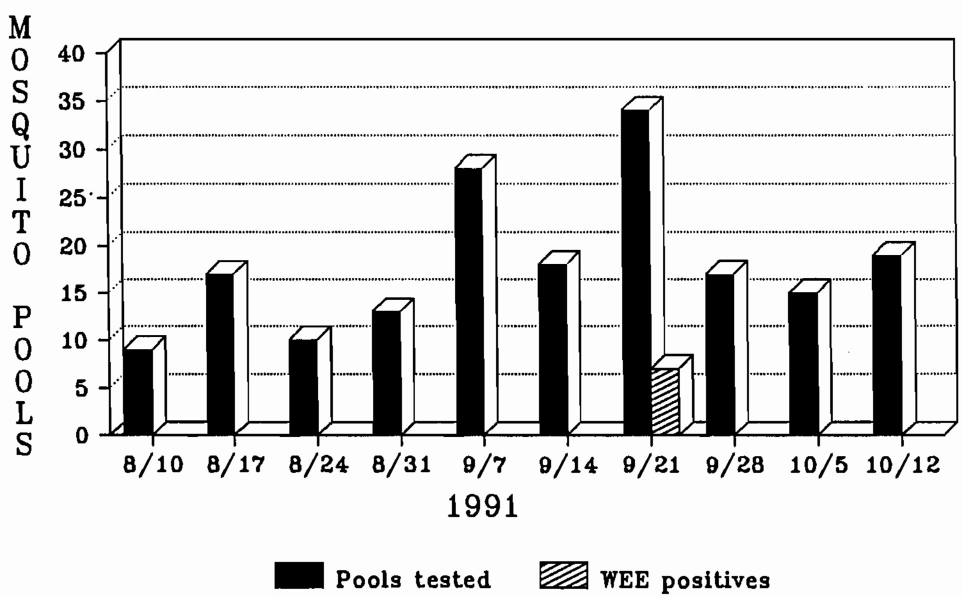

Figure 2. WEE isolations relative to the weekly collections of mosquito pools.

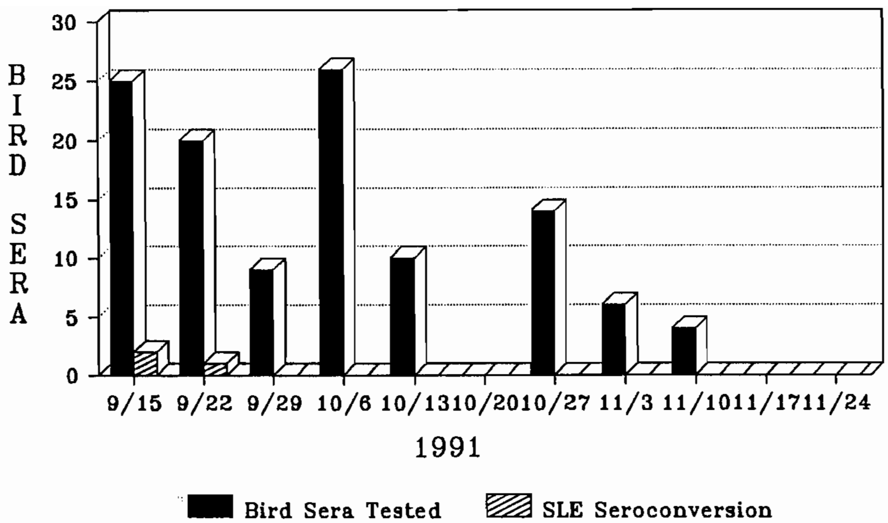

Figure 3. Feral bird seroconversions for SLE virus relative to the weekly number of sera tested.

necessary medium for virus transmission.

Virus amplification is favored when meteorological conditions favor the simultaneous expansion of mosquito populations and that of nestling birds. However, all the factors which suppress virus appearance (SLE and WEE) in mosquitoes for most of the year yet suddenly induce their appearance at a given time, such as in this case mid-September, elude us.

One factor we followed, was ambient temperature. On September 16, a shift in wind direction brought unusually warm and dry conditions to the Los Angeles basin. Mean average temperatures exceeded 75° F for five days preceding the detected WEE activity in the mosquitoes (Fig. 4). Maybe that sustained increase in mean temperature was the catalyst responsible for the bird to mosquito transmission of WEE virus.

Acknowledgements.

The author thanks Robert Cummings and Greg Pierson, L.A. County West Mosquito Abatement District, for their assistance in collecting mosquitoes, bleeding the sentinel chickens and the

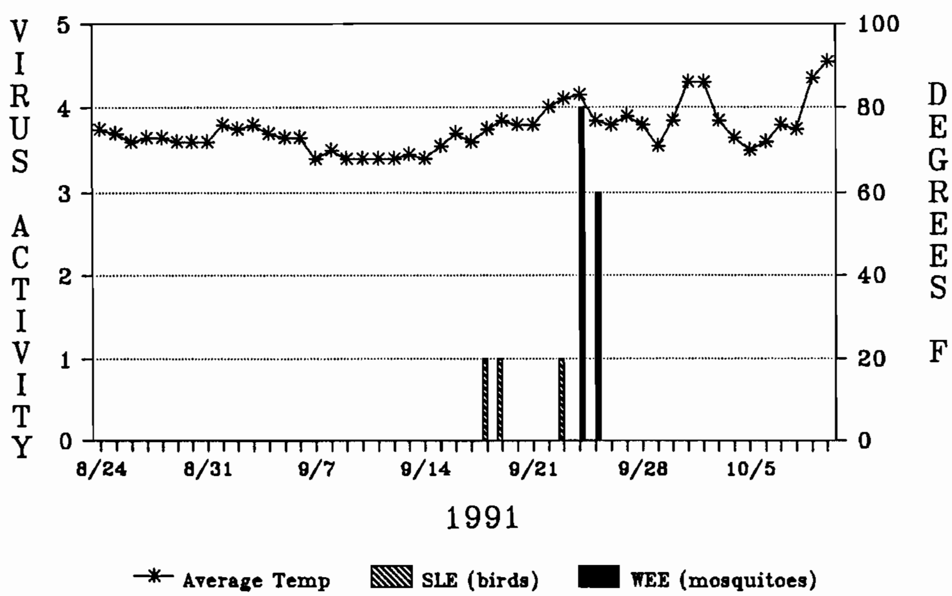

Figure 4. Mean daily temperature and observed virus activity for western L.A. County, 1991.

feral birds. Thanks are also extended to Dr. Jim Webb, Orange County Vector Control District, for his expertise and assistance in the feral bird bleeding program and for reviewing this document. In addition, gratitude is offered to Carrie Fogarty of that agency for doing the feral bird serology.

References.

Gruwell, J.A., B.L. Brown and J.P. Webb, Jr. 1988. Passeriform birds as a surveillance method for arbovirus activity in rural and suburban sites in Orange County, California, 1987. Proc. Calif. Mosq. Vector Control Assoc. 56:58-65.

Reiter, P. 1983. A portable, battery-powered trap for collecting gravid *Culex* mosquitoes. Mosq. News 43:496-498.

Webb, J.P., E.T. Shreiber, S.G. Bennett, R. Allen, T.J. Smith, and G.L. Challet. 1990. Evaluation of mosquito and arbovirus activity in Orange County, 1988. Proc. Calif. Mosq. Vector Control Assoc. 57:18-22.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 44-51

EVALUATION OF MOSQUITO AND ARBOVIRUS ACTIVITY IN ORANGE COUNTY, CALIFORNIA, 1991

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In 1991 the Orange County Vector Control District (OCVCD) continued its mosquito and encephalitis virus surveillance throughout the year. Mosquitoes were collected at ten permanent sites throughout the county (Bennett et al. 1990) utilizing 19 CDC CO_2-baited traps as well as five modified Reiter ovipositional traps (Reiter 1983). Additionally, blood-fed female mosquitoes were collected inside three stable traps (Magoon 1935) containing five white leghorn chickens each.

A total of 33,962 mosquitoes was collected from which 888 mosquito pools were submitted to the California State Department of Health Services' Viral and Rickettsial Diseases Laboratory at Berkeley for virus testing (Table 1). The collections included 663 pools of *Culex quinquefasciatus* Say and 225 pools of *Culex tarsalis* Coquillett. None of these pools tested positive for St. Louis encephalitis (SLE) or western equine encephalomyelitis (WEE) viruses. However, one pool of *Culex stigmatosoma* Dyar females collected September 23 from the campus of California State Polytechnical University at Pomona in neighboring Los Angeles County was found positive for SLE virus.

Sentinel chicken flocks used during 1991 included one large flock (25 chickens) at the 20 Ranch Duck Club in Irvine and three mini-flocks (5 chickens each) held in stable traps in Fullerton, Buena Park, and the 20 Ranch Duck Club. There were no seroconversions to SLE or WEE viruses observed in any Orange County sentinel flock this year. However, adjacent Los Angeles County had 15 SLE seroconversions between September and November; thirteen from Irwindale on September 17; one from Irwindale on October 16; and one from Long Beach on November 12.

The only reported case of SLE from the greater Los Angeles Basin was from Valinda in Los Angeles County (onset October 11).

Wild bird sera collected by Dr. John Gruwell, Becky Brown, and Allyson Reinig were tested for SLE and WEE antibodies at the laboratories of the Orange County Health Department. Nine modified Australian Crow traps (McClure 1984) were used in 1991 to trap a total of 18,033 birds from which 5,202 blood samples were taken and tested (Table 2). The overall percentage of SLE-positive house sparrows for the year was 4.9%, while house finches and white-crowned sparrows were found SLE-positive at 0.95% and 0.90%, respectively (3.0, 1.4, and 2.4%, respectively in 1990). House sparrows were found SLE-positive during every month of the year with the highest SLE activity (9.6% positive) observed in September (3.3% positive in 1990); a significant peak prior to the chicken sero-conversions, positive mosquito pool, and human SLE case in the Los Angeles Basin (Fig. 1). In contrast, only 1.4% of house finches were found to be SLE-positive during this same period in September. The second highest peak of SLE activity in the captured house sparrows (7.9% positive) occurred in April (7.5% positive in 1990).

Central Park in Huntington Beach and a residential source three kilometers from the park produced the majority of SLE-positive sparrows in both 1990 and 1991 (Fig. 2). *Culex quinquefasciatus* was the most common mosquito at these sites, persisting in low numbers through the fall and winter while *Cx. tarsalis* disappeared by the end of September. As in previous years, this trend repeated itself at most other localities in Orange County during 1991. At the Central Park site, *Culex tarsalis* had the highest counts during May (Week 19) at nearly 60 females per trap-night (8 females

Table 1. Number of mosquito pools submitted for SLE and WEE virus testing by species and trap type from Orange County, California during 1991.

Species	Stable traps	Reiter traps	CO_2-baited traps	Total pools
Culex quinquefasciatus	337	196	130	663
Culex tarsalis	70	-	155	225
Totals	407	196	285	888

per trap-night in 1990) while *Cx. quinquefasciatus* was highest during late June and early July (Week 25) at 45 females per trap-night (38 females per trap-night in August of 1990). The highest percentage of SLE-positive sparrows was collected in October (Week 39) with 19.4% positive. In general, the temporal distribution of SLE-positive wild birds collected in Central Park during 1991 was the same as in 1990 (Bennett et al. 1991).

Culex tarsalis was predominant in rural/ suburban areas such as the San Joaquin Marsh and the 20 Ranch Duck Club, both in Irvine (Figs. 3 and 4). Populations of *Cx. tarsalis* in the marsh were highest in June (155 females per trap-night), July (125 females per trap-night), and mid-August (100 females per trap-night). In contrast, the highest *Cx. tarsalis* count for 1990 was approximately 40 females per trap-night in May. As noted in previous reports, *Cx. quinquefasciatus* is not very abundant in the San Joaquin Marsh and only reached a high of 25 females per trap-night in late October (8 females per trap-night in November of 1990). *Culex tarsalis* activity at the 20 Ranch Duck Club mirrored that at the San Joaquin Marsh beginning during Week 17 (April 9 in Fig. 3) and ending in Week 43. Counts and activity periods were virtually the same as 1990 with the highest mosquito activity peak occurring in July (Week 27) at 25-28 females per trap-night and a second peak in August (Week 33) at 20 females per trap-night (<10 females per trap-night in 1990). A peak of 15 females per trap-night did occur in September during 1991, whereas in 1990, the average was only 5 females per trap-night. For the second year in a row, *Cx. quinquefasciatus* was more abundant than *Cx. tarsalis* at the 20 Ranch Duck Club site. Highest numbers were obtained from the end of September to October (Weeks 36-41) and ranged from 35 to 55 females per trap-night (45-65 females per trap-night in July of 1990).

In addition to the host-seeking females collected in the CDC CO_2-baited traps, female mosquitoes were collected from the stable trap at the 20 Ranch Duck Club four days (Monday-Thursday) each week (Fig. 5). At the peak of mosquito activity between August and October, 560-1,500 *Cx. quinquefasciatus* were collected during each four day period (80-220 females per trap-night). These figures were significantly higher than

Table 2. Small bird seroconversions for SLE and WEE antibodies in Orange County, California during 1991.

Species	No. positive SLE	No. positive WEE	No. bloods sampled	% positive SLE	% positive WEE
House Sparrow	110	0	2246	4.90	0
House Finch	26	0	2734	0.95	0
White-Crowned Sparrow	2	0	222	0.90	0
Totals	138	0	5202	2.65	0

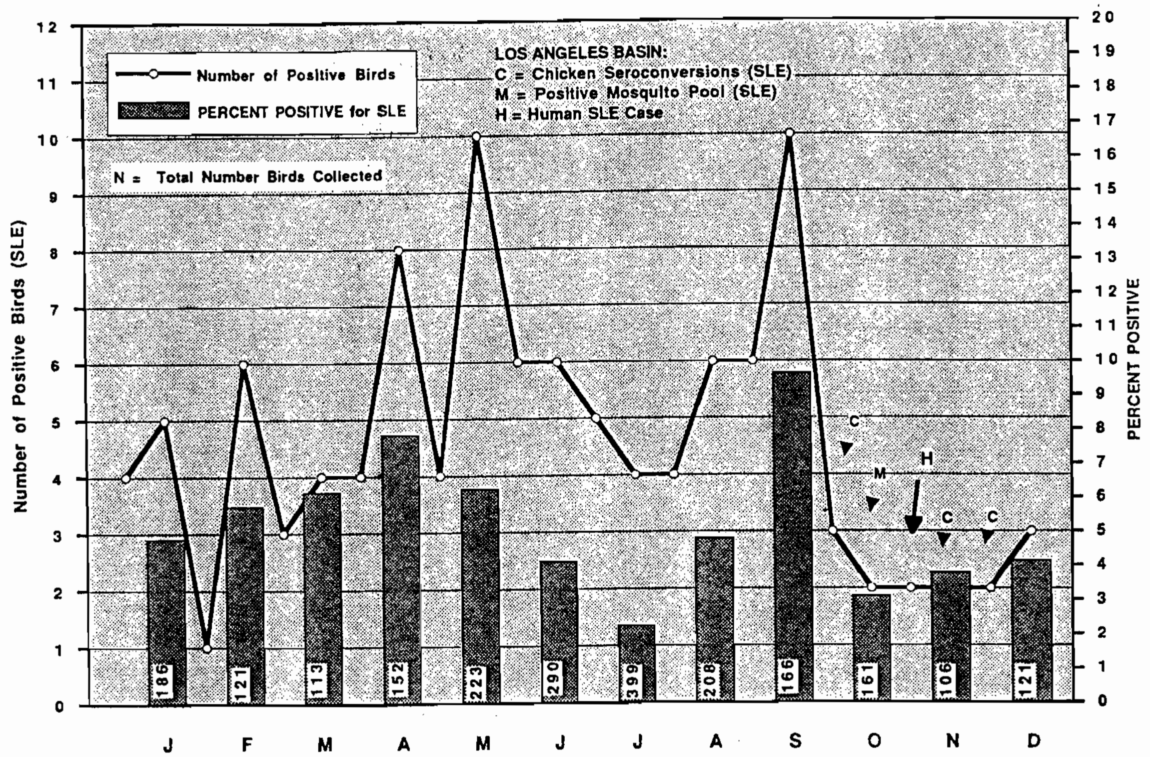

Figure 1. SLE virus activity in the Los Angeles basin and wild bird (house sparrow) seroconversions in Orange County, California during 1991.

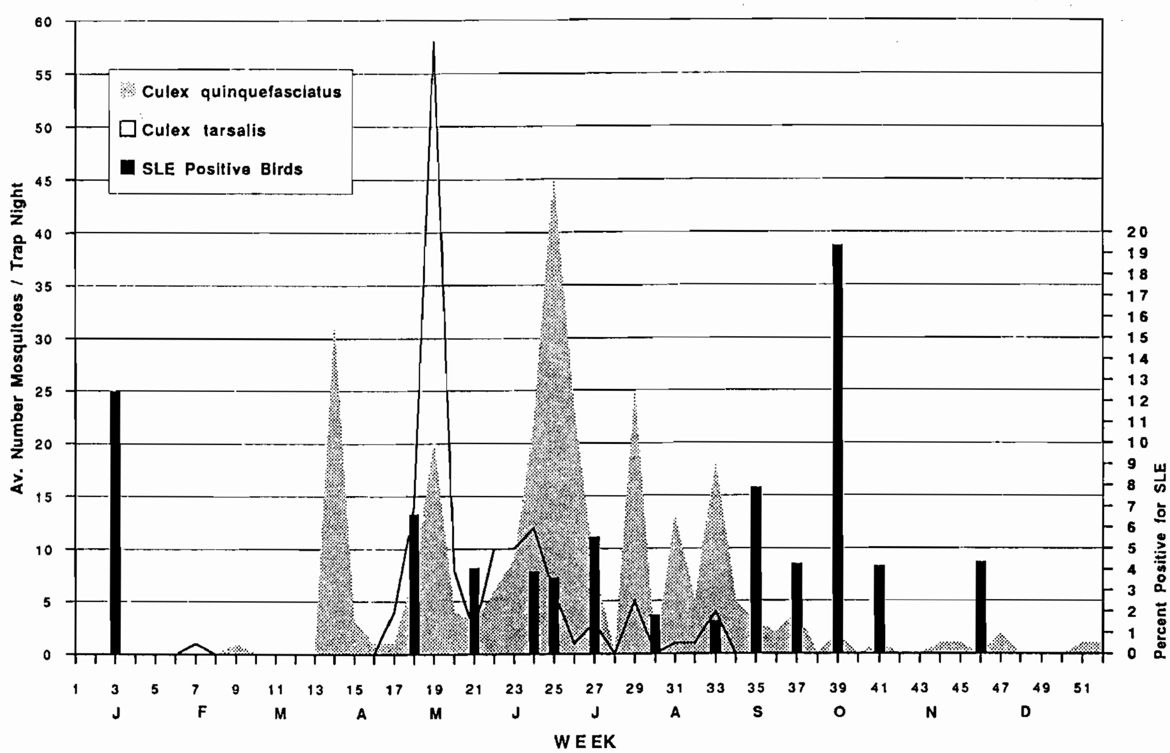

Figure 2. Host-seeking female mosquito and SLE activity in wild birds from Central Park, Huntington Beach, California during 1991.

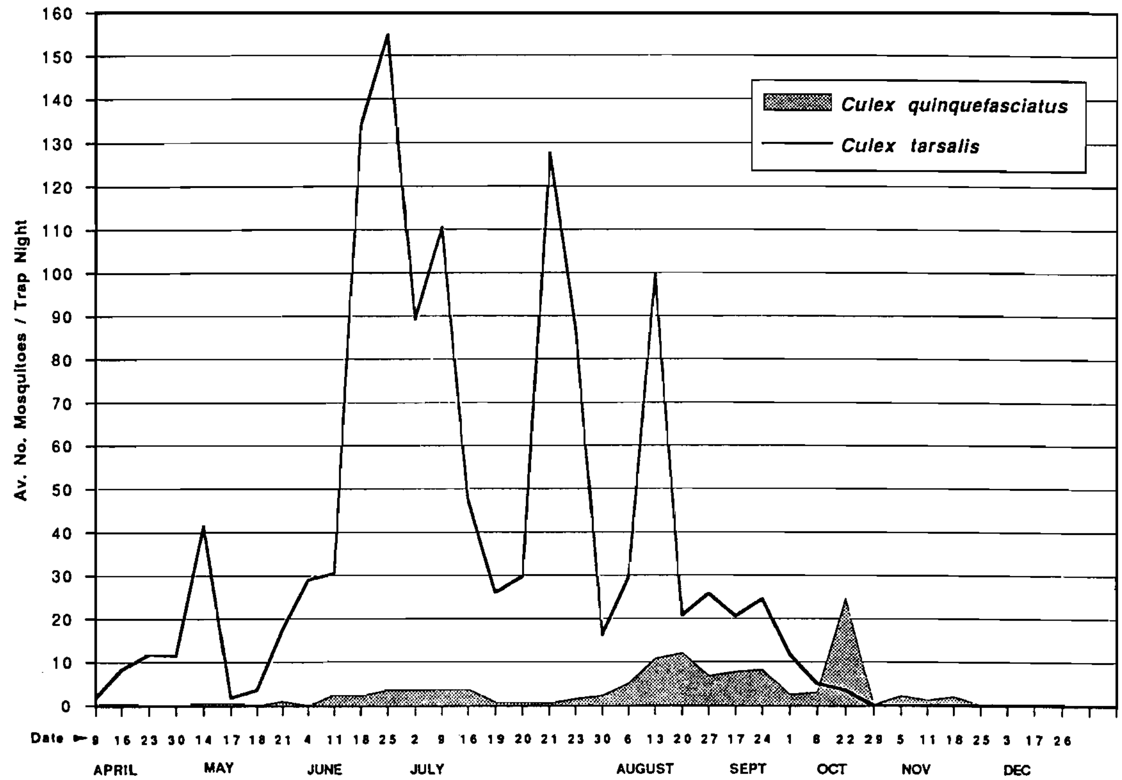

Figure 3. Host-seeking female mosquito activity at the San Joaquin Marsh in Irvine, California during 1991 as determined by CDC CO_2-baited traps.

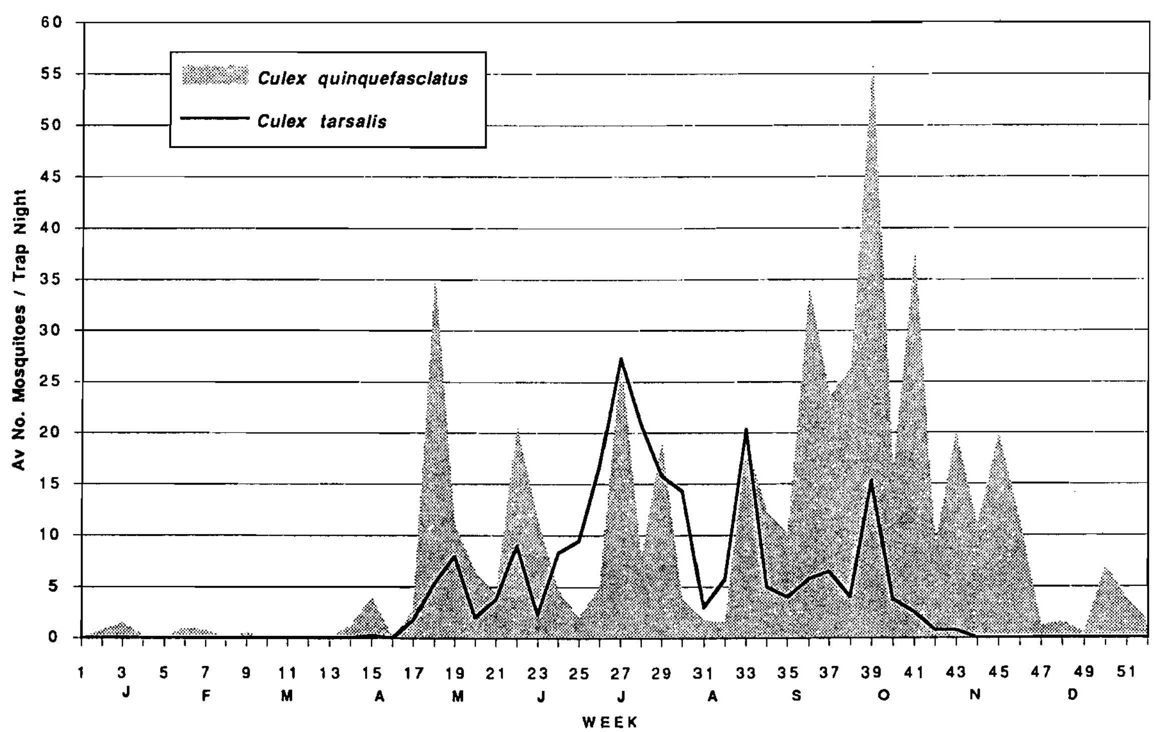

Figure 4. Host-seeking female mosquito activity at the 20 Ranch Duck Club in Irvine, California during 1991 as determined by CDC CO_2-baited traps.

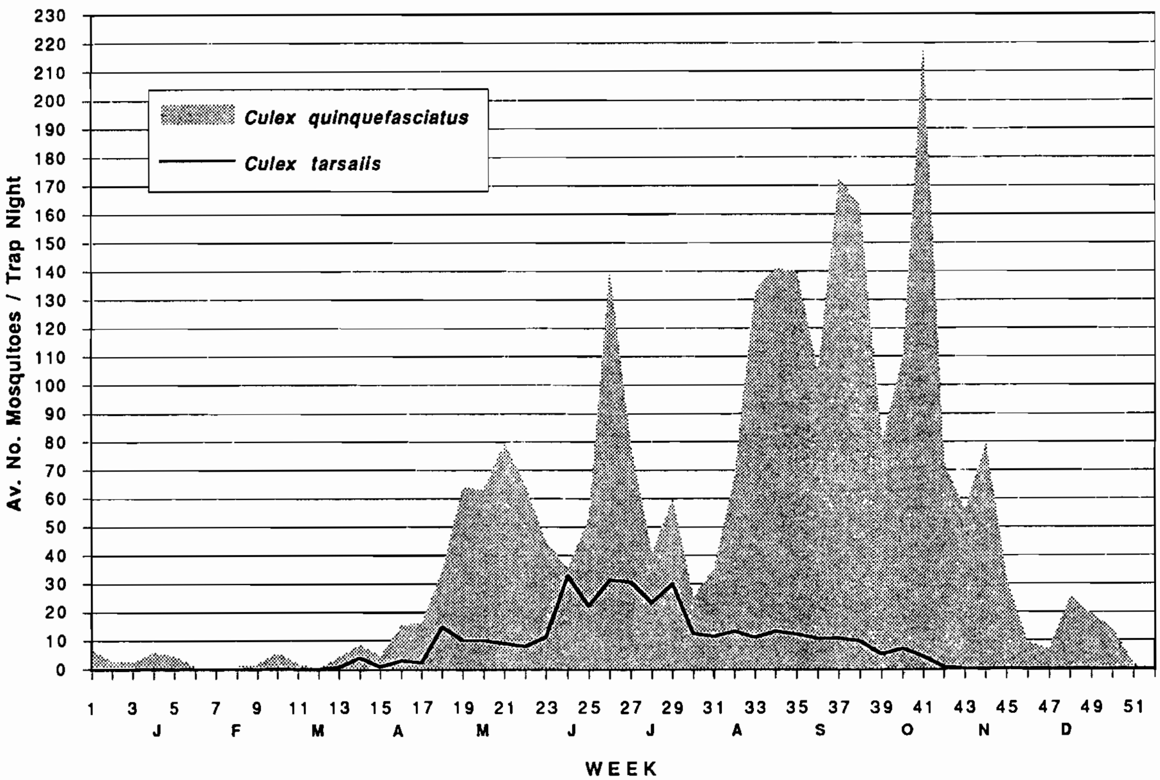

Figure 5. Host-seeking female mosquito activity at the 20 Ranch Duck Club in Irvine, California during 1991 as determined by collections from stable traps.

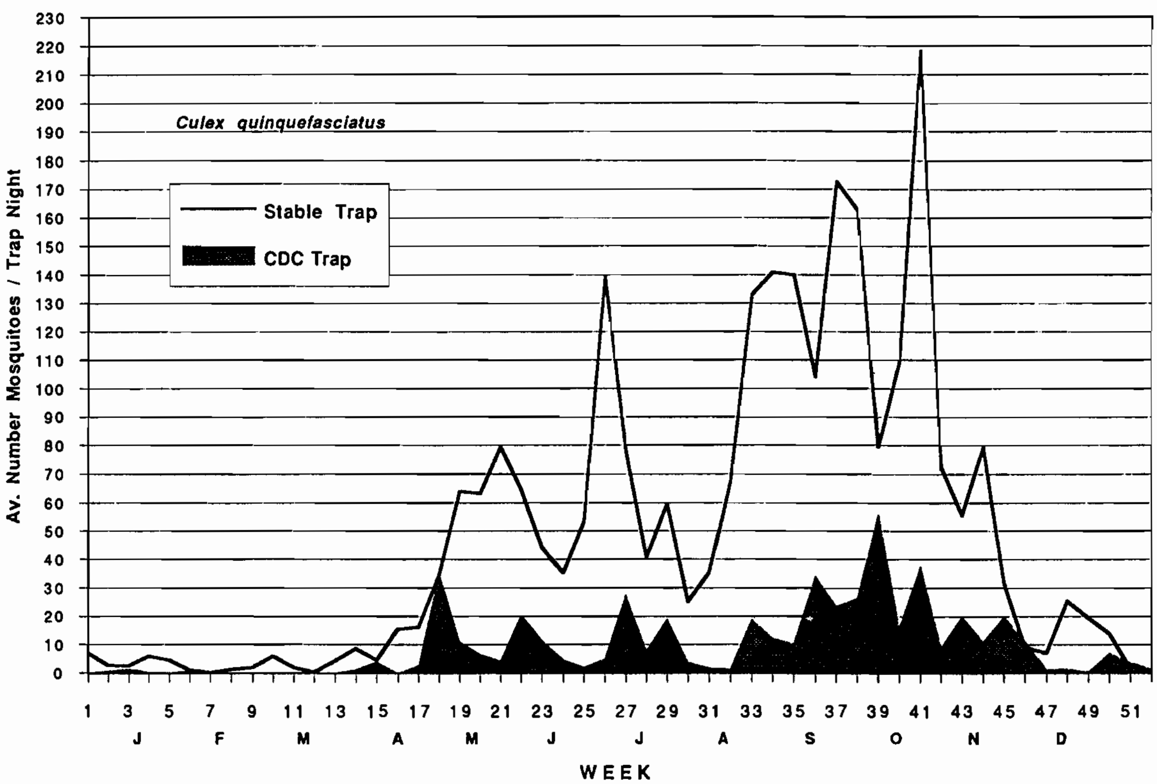

Figure 6. Host-seeking female *Cx. quinquefasciatus* activity from stable traps and CDC CO_2-baited traps at the 20 Ranch Duck Club in Irvine, California during 1991.

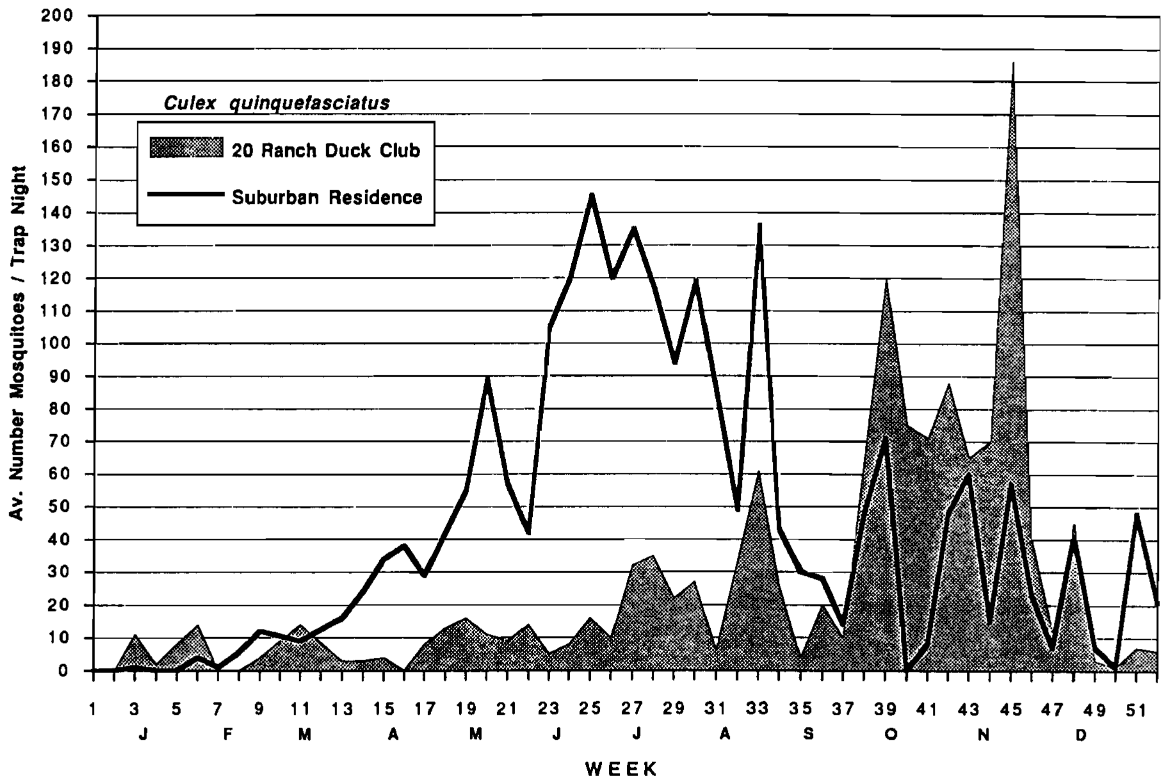

Figure 7. Gravid female *Cx. quinquefasciatus* activity in Irvine, California during 1991 as determined by Reiter ovipositional traps at two sites.

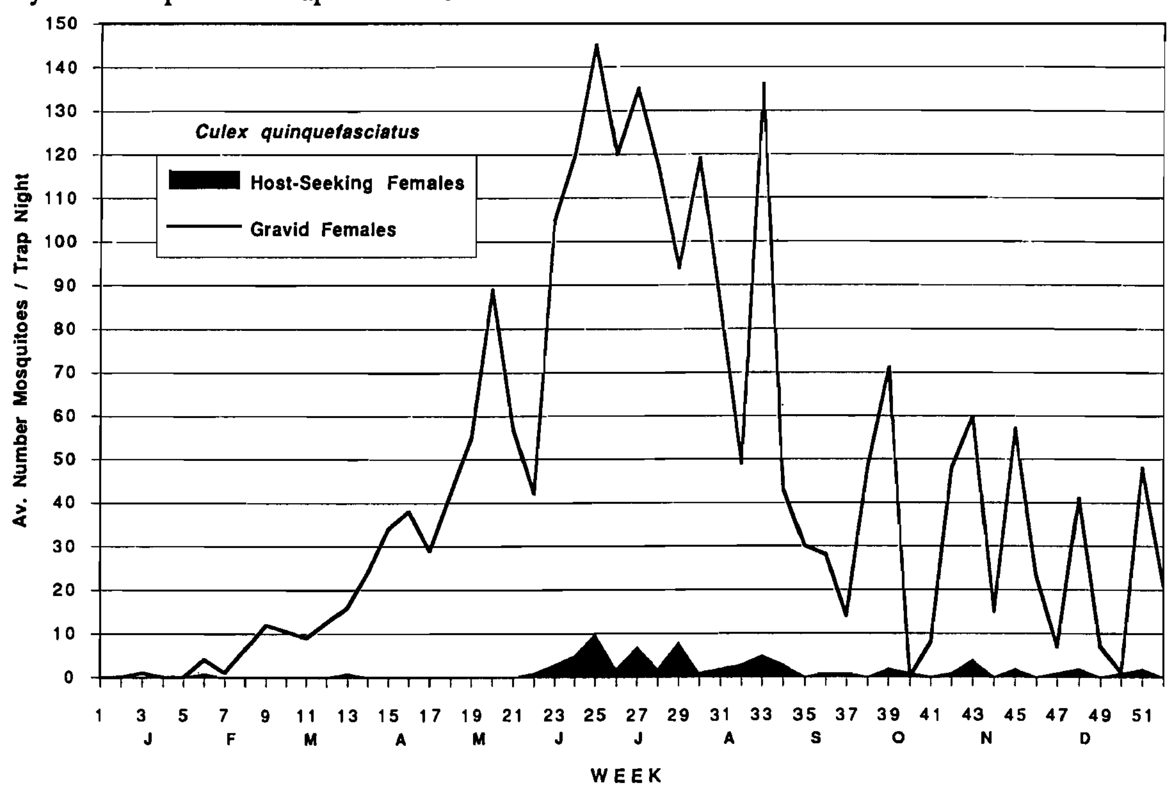

Figure 8. *Culex quinquefasciatus* activity at a suburban residence in Irvine during 1991 as determined by CDC CO_2-baited and Reiter ovipositional traps.

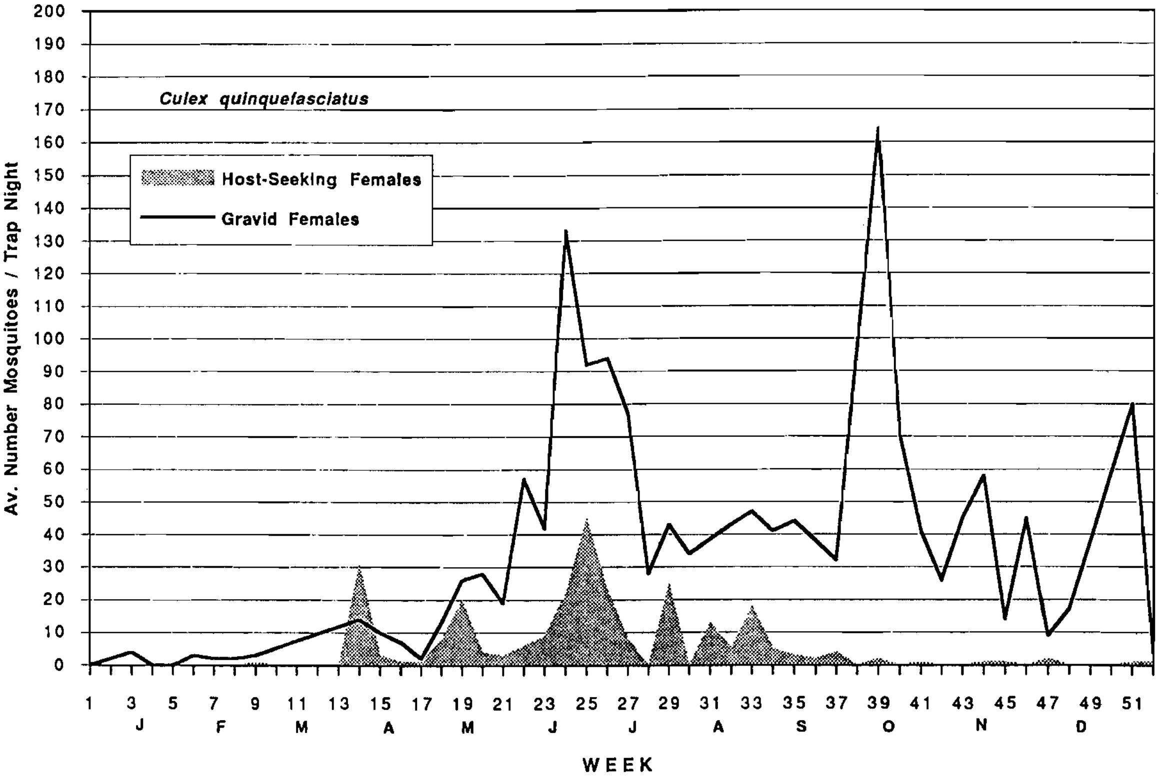

Figure 9. *Culex quinquefasciatus* activity at Central Park, Huntington Beach during 1991 as determined by CDC CO_2-baited and Reiter ovipositional traps.

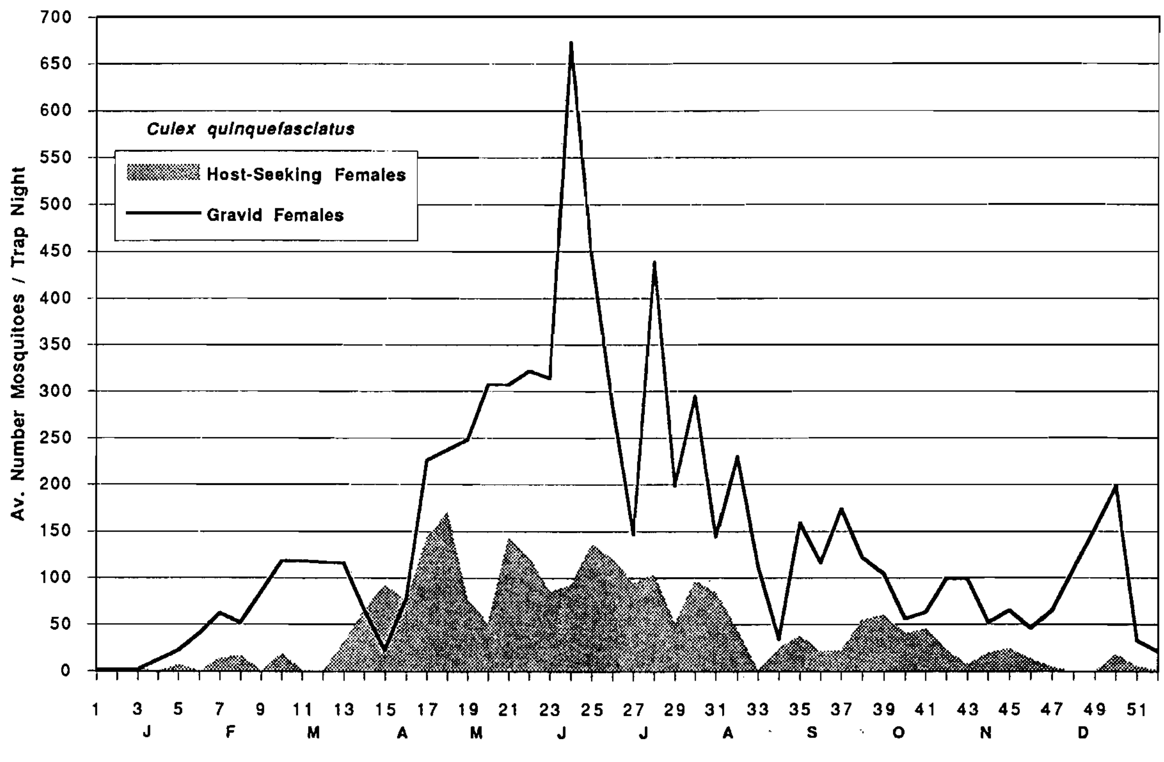

Figure 10. *Culex quinquefasciatus* activity at a suburban residence in Anaheim during 1991 as determined by CDC CO_2-baited and Reiter ovipositional traps.

1990 when 200-300 females were being collected during each four day period. Although *Culex tarsalis* was most abundant between June and July (23-30 females per trap-night), far fewer were collected from the stable trap when compared to *Cx. quinquefasciatus*. The stable trap was much more efficient than the CDC CO_2-baited trap (hanging from the stable trap) at collecting large numbers of *Cx. quinquefasciatus* at the 20 Ranch Duck Club (Fig. 6). In contrast, the number of *Cx. tarsalis* collected from both trap types was approximately the same (Figs. 4 and 5).

Gravid female *Cx. quinquefasciatus*, obtained from modified Reiter ovipositional traps at both the 20 Ranch Duck Club in a rural area of Irvine and at a residential site six kilometers away, displayed somewhat dissimilar patterns of temporal activity to each other but similar patterns to prior years. High numbers of gravid females (90-185 per trap-night) were collected at the 20 Ranch Duck Club site starting in September (Week 39) and continuing through November (Week 45) (100-120 females per trap-night during August-November of 1990). At the residential site in Irvine, gravid *Cx. quinquefasciatus* began increasing from March (Week 12), reached their peak of activity in June (Week 25) at 145 females per trap-night and August (Week 33) at 140 females per trap-night, and decreased sharply in September. Except for the four peaks of 50-70 gravid females per trap-night during the fall and winter months, the temporal patterns in Figure 7 were quite similar to those observed in 1990. An interesting observation was noted concerning these two Irvine sites. While the 20 Ranch Duck Club stable and CDC CO_2-baited traps continuously collected host-seeking *Cx. quinquefasciatus* throughout the summer and fall (Figs. 4 and 5), very few host-seeking females and many gravid females were taken at the residential site during this time period (Fig. 8), indicating that gravid mosquitoes may be flying to the trap from another source.

Oviposition cycles of *Cx. quinquefasciatus* at Central Park in Huntington Beach during 1991 (Fig. 9) varied considerable from 1990 when there was very little mosquito activity from January to July, November, or December. The gravid female counts for 1990 reached a high of 320 per trap-night in September and dropped to about 160 females per trap-night in October. Although the numbers were lower in 1991 (130 females per trap-night in June and 160 females per trap-night in late September), several peaks of activity occurred throughout the year from March to December.

The most productive site for gravid *Cx. quinquefasciatus* females in 1991 was a residence near Modjeska Park in Anaheim (Fig. 10). Over 100 gravid females per trap-night were being taken as early as February (Week 10). This number continued to increase up to 670 females per trap-night in June (Week 24) and averaged approximately 100 gravid females per trap-night through the fall and winter. The pattern was similar in 1990 except peak mosquito abundance occurred in July and only reached 180 females per trap-night.

References.

Bennett, S.G., J.P. Webb, Z.T. Siruno and T.J. Smith. 1990. Evaluation of mosquito and arbovirus activity in Orange County, California, 1989. Proc. Calif. Mosq. Vector Control Assoc. 58:29-36.

Bennett, S.G., J.P. Webb, Z.T. Siruno and T.J. Smith. 1991. Evaluation of mosquito and arbovirus activity in Orange County, California, 1990. Proc. Calif. Mosq. Vector Control Assoc. 59:35-41.

Magoon, E.H. 1935. A portable stable trap for capturing mosquitoes. Bull. Entomol. Res. 26:363-369.

McClure, E. 1984. Bird Banding. Boxwood Press, Pacific Grove, CA 341 pp.

Reiter, P. 1983. A portable battery-powered trap for collecting gravid *Culex* mosquitoes. Mosq. News 43(4):496-498.

MOSQUITO ABUNDANCE AND ARBOVIRAL ACTIVITY IN SAN BERNARDINO COUNTY DURING 1991

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ABSTRACT

Of the total mosquitoes collected in New Jersey light traps and dry ice (CO_2)-baited traps in San Bernardino County during 1991, *Cx. tarsalis* (69.8%), *Cs. inornata* (21.1%), and *Ae. vexans* (6.8%) dominated in the desert region while *Cx. stigmatosoma* (39.6%), *Cx. tarsalis* (38.3%), and *Cx. quinquefasciatus* (15.2%) were predominant in the valley region. Mosquito activity in the desert region was lower in the suburban habitats (7.4%) than the rural (62.6%) or urban sites (30.0%). In the valley region, however, more mosquitoes were found at the suburban sites (55.0%) than the other two habitats. Mosquito populations peaked in October and November in the desert region and June through August in the valley region.

One chicken serum sample from the desert region tested positive for SLE virus in mid-September. All mosquito pools and other sera samples from both regions showed no viral activity.

Introduction.

As part of the California encephalitis virus surveillance (EVS) system, the San Bernardino County Vector Control Program (SBCVCP) has carried out EVS and other mosquito control activities in both the valley and desert regions of San Bernardino County for a number of years. Geographically, the county consists of three distinct regions; the desert, mountain, and valley regions. Demographically, the valley region houses over 80% of the nearly 1.4 million county population with the remainder scattered over various parts of the desert and mountain regions. Historically, cases of both Saint Louis encephalitis (SLE) and western equine encephalomyelitis (WEE) have been reported in the desert and valley regions from time to time.

After experiencing 26 cases of SLE in southern California during 1984, the only case of encephalitis (SLE) in California during 1987 was reported from the city of San Bernardino (Emmons et al. 1988). Of the two cases reported statewide in 1988, one was from the same San Bernardino site (Emmons et al. 1989). During the same period, both SLE and WEE virus activities were reported in the desert region, especially Needles and adjoining areas along the Colorado River. Due to the periodic incidence of encephalitis disease, mosquito control and EVS activities have been routinely carried out in the desert and valley regions of this county. Data generated in routine EVS activities are appraised here in relation to the population dynamics of adult mosquitoes and arboviral activity in San Bernardino County during 1991.

Materials and Methods.

The general EVS procedures as described by Mian and Prochaska (1990) were continued in these studies as follows:

Adult Mosquito Population Dynamics: The abundance of various mosquito species was monitored on a weekly basis through a number of New Jersey light traps. In the valley region, the traps were stationed at seven locations; Yucaipa Regional Park, Loma Linda, Fifth Street and a flood control basin in San Bernardino, Fontana Regional Park, Ontario, and Upland. Within the valley region, there were two trap sites each in suburban and rural environments and three sites in urban environments. In the desert region (Needles area), one trap each was operated in urban, suburban, and rural areas along the Colorado River.

Adult mosquitoes collected weekly in all traps were counted and identified to species and sex with the Adult Mosquito Occurrence Reports submitted to the California Department of Health Services.

Arboviral Activity in Female Mosquitoes: Arboviral activity in local mosquito populations was monitored in both the desert and valley regions using dry ice (CO_2)-baited traps to collect host-seeking adult female mosquitoes. Eight or more such traps were operated on a biweekly (valley region) or monthly (desert region) basis.

Female mosquitoes collected overnight were anesthetized using triethylamine (TEA), counted, identified to species and sex, and then pooled by species with 10-50 adults per each labelled vial. All pools (vials) were stored in dry ice in the field or in a deep freezer at -60° F in the laboratory before being shipped in dry ice-packed containers by overnight express mail to the Viral and Rickettsial Disease Laboratory (VRDL) in Berkeley.

Arboviral Activity in Sentinel Chickens: Both wild and domestic birds are known to play a significant role in the epidemiology of mosquito-borne encephalitides by acting as reservoir hosts for the encephalitis virus(es). Therefore, one sentinel flock consisting of 15 white leghorn chickens was maintained in both the valley and desert regions. The valley flock was stationed near a horse ranch at the northeastern corner of Meridian Avenue and Olive Street in the city of Colton. This site is within the area which had one SLE case in 1987 and 1988. The desert flock was maintained at the sewage treatment facility in the city of Needles. New Jersey light traps were regularly operated at both flock sites. Blood serum samples from all sentinel chickens, taken on pre-determined dates during the mosquito season, were sent to the VRDL for detection of arboviral activity.

Results and Discussion.

Of the total 10,383 mosquitoes collected in New Jersey light traps and CO_2-baited traps at various sites in the county during 1991, the most abundant culicine species in the desert region was *Culex tarsalis* Coquillett (69.8%, Table 1). In the desert region, *Culiseta inornata* Williston was the second most abundant species (21.1%) followed by *Aedes vexans* Meigen (6.8%). Other species totalling <1.0% each of the total included *Anopheles franciscanus* McCracken, *Culex erythrothorax* Dyar, *Culex quinquefasciatus* Say, *Culex stigmatosoma* Dyar, and *Psorophora signipennis* (Coquillett). Earlier studies in this area, indicated *Cx. tarsalis* as most abundant, comprising as much as 72%, 62%, and 86% of the mosquitoes collected in 1986, 1987 (Reisen et al. 1988) and 1989 (Mian and Prochaska 1990), respectively.

In the valley region, mosquito composition by species was *Cx. stigmatosoma* (39.6%), *Cx. tarsalis* (38.3%), *Cx. quinquefasciatus* (15.2%), *Culiseta incidens* (Thompson) (3.5%), *Cx. inornata* (2.1%), with *Aedes increpitus* Dyer, *Anopheles hermsi* Barr and Guptavanji, *Cx. erythrothorax*, and *Culiseta particeps* Adams each comprising <1.0% of the total. In the Chino area of this valley region, the three culicine species in order of their relative abundance have previously been reported to be *Cx. quinquefasciatus, Cx. stigmatosoma* and *Cx. tarsalis* (Pfuntner 1988). The Chino area is composed of various agricultural biotypes included but not limited to dairy farming. These biotopes provide ideal habitats for the breeding of mosquito species in the aforementioned order.

Based on New Jersey light trap data, mosquito activity was greatest in the desert region at rural sites (62.6%) followed by urban (30.0%) and suburban sites (7.4) (Table 2). Both the rural and urban sites were closer to the Colorado River than the suburban site. In the valley region, mosquitoes were found in higher numbers in both suburban (55.0%) and rural (25.5%) habitats than at urban sites (19.5%). This distribution pattern could be attributed to the proximity of trap sites to mosquito breeding habitats ranging from domestic or residential swimming pools to flood control structures in the urban and suburban habitats, or to seepage water in ponds, ground depressions, and irrigation ditches in cultivated crops by the Colorado River in rural areas.

Mosquitoes from the desert region showed population peaks in all habitats during October and November (Table 3). Two small peaks of mosquito activity also occurred during January and May. High fall mosquito population levels in the urban and suburban habitats necessitated adulticidal applications of Pyrenone® MAGC (a mixture of pyrethroids and piperonyl butoxide) during the third week of October.

Culex tarsalis was predominant in New Jersey

Table 1. Mosquito composition from all traps in San Bernardino County during 1991. Total collected mosquitoes are 7,950 and 2,433 in the desert and valley regions, respectively.

Species	% Composition	
	Desert	Valley
Aedes increpitus	0.0	0.1
Aedes vexans	6.8	0.0
Anopheles franciscanus	0.4	0.0
Anopheles hermsi	0.0	0.2
Culex erythrothorax	0.6	0.5
Culex quinquefasciatus	0.3	15.2
Culex stigmatosoma	0.9	39.6
Culex tarsalis	69.8	38.3
Culiseta incidens	0.0	3.5
Culiseta inornata	21.1	2.1
Culiseta particeps	0.0	<0.1
Psorophora signipennis	0.1	0.0

Table 2. Distribution of mosquitoes collected in New Jersey light traps at various locations in San Bernardino County during 1991. Total collected mosquitoes are 3,993 and 851 in the desert and valley regions, respectively.

Trap location	% Mosquitoes/trap-night	
	Desert	Valley
Rural	62.6	25.5
Suburban	7.4	55.0
Urban	30.0	19.5

light traps during the spring, summer, and fall months, whereas *Cs. inornata* prevailed during the fall and winter months (Table 4). *Cx. tarsalis* was similarly the most abundant species in the CO_2-baited traps of this region during May through October (Table 4).

In the valley region, mosquito populations peaked in the urban sites during June through August. Population peaks in the rural and suburban sites were noticed during June and in the urban sites during July (Table 3). Mosquito activity at these habitats during May through October was mainly due to *Cx. stigmatosoma*, *Cx. tarsalis*, and *Cx. quinquefasciatus* (Table 5). CO_2-baited traps, however, presented a slightly different pattern of mosquito abundance with *Cx. tarsalis* most abundant followed by *Cx. stigmatosoma* and *Cx. quinquefasciatus* during June through October (Table 5).

None of the 130 mosquito pools submitted to the VRDL showed arboviral activity. One seroconversion was detected during the middle part of September from the sentinel chicken flock located in the desert region at Needles. All sera samples from the sentinel flock maintained in the valley area did not show any arbovirus activity during the 1991.

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References.

Emmons, R.W., D.V. Dondero, C.S. Chan, M.M. Milby, J.W. Walsh, W.C. Reeves, L.T. Hui, F. Ennik, J. Griffin, E.V. Bayer, and R.A. Murray. 1988. Surveillance for arthropod-borne viral activity and disease in California during 1987. Proc. Calif. Mosq. Vector Control Assoc. 56:1-10.

Emmons, R.W., D.V. Dondero, C.S. Chan, M.M. Milby, L.T. Hui, E.V. Bayer, F. Ennik, L. Pitstick, J.L. Hardy, S. Presser, W.C. Reeves, R.A. Murray, and J.W. Walsh. 1989. Surveillance for arthropod-borne viral activity and disease in California during 1988. Proc. Calif. Mosq. Vector Control Assoc. 57:6-12.

Mian, L.S. and R.G. Prochaska. 1990. Mosquito abundance and arboviral activity in San Bernardino County during 1989. Proc. Calif. Mosq. Vector Control Assoc. 58:35-42.

Pfuntner, A.R. 1988. Mosquito abundance and virus activity in the Chino area, San Bernardino County, California, 1987. Proc. Calif. Mosq. Vector Control Assoc. 56:26-31.

Reisen, W.K., R.P. Meyer, M.M. Milby, S.L. Durso, W.C. Heath, S.B. Presser, J.L. Hardy and R.W. Emmons. 1988. Mosquito abundance and arbovirus activity along the Colorado River during 1986-87. Proc. Calif. Mosq. Vector Control Assoc. 56:13-19.

Table 3. Seasonal abundance by habitat of mosquitoes collected in New Jersey light traps from the desert and valley regions of San Bernardino County during 1991.

Region	Month	% Mosquitoes/trap-night Urban	Suburban	Rural	Mean
DESERT	JAN	26.6	5.3	1.2	11.0
	FEB	6.8	2.8	3.8	4.5
	MAR	1.7	1.1	0.7	1.2
	APR	3.1	0.1	13.9	5.9
	MAY	6.8	2.4	16.9	8.7
	JUN	2.7	0.5	3.8	2.3
	JUL	3.8	0.2	4.5	2.8
	AUG	3.4	0.7	1.3	1.8
	SEP	3.4	0.8	3.3	2.5
	OCT	21.5	11.7	33.2	22.2
	NOV	12.0	51.7	13.1	25.6
	DEC	8.2	22.7	4.3	11.7
VALLEY	MAY	6.9	6.4	18.1	10.5
	JUN	28.1	31.4	30.1	29.9
	JUL	39.6	20.3	16.9	25.6
	AUG	25.4	17.3	19.3	20.6
	SEP	0.0	16.7	9.6	8.8
	OCT	0.0	7.9	6.0	4.6

Table 4. Seasonal abundance by species of mosquitoes collected in New Jersey light traps and CO_2-baited traps from the desert region of San Bernardino County during 1991. Total collected mosquitoes are 3,993 and 3,957 in the New Jersey and CO_2-baited traps, respectively.

Month	% Mosquitoes/trap-night							
	Ae. vexans	An. fran.	Cx. erythro.	Cx. quinque.	Cx. stigmat.	Cx. tarsalis	Cs. inorn.	Ps. sign.
N.J. TRAPS								
JAN	0.0	0.0	0.0	0.0	0.0	0.6	3.6	0.0
FEB	0.0	0.0	0.0	0.0	0.0	2.2	1.5	0.0
MAR	0.0	0.0	0.0	0.1	0.0	0.4	0.5	0.0
APR	0.4	0.0	0.0	0.0	0.0	8.4	0.2	0.0
MAY	<0.1	0.0	0.0	0.2	<0.1	11.5	<0.1	0.0
JUN	0.0	0.0	0.0	<0.1	0.0	2.7	0.0	0.0
JUL	0.0	0.0	0.0	<0.1	0.0	3.3	<0.1	0.0
AUG	0.0	<0.1	0.0	0.0	0.0	1.2	<0.1	0.0
SEP	0.4	<0.1	0.0	<0.1	0.0	1.9	<0.1	<0.1
OCT	0.0	<0.1	<0.1	0.3	0.2	18.4	6.8	0.0
NOV	0.0	<0.1	<0.1	0.4	0.0	4.7	19.4	0.0
DEC	0.0	0.0	0.0	0.1	0.0	1.5	8.6	0.0
CO2 TRAPS								
MAY	7.6	0.0	0.3	<0.1	0.1	27.8	0.1	0.0
JUN	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0
JUL	0.1	0.6	0.6	2.3	1.8	19.9	0.0	0.0
AUG	0.0	0.1	0.0	0.5	0.0	2.1	0.0	0.0
SEP	0.0	0.1	<0.1	0.2	0.1	2.1	<0.1	0.0
OCT	0.2	0.0	0.0	0.0	0.0	13.7	1.7	0.0

Table 5. Seasonal abundance by species of mosquitoes collected in New Jersey light traps and CO_2-baited traps from the valley region of San Bernardino County during 1991 Total collected mosquitoes are 851 and 1,582 in the New Jersey and CO_2-baited traps, respectively.

Month	% Mosquitoes/trap-night								
	Ae. increp.	An. herm.	Cx. erythro.	Cx. quinque.	Cx. stigmat.	Cx. tarsalis	Cs. incidens	Cs. inorn.	Cs. part.
N.J. TRAPS									
MAY	0.0	0.0	0.1	0.7	4.2	2.0	1.4	0.4	0.0
JUN	0.0	0.0	0.1	4.0	16.1	7.4	2.7	0.2	0.0
JUL	0.0	0.0	0.1	4.7	13.4	5.4	0.7	0.0	0.0
AUG	0.0	0.0	0.1	4.0	8.7	5.1	1.8	0.1	0.0
SEP	0.0	0.0	0.0	1.5	5.7	2.0	1.1	0.8	0.0
OCT	0.0	0.0	0.0	0.0	2.1	2.9	0.0	0.5	0.0
CO2 TRAPS									
MAY	0.1	0.1	3.0	1.1	5.6	1.6	0.5	1.9	<0.1
JUN	0.0	<0.1	0.0	0.9	8.3	4.0	0.2	<0.1	0.0
JUL	0.0	0.0	0.1	3.5	6.2	3.7	0.0	2.5	0.0
AUG	0.0	0.0	0.0	3.5	4.0	6.8	0.1	0.3	0.0
SEP	0.0	0.0	0.0	3.5	6.8	10.7	0.0	0.0	0.0
OCT	0.0	0.0	0.0	1.3	2.0	17.2	0.0	0.1	0.0

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THE RELATIONSHIP BETWEEN THE ISOLATION OF WESTERN EQUINE ENCEPHALOMYELITIS VIRUS IN LOS ANGELES COUNTY AND THE LONG DISTANCE MIGRATION OF *CULEX TARSALIS*

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Introduction.

On October 11, 1991, the Viral and Rickettsial Disease Laboratory (VRDL) of the California State Department of Health Services (CDHS) advised the Los Angeles County West Mosquito Abatement District (LACWMAD) that seven *Culex tarsalis* Coquillett pools collected the week of September 21, 1991, had tested positive for western equine encephalomyelitis (WEE) virus. The positive pools were concentrated in the Malibu and Torrance areas. The suspected breeding source in Torrance was identified, isolated, and abated within a week. However, the source of the *Cx. tarsalis* breeding in Malibu proved to be more difficult to identify.

Materials and Methods.

A ten square mile target area, encompassing the locations in Malibu where the positive mosquito pools were collected, was divided into a grid of one-quarter square mile zones. The target area was surveyed for several weeks. At the end of that time only twelve minor breeding sources were found. Of those breeding sources, only one was identified as producing *Cx. tarsalis*. The magnitude of the single *Cx. tarsalis* source was insignificant and could not account for the total numbers of *Cx. tarsalis* being recorded at the trapping sites.

It was first believed that prevailing winds off the ocean were transporting the mosquitoes into the target area from a remote breeding source to the south. A series of seven CDC CO_2-baited traps were strategically placed around the positive sites and monitored for *Cx. tarsalis* activity. These results were not consistent with a northernly wind transport of mosquitoes (Table 1). Instead, the results suggest that a secondary inland wind pattern may be importing the mosquitoes in from the west (Fig. 1).

The survey was expanded an additional ten miles to the west into neighboring Ventura County. The results revealed no *Cx. tarsalis* breeding sources in the expanded target area. A new series of five CDC CO_2-baited traps were set leading from the WEE-positive sites in Malibu to a grouping of duck hunting club ponds in Ventura County (Fig. 2). Results revealed that *Cx. tarsalis* counts consistently increased the closer the traps were placed to the duck hunting club ponds. These ponds were examined and heavy *Cx. tarsalis* breeding was observed throughout the 500 acre site.

The Ventura County Health Department was contacted and a request for trapping data was made. It was found that high counts for *Cx. tarsalis* were also being recorded approximately 15 miles to the northeast of the duck hunting club ponds in Newbury Park without identification of a local known breeding source.

Culex tarsalis counts were negative from October through July for the three previous years at the Malibu site. However, each year from late August through early November, *Cx. tarsalis* counts would routinely rise, peak, and then disappear. It was found that the duck hunting club ponds are filled with water each year at the beginning of August and drained in November. Data collected by the Ventura County Health Department during August and September showed a steady and rapid increase in *Culex tarsalis* trap counts in and around the duck hunting ponds each year after they are filled. Results from traps placed adjacent to the ponds during August and early September, 1991, indicate a typical escalation pattern which coincided with those observed at the Malibu site (Table 2).

Table 1. *Culex tarsalis* collections in the seven CO_2-baited traps within the Malibu target area.

Trapping Site	*Cx. tarsalis* per trap-night
1	500
2	560
3	284
4	322
5	100
6	172
7	80

Table 2. *Culex tarsalis* collections during August and early September, 1991 at the Ventura County duck hunting club ponds.

Collection Date	*Cx. tarsalis* per trap-night
8/06/91	24
8/13/91	118
8/20/91	684
8/27/91	1200
9/03/91	1008

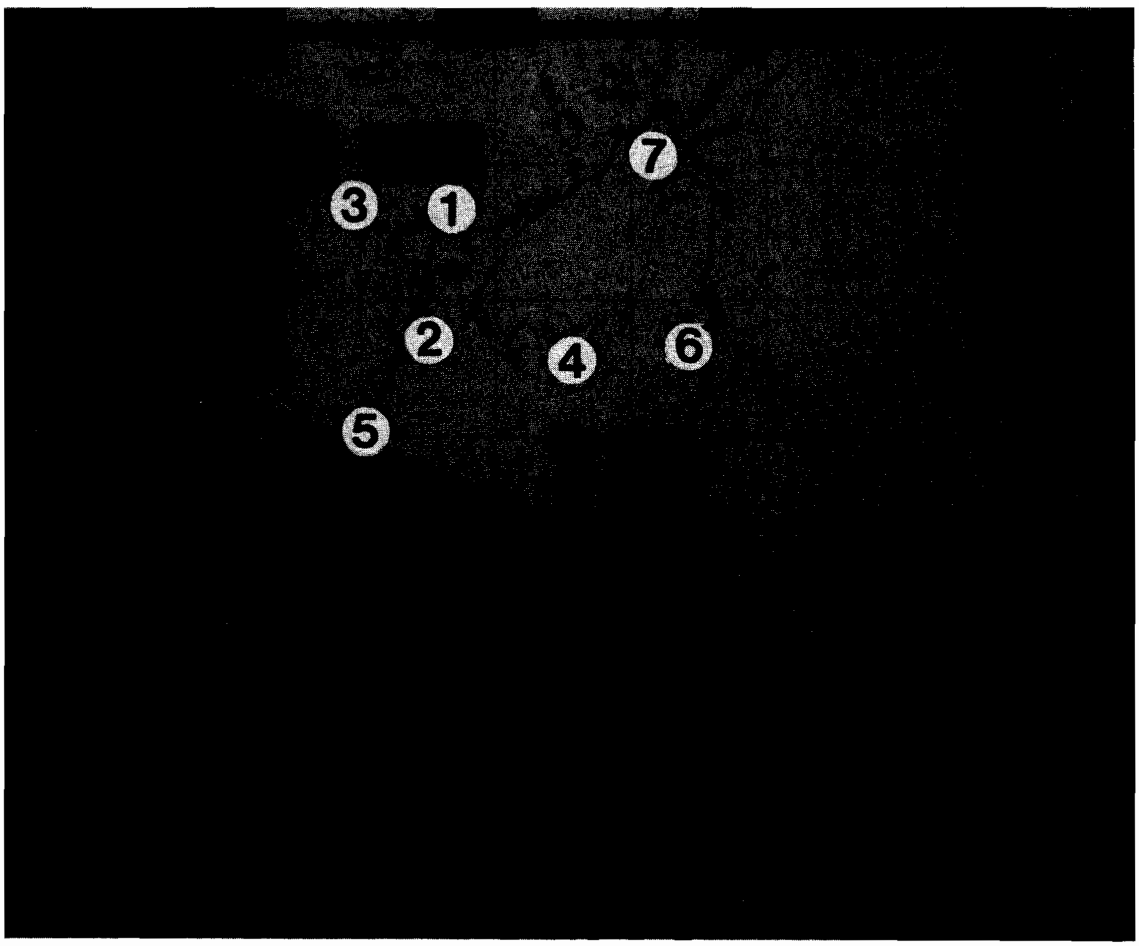

Figure 1. Map indicating locations of CDC CO_2-baited traps around the Malibu target area and the two hypothesized directions of wind transport of mosquitoes into the area.

Figure 2. Map indicating locations of CDC CO_2-baited traps leading from the Malibu target area to the Ventura County duck hunting club ponds.

Discussion and Conclusions.

Wind patterns of the area were studied and matched with the mosquito concentrations. It was, therefore, hypothesized that the prevailing winds which typically blow from west to east across the Oxnard plain were transporting large numbers of *Culex tarsalis* adults from the duck hunting club ponds 15 to 20 miles through inland canyons to Malibu and Newbury Park (Fig. 2). This experience serves to remind us that the sphere of influence on public health matters can be far reaching. Neighboring districts and counties can have a significant influence on public health matters in surrounding communities. The Los Angeles County West Mosquito Abatement District may be influenced by areas as much as 20 miles outside its own boundaries.

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THE USE OF METEOROLOGICAL DATA TO PREDICT MOSQUITO-BORNE VIRUS ACTIVITY IN CALIFORNIA

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ABSTRACT

The Arbovirus Research Unit has monitored mosquito-borne encephalitis virus activity in the Coachella Valley since 1985. In this 7-year period, western equine encephalomyelitis (WEE) virus was detected in five years and St. Louis encephalitis (SLE) virus in all but one year. The early detection of WEE virus in May, 1991, following an unusually cool spring, led us to ask if this pattern of virus activity could have been predicted by analyses of temperature data as described by Hess et al. (1963).

Application of their techniques to the Coachella Valley observations showed that the years with the highest levels of WEE virus activity were those with the latest dates for the accumulation of 50 degree-days (DD) over 80° F; i.e., those with the coolest springs. Studies in our laboratory have shown that *Culex tarsalis* females held at 90° F are less competent vectors for WEE virus than those held at 64 or 79° F. The mosquitoes become infected, but some females held at the higher temperature modulate viral multiplication and/or dissemination and are unable to transmit the infection. Furthermore, elevated larval rearing temperatures result in genetic selection of females with this trait. The temperature parameter most significantly correlated with the percent of Coachella Valley chickens seropositive for SLE virus was mean temperature in January.

Similar analyses were done using observations from Kern County for 1980-1991. Significant relationships were found between WEE virus transmission to sentinel chickens and the date of 10 DD >70° F and mean temperature in May. The years with WEE virus activity were ones where the degree day accumulation was late but the May temperature was high. Very little SLE activity occurred in Kern County during this period, except for the outbreak in 1989 which resulted in 28 human cases in the southern San Joaquin Valley. For SLE virus, the only significant correlation in Kern County was with the date of 10 DD >85° F, which occurred 16 days earlier in 1989 than in any of the 11 other years.

The overall conclusion is that an increased level of WEE virus activity usually is associated with a cool spring, which enhances the transmission of WEE virus in its basic cycle between birds and *Cx. tarsalis*. This is especially true in years when temperatures are warm enough by late spring to allow the build-up of a sufficiently large mosquito population to disseminate the virus over a wide-spread area. The picture is less clear for SLE virus, but its activity generally increases with warm winter and early spring temperatures. We will continue to look for predictors of SLE virus activity in areas such as southern California where this virus is detected in most years.

Acknowledgements.

Data on WEE and SLE virus activity came from the California Encephalitis Surveillance Program. Temperature data were obtained from the IMPACT system operated by the Statewide Integrated Pest Management Project, University of California, Davis. Drs. W.C. Reeves and J.L. Hardy provided useful suggestions on the interpretation of these results.

Reference.

Hess, A.D., C.E. Cherubin and L.C. LaMotte. 1963. Relation of temperature to activity of western and St. Louis encephalitis viruses. Amer. J. Trop. Med. Hyg. 12:657-667.

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SMALL ANIMAL AND HUMAN INFESTATION BY IMMATURE AND ADULT *IXODES PACIFICUS* IN BUTTE COUNTY, CALIFORNIA

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ABSTRACT

During 1989 and 1990, 46 cases of Lyme disease were diagnosed and reported from residents of Butte County, California. Nine of these individuals (28%) did not remember having a tick attached, suggesting possible transmission by an immature stage of *Ixodes pacificus*. Nymphal and larval stages of *I. pacificus* were collected during a 12-month survey from throughout Butte County to gather data on small animal infestations, seasonal activity periods, and *Borrelia burgdorferi* infection rates.

Lyme disease is a tick-borne multiple system illness which if left untreated often develops serious complications. From January, 1989, to December, 1990, 46 residents of Butte County, California, were diagnosed with Lyme disease (pers. commun. - B. Barnhouse, Butte Co. Health Dept.). Yet, 28% of these cases do not remember having had a tick attached (Monsen et al. 1990). Piesman et al. (1987) reported a duration period of at least 24-36 hours of host attachment for successful transmission of *Borrelia burgdorferi* Johnson, Schmid, Hyde Steigerwalt, and Brenner spirochetes. The bite of an adult black-legged tick, *Ixodes pacificus* Cooley and Kohls, generally causes a noticeable local reaction (Furman and Loomis 1984).

Ixodes pacificus, has been implicated as the primary vector of *B. burgdorferi* in California (Burgdorfer et al. 1985). Moreover, *B. burgdorferi* exists in local populations of adult black-legged ticks in various habitats of Butte County (Monsen et al. 1990). Transovarial and transstadial transmission of *B. burgdorferi* spirochetes have been reported in *I. pacificus* (Burgdorfer et al. 1988, Lane and Burgdorfer 1987). The larval and nymphal stages of *Ixodes pacificus* are extremely small in comparison to the adults. As a result, penetration of the feeding structures of the immature stages into the host dermal tissues are not as deep as the deeper penetrating adult mouthparts (Kaufman 1989). Thus, in comparison to adults, larvae and nymphs have a smaller body size, and a shallower feeding lesion, coupled with potential transovarial and transstadial spirochete transmission, which together would seem to allow the infected immature stages a greater opportunity to remain attached and undetected a longer time, and create an increased potential of spirochete transmission to humans. Because of concern about this increased potential for *B. burgdorferi* transmission by the immature stages of ticks to the residents and visitors of Butte County, we gathered data concerning host infestation, infection rate, and period of activity for immature and adult *I. pacificus*.

Materials and Methods.

Subadult stages of *I. pacificus* were removed from wild rodents and lizards collected from particular habitats in Butte County, California, between September, 1989 and August, 1990. Forty-two sites throughout Butte County were randomly selected and sampled once. Rodents were trapped in Sherman and National live traps, baited with a mixture of cotton, peanut butter, and rolled oats. A total of 50 traps, placed on a transect line six meters apart, were set overnight in each site. Captured rodents were euthanized, identified, and examined in the laboratory under a dissecting microscope for immature ticks.

Western fence lizards, *Sceloporus occidentalis*, were noosed using nylon fishing line attached to a two-meter wooden handle. These were identified and examined for ticks using an 8-power hand lens. Ticks were removed in the field and held for testing.

Host-seeking adult ticks were collected from the same locations using one meter square tick flags. Such sampling emphasized animal trails, beds, and micro-ecotones within the habitat site.

Ticks were identified to species using the identification keys of Furman and Loomis (1984) and Webb and Bennett (1990). Each tick was then individually assayed for spirochetes using an indirect immunofluorescence antibody assay (IFA) with *B. burgdorferi*-specific monoclonal antibody H5332 (Barbour et al. 1983, Wilske et al. 1988). Additionally, ticks brought into the District by local residents were also tested for *B. burgdorferi* with the midgut contents and salivary tissues being dissected from adult ticks. Internal organs of immature ticks were smeared on fluorescent well slides (Van Water and Rogers). Positive control slides consisting of heat-killed *B. burgdorferi* (ATCC 35210) were included with each assay. Fluoroscopy was conducted under epi-fluorescent illumination.

In another part of this study, twelve physicians who reported cases of Lyme disease in Butte County residents were contacted and asked if they routinely prescribed antibiotic treatment after removal of an embedded tick or if they waited for signs and/or symptoms of developing Lyme Borreliosis.

Table 1. *Borrelia burgdorferi* isolations from all stages of *Ixodes pacificus* ticks collected and tested by IFA using monoclonal antibody H5332.

Stage	Total tested	Positive isolations	Percent infected
Male	430	10	2.3
Female	443	12	2.7
Nymph	61	0	0.0
Larva	129	2	1.7
Totals	1,063	24	2.3

Results.

Lyme disease spirochetes were found in male, female, and larval, but not nymphal, ticks (Table 1). Black-legged ticks were collected from chaparral, ponderosa pine, and digger pine/oak habitats. No ticks were found in low (100' to 300') or mid-elevation (300' to 750') riparian deciduous habitats, nor in annual grassland.

We examined nine species of rodents for attached ticks and found subadult stages parasitizing five of these, including *Peromyscus maniculatus, Peromyscus boylii, Peromyscus truei, Neotoma fuscipes*, and *Microtus californicus* (Table 2).

Table 2. All stages of *Ixodes pacificus* ticks retrieved from hosts collected in four principal habitat types.

Species	Total collected	*Ixodes pacificus* Larvae	Nymphs	Adults	Habitat*
Canis familiaris	4	-	-	43	C,P
Eutamias amoenus	3	-	-	-	P
Felis canis	4	-	3	4	C,P
Microtus californicus	2	23	-	-	P
Neotoma fuscipes	7	9	1	-	P,C
Peromyscus boylii	5	4	-	-	P
Peromyscus maniculatus	70	82	7	-	C,P,D,R
Peromyscus truei	5	3	2	-	C,P
Rattus rattus	5	-	-	-	R,D
Sceloporus occidentalis	42	29	38	-	C,P
Sciurus griseus	11	-	-	-	C,P
Spermophilus beecheyi	1	-	-	-	P

* Habitats: C- Chaparral; P- Ponderosa Pine; D- Digger Pine/Oak; R- Low to Mid-elevation Riparian Deciduous

Peromyscus maniculatus was the most heavily parasitized host, averaging 1.2 larvae and 0.1 nymphs per mouse. Although *P. maniculatus* was collected from all of the habitats sampled, subadult ticks parasitized these mice only in the digger pine/oak, ponderosa pine, and chaparral habitats. Additionally, we examined 4 domestic cats, 11 western gray squirrels (*Sciurus griseus*); 5 black rats (*Rattus rattus*); 1 California ground squirrel (*Spermophilus beecheyi*); and 3 yellow pine chipmunks, (*Eutamias amoenus*), but only domestic cats had black-legged ticks (3 nymphs). Adult ticks were flagged from vegetation in the ponderosa pine, chaparral, and digger pine/oak habitats.

The seasonality of host-seeking subadult black-legged ticks did not coincide with that of adults (Fig. 1). Adults began to seek hosts in October shortly after the first seasonal rain storms but disappeared in early June. Larvae first appeared in January and peaked in May where the average number collected per host animal reached 10.8. Nymphal tick activity commenced in January and peaked in June where the average number collected per host animal reached 4.7. Both larvae and nymphs remained active during the summer in low numbers after the adults had entered a quiescent period (Fig. 1).

Western fence lizards averaged 0.9 nymphs and 0.7 larvae apiece (N=42 lizards). Lizard activity was restricted to the warmer months, March-October, and to the chaparral and ponderosa pine habitats (Fig. 2).

Twenty-eight Butte County residents submitted ticks they had found attached to themselves or to their children to the District for identification and testing (Table 3). These included 6 larvae (mainly from children), 4 nymphs, and 23 female ticks. One 4-year old child presented with four larvae attached. Only 1 of the 23 examined female ticks (3.1%) was found to be harboring spirochetes.

Ten of the twelve contacted physicians responded to our survey (Table 4). Those who diagnosed and reported 31 of the 39 human Lyme Borreliosis cases (80%) in 1989-1990 treated persons with tick bites prophylactically with antibiotics after removal of the ticks.

Discussion.

There appears to be a potential for Lyme disease transmission to humans by the immature stages of *I. pacificus* in Butte County since larvae and nymphs were both found to be feeding on residents of Butte County. Larvae in nature were found to be harboring spirochetes identified as *B. burgdorferi*. It could not be determined whether the larval infections were the result of transovarial transmission or new infections acquired from the rodent host from which they were collected. On humans, the larvae were found most often on small children who may come in contact with clusters of

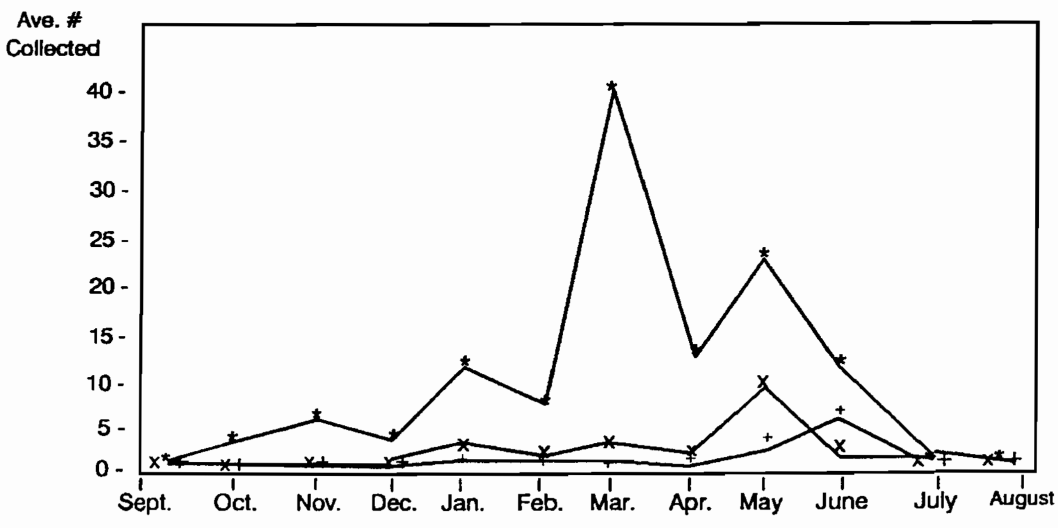

Figure 1. Seasonality of host-seeking by all stages of *Ixodes pacificus*. Adults measured by flagging and subadults collected from hosts.

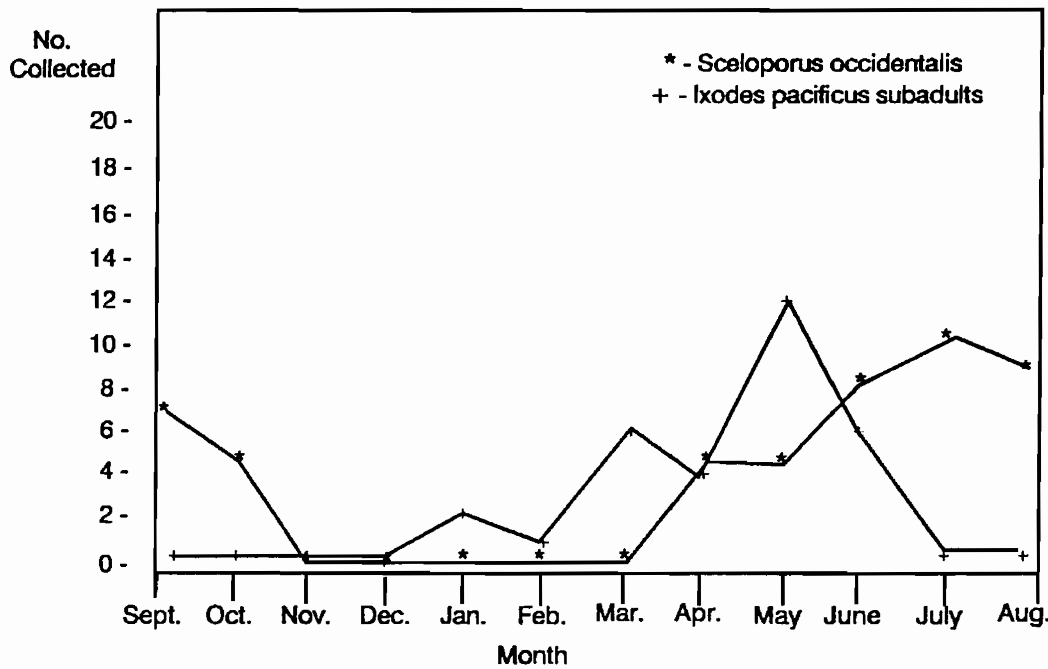

Figure 2. Seasonality of the western fence lizard, *Sceloporus occidentalis*, captured by noosing and subadult ticks, *Ixodes pacificus*, collected from hosts.

larvae in areas where they sit or play. In 1989, 6 of 32 (19%) of the reported Lyme disease cases in Butte County, were in children under 10 years of age (pers. commun.- B. Barnhouse, Butte Co. Health Dept.).

The data supplied for all persons bitten by ticks seems to suggest that the adult female black-legged tick is the most frequent stage which feeds on humans in Butte County (Table 3). Seventy-nine percent (23 out of 28) of the tick bites reported to the District were by female *I. pacificus*.

Larvae were found most frequently feeding on *P. maniculatus* and *S. occidentalis*. *Sceloporus occidentalis* has been found in a previous study to be a heavily infested host (Lane and Loye 1989). Despite this finding, *P. maniculatus* appears to be a preferred host when compared to lizards (James and Oliver 1990). The deer mice also seem to be an ubiquitous animal, found in a wide variety of habitats and active throughout the year (Hess et al. 1937). Lane (1990b), found *P. maniculatus* and *P. truei* to be naturally infected with *B. burgdorferi* in chaparral and woodland grass habitats in Sonoma County, California. Each of the individual species of cricetids collected may be possible candidates as rodent reservoirs of the etiologic agent of Lyme disease. More studies concerning infection and infectiousness to tick vectors must be conducted, however, before they can be implicated as reservoirs.

Sceloporus occidentalis lizards collected during a survey in Sonoma County were found to have a greater tick burden per host than deer mice (Lane and Loye 1989). In a focus of *B. burgdorferi* transmission in Sonoma County, the western fence lizard has been strongly suspected of providing a natural zooprophylaxis by breaking the cycle of transmission as an incompetent reservoir for the spirochete (Lane and Loye 1989; Lane 1990a, 1990b). Natural zooprophylaxis by lizards may not be occurring in all habitats or only during certain times of the year in Butte County as lizards were not active during the entire period of immature tick activity nor found in high numbers in all habitats where immature ticks were collected (Fig. 2). Thus, humans may be at greater risk of acquiring a *B. burgdorferi* infection in habitats which have low numbers of lizards or during the months when lizards are not active.

In this survey, nymphs were found more often on lizards than on the rodents. However, the low number of nymphs collected (61) raises questions

Table 3. *Ixodes* ticks brought to BCMAD by local residents for testing.

Date	Initials	Host	*Ixodes pacificus* Larva	Nymph	Female
8-28-90	C.S.	Adult		1	
7-25-90	E.N.	Adult			1
6-25-90	J.V.	Adult		1	
6-23-90	D.J.	Adult			1
6-23-90	M.S.	Child		1	
6-23-90	C.P.	Adult			1
6-12-90	B.S.	Child	4		
6-12-90	M.S.	Child	1		
6-05-90	K.B.	Adult			1
6-05-90	T.C.	Child			1
5-29-90	A.C.	Adult			1
5-22-90	C.G.	Adult			1
5-22-90	M.D.	Adult			1
5-14-90	C.P.	Child		1	
5-14-90	K.M.	Adult			1
4-23-90	J.M.	Adult			1
4-23-90	D.B.	Adult			1
4-23-90	S.B.	Adult			2
4-03-90	A.L.	Adult			1
3-27-90	C.M.	Adult			1
3-25-90	D.H.	Adult			1
3-20-90	D.H.	Child	1		
3-20-90	J.H.	Adult			1
2-26-90	T.C.	Child			1
2-26-90	J.B.	Adult			1
2-05-90	S.D.	Adult			1
11-10-89	B.C.	Adult			1
11-06-89	J.H.	Adult			1
Adults		21	-	2	21
Children		7	6	2	2
Totals		28	6	4	23

Table 4. Butte County physicians diagnosing Lyme disease cases during 1989-1990 and survey response about prescribing prophylactic antibiotics for tick attachment.

Physician #	Diagnosed cases	Percent total	Antibiotic response
1	1	2.5	Yes*
2	1	2.5	Yes
3	2	5.0	No
4	2	5.0	No
5	23	59.0	Yes
6	1	2.5	Yes**
7	2	5.0	Yes
8	1	2.5	No Response
9	1	2.5	No Response
10	3	8.0	Yes
11	1	2.5	No
12	1	2.5	No
	39		Yes- 6 (80%)
			No- 4 (15%)
			N.R.- 2 (5%)

* Only with inflammation at the bite site.
** Not in every instance.

concerning the hosts most frequently fed on by this stage of black-legged tick in Butte County habitats. Larger animals such as lagomorphs and deer have been found by other workers to be heavily infested by this subadult stage (Furman and Loomis 1984, Westrom et al. 1985). From our collection data, it appears that the adults of *I. pacificus* do not feed on rodents since no adults were found on the 109 rodents collected.

The *B. burgdorferi* infection rate of the 873 adult *I. pacificus* examined in 1989-90 was 2.5% (22 isolations from 873 tested). In 1988-89, there were a total of 19 isolations from 1,122 (1.5%) adult ticks tested (Monsen et al. 1990). The *B. burgdorferi* rate of infection in adult *I. pacificus* in 1990 appears to be 60% higher than that of the previous year. Despite this measured increase in the infection rate in the adult tick population, the number of reported human Lyme Borreliosis cases dropped in 1990. Borreliosis protection by the use of precautionary antibiotic treatment may have reduced the number of people who might otherwise have developed the disease, thereby reducing the number of officially reported cases as well. Certainly, the use of antibiotics prophylactically for Lyme Borreliosis by a number of physicians who are seeing the bulk of the Lyme Borreliosis cases can reduce or mask the degree of transmission to humans which might otherwise be occurring. This situation would seem to further complicate the vexing phenomenon of determining the incidence or severity of Lyme Borreliosis in Butte County.

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References.

Barbour, A.G., S.L. Tessier and W.J. Todd. 1983. Lyme disease spirochetes and Ixodid tick spirochetes share a common surface antigenic determinant defined by a monoclonal antibody. Infect. Immun. 41:795-804.

Burgdorfer, W., R.S. Lane, A.G. Barbour, R.A. Gresbrink and J.R. Anderson. 1985. The western black-legged tick, *Ixodes pacificus*: a vector of *Borrelia burgdorferi*. Amer. J. Trop. Med. Hyg. 34(5):925-930.

Burgdorfer, W., S.F. Hayes and J.L. Benach. 1988. Development of *Borrelia burgdorferi* in Ixodid tick vectors. Ann. N.Y. Acad. Sciences 539:172-179.

Furman, D.P. and E.C. Loomis. 1984. The Ticks of California (Acari: Ixodidae). Bull. Calif. Insect Survey #25.

Hess, R., W.C. Allee and K.P. Schmidt. 1937. Ecological Animal Geography. John Wiley and Sons, New York, NY.

James, A.M. and J.H. Oliver, Jr. 1990. Feeding and host preference of immature *Ixodes dammini*, *I. scapularis*, and *I. pacificus* (Acari: Ixodidae). J. Med. Entomol. 27(3):324-330.

Kaufman, W.R. 1989. Tick-host interaction: a synthesis of current concepts. Parasit. Today 5(2):47-56.

Lane, R.S. 1990a. Susceptibility of the western fence lizard (*Sceloporus occidentalis*) to the Lyme borreliosis spirochete (*Borrelia burgdorferi*). Amer. J. Trop. Med. Hyg. 42:75-82.

Lane, R.S. 1990b. Infection of Deer Mice and Pinon Mice (*Peromyscus* spp.) with spirochetes at a focus of Lyme borreliosis in northern California, U.S.A. Bull. Soc. Vector Ecol. 15(1):25-32.

Lane, R.S. and J.E. Loye. 1989. Lyme disease in California: interrelationship of *Ixodes pacificus* (Acari: Ixodidae), the western fence lizard (*Sceloporus occidentalis*), and *Borrelia burgdorferi*. J. Med. Entomol. 26(4):272-27.

Lane, R.S. and W. Burgdorfer. 1987. Transovarial and transstadial passage of *Borrelia burgdorferi* in the western black-legged tick, *Ixodes pacificus* (Acari: Ixodidae). Amer. J. Trop. Med. Hyg. 37:188-192.

Monsen, S.E., W.E. Hazeltine and T.L. Henderson. 1990. Lyme borreliosis surveillance in Butte County, California. Bull. Soc. Vector Ecol. 15(1):63-72.

Piesman, J., T.N. Mather, R.J. Sinsky and A. Spielman. 1987. Duration of tick attachment and *Borrelia burgdorferi* transmission. J. Clin. Microbiol. 557-558.

Webb, J.P., S.G. Bennett and G.L. Challet. 1990. The larval ticks of the genus *Ixodes* Latreille (Acari: Ixodidae) of California. Bull. Soc. Vector Ecol. 15(1):73-124.

Westrom, D.R., R.S. Lane and J.R. Anderson. 1985. *Ixodes pacificus* (Acari:Ixodidae): Population dynamics and distribution on Columbian black-tailed deer (*Odocoileus hemionus columbianus*). J. Med. Entomol. 22(5):507-511.

Wilske, B., V. Preac-Mursic, G. Schierz, R. Kuhbeck, A.G. Barbour and M. Kramen. 1988. Antigenic variability of *Borrelia burgdorferi*. Ann. N.Y. Acad. Sciences 539:126-143.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 67-70

LANDSCAPE ECOLOGY OF ENCEPHALITIS VIRUS TRANSMISSION IN THE COACHELLA VALLEY: SPATIAL PATTERNS OF SEROCONVERSIONS IN SENTINEL CHICKENS[1,2]

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ABSTRACT

Fifteen study sites were established in the southern Coachella Valley in March 1991, to relate spatial variation in the activity of western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) viruses to habitat type and juxtaposition to the Whitewater Channel and Salton Sea shoreline. WEE virus was detected at 14 of 15 sites, but the seasonal seroconversion rate among sentinel chickens varied independently of habitat type and geographical location. SLE virus was active at 10 of 15 sites; the sentinel seroconversion rate varied significantly as an inverse function of distance from the Salton Sea, but independently of habitat type and distance from the Whitewater Channel. Sentinel flock placement rather than flock size was most important in virus detection.

Introduction.

Present knowledge of the spatial patterns of western equine encephalomyelitis (WEE) virus and St. Louis encephalitis (SLE) virus transmission in California is based on "best estimate" sampling over widely spaced sites by the statewide encephalitis virus surveillance (EVS) program. Sampling methods include the monthly bleeding of flocks of sentinel chickens to monitor seroconversions and the testing of pools of mosquitoes to detect virus infections. The purpose of this program has been the early detection of encephalitis virus activity that may later result in the occurrence of human cases. However, data obtained from this program has provided little information on heterogeneity in the intensity of virus activity in ecologically diverse habitats located within a relatively small geographical area. An estimate of this variation in transmission intensity is critical to allocating surveillance activities using limited resources.

The objectives of the present study were to 1) improve the sensitivity of the "best estimate" sampling scheme by describing spatial variability of virus activity within relatively small geographic areas, 2) associate transmission intensity with habitat type, and 3) compare the sensitivity of large

[1] This research was funded by Grant No. AI-3028 from the National Institute of Allergy and Infectious Diseases, by special funds for mosquito research allocated annually through the Division of Agriculture and Natural Resources, University of California, and by the Coachella Valley Mosquito Abatement District.

[2] A complete summary of this research will be submitted for publication to the Journal of Medical Entomology.

[3] Coachella Valley Mosquito Abatement District, 83-733 Avenue 55, Thermal, California 92274.

flocks of 20 chickens to small flocks of 10 chickens. A companion paper (Reisen et al. 1992) will describe the temporal patterns of virus activity in relation to mosquito abundance.

Materials and Methods.

The southern half of the Coachella Valley, bordered on the west by the San Jacinto and Santa Rosa Mountains, on the north and east by the San Bernardino Mountains and the Mecca Hills, and on the south by the Salton Sea, was selected for study because of its ecological diversity and history of consistent encephalitis virus activity. Within this area stretches a mosaic of agricultural crops (irrigated by different methods), interspersed residential areas (small towns and rural farm houses), and undeveloped desert. Fifteen study areas were selected to sample representative habitat types as well as terrain features and geographical regions (Fig. 1). The realities of access and cooperation from landowners resulted in some sites being placed at the interface between habitat types.

The eastern and southwestern regions of the study area were predominantly citrus/grape orchards with a few parcels of row crops, date groves, and undeveloped desert. The duck hunting club region extends around the northern shore of the Salton Sea. The region along the Whitewater Channel, north of the duck hunting clubs, is predominantly row crops and undeveloped desert. The western central region is a mosaic of row crops, citrus orchards, and date groves. The northern region includes lesser amounts of these crops as well as interspersed residential areas. The 15 study areas were allocated to the following principal habitat types: residential (sites 5 and 13), date groves (sites 14, 15, 10, and 6), citrus/grape orchards (sites 4, 12, and 8), duck hunting clubs (sites 1, 2, and 3), mixed row crops (site 9), irrigated pasture (site 11), and Salton Sea shoreline (site 7). The study areas sampled the southern approaches to the Coachella Valley from the Imperial Valley, the northern shore of the Salton Sea, and a south-to-northwest transect along the

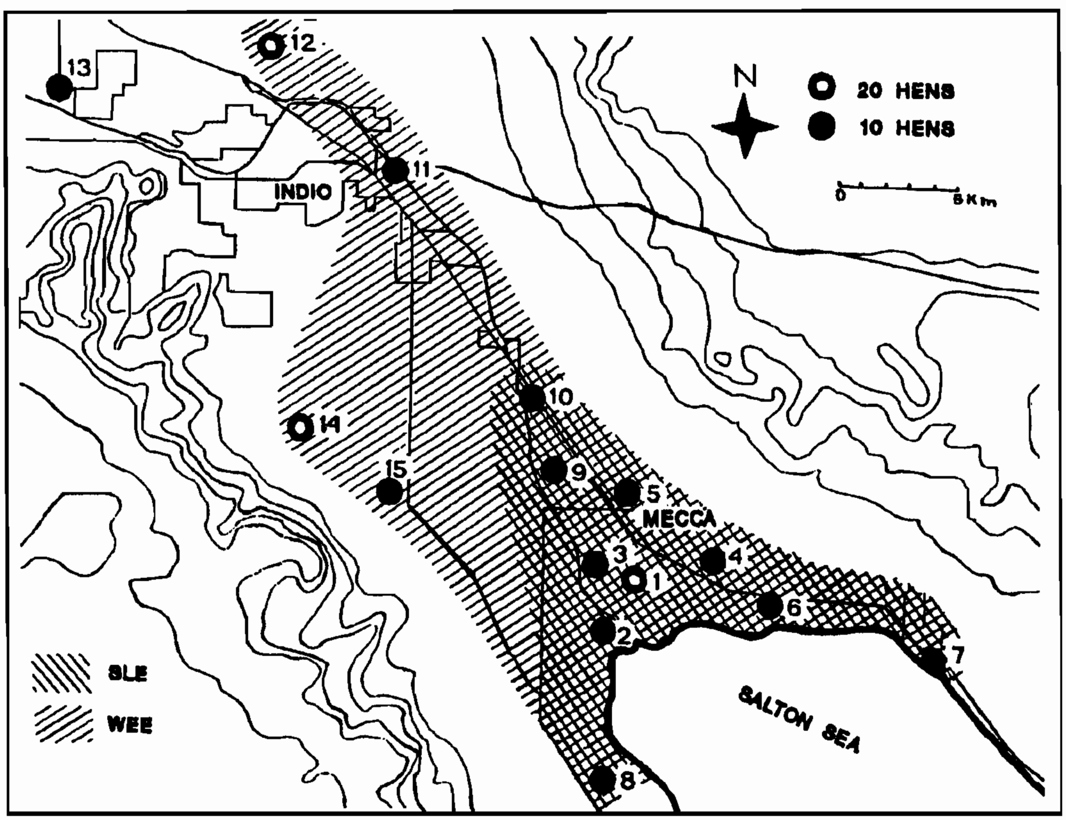

Figure 1. Map of the Coachella Valley showing the position of the 15 study areas and the overall distribution of SLE and WEE virus activity.

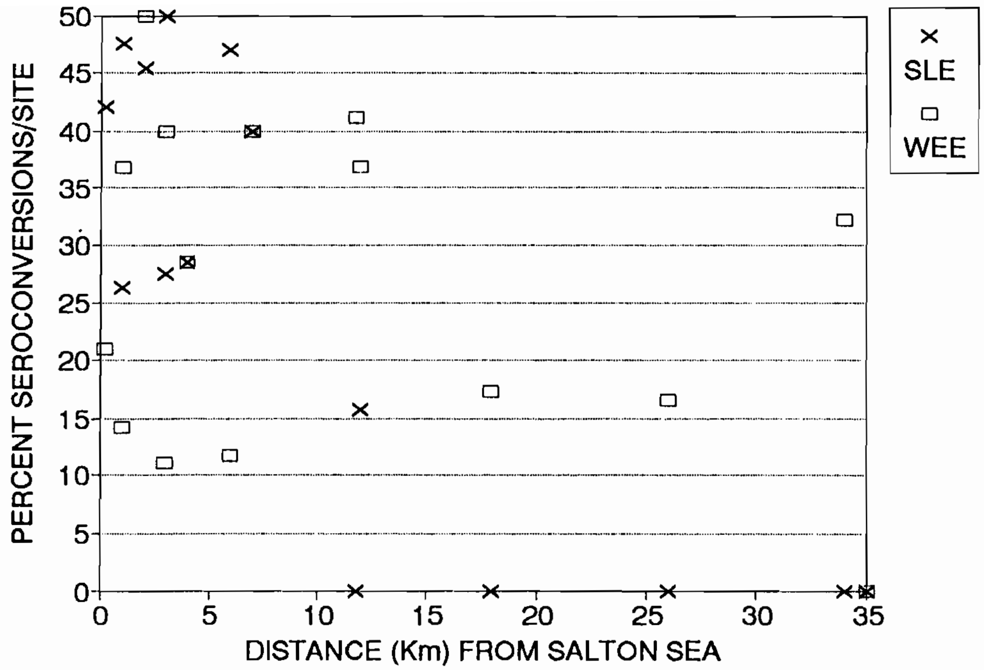

Figure 2. Percentage of total sentinel chickens seroconverting to SLE and WEE viruses plotted as a function of study area distance from the Salton Sea.

Whitewater Channel.

From March through October 1991, mosquito abundance was monitored at each study area on alternate weeks using 2-3 CDC-style traps baited with dry ice and hung on fixed standards which set the trap entrance between 1.0 and 1.2 meters above ground. Virus infection was monitored by testing up to 10 pools of 50 females each of the primary vector species, *Culex tarsalis* Coquillett, per study area per sampling occasion. Flocks of 20 or 10 white leghorn hens were deployed at each site and bled at monthly intervals to detect seroconversions to WEE or SLE viruses. Chickens which seroconverted were replaced the following month after a confirmatory bleeding. Seroconversions may have gone undetected in dual infections, if the chickens were infected with the second virus within 7-10 days prior to replacement. Mortality provided an additional source of data loss.

Results and Discussion.

The overall geographical distribution of virus activity during 1991 was different for WEE and SLE viruses (Fig. 1). WEE virus was active at 14 of 15 sites, extending from the shore of the Salton Sea to the west side of the valley (site 14) and to the north of the city of Indio (site 12). Only site 13 in a highly residential habitat in the city of Palm Desert remained negative for WEE virus. In contrast, SLE virus was detected at 10 of 15 sites, and was limited to the shore of the Salton Sea and the portion of the valley south and east of site 10 (Fig. 1).

The percentage of total chickens deployed at each site that seroconverted for each virus during the 1991 season then was grouped by habitat, distance from the Whitewater Channel, and distance from the Salton Sea. No clear pattern was evident when the seroconversion rates for each virus were grouped by habitat type or distance from the Whitewater Channel. However, the seroconversion rates for SLE ($r = -0.81$, $df = 13$, $P < 0.01$), but not WEE ($r = -0.34$, $P > 0.05$), virus decreased significantly as a function of distance in kilometers from the shore of the Salton Sea (Fig. 2). This distributional pattern was in general agreement with trends observed during more limited sampling of the same area in 1989 and 1990 for SLE virus (Reisen et al. 1992) and 1987 for WEE virus (Durso and Burguin 1988).

There was no apparent difference in the sensitivity of flocks of 10 or 20 chickens in detecting WEE or SLE virus transmission. Adjacent flocks of 10 hens at site 15 and at sites 2 and 3 detected

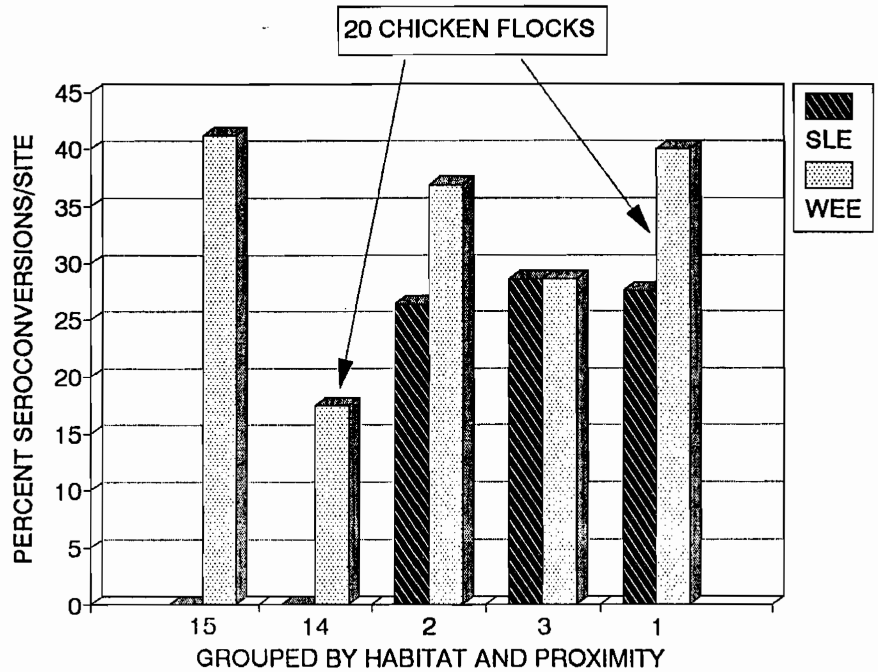

Figure 3. Percentage of sentinel chickens in adjacent flocks of 10 hens (sites 15, 2, and 3) or 20 hens (sites 14 and 1) that seroconverted to either SLE or WEE virus.

WEE and SLE virus activity comparable to or greater than flocks of 20 hens at sites 14 and 1, respectively (Fig. 3). These and previous data strongly indicated that flock placement is far more important than flock size in detecting virus activity.

The current research project is ongoing and will continue to monitor virus overwintering during 1991-1992. Planned modifications in 1992 will include the standardization of flock size to 10 hens, the increased frequency of serum sampling from 4- to 2-week intervals, and the extension of sampling into more northern and residential areas.

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References.

Durso, S.L. and M.J. Burguin. 1988. Mosquito abundance and arboviral activity in the Coachella Valley -1987. Proc. Calif. Mosq. Vector Control Assoc. 56:20-25.

Reisen, W.K., J.L. Hardy, S.B. Presser, M.M. Milby, R.P. Meyer, S.L. Durso, M.J. Wargo and E. Gordon. 1992. Mosquito and arbovirus ecology in southeastern California, 1986-1990. J. Med. Entomol. 29(3):512-524.

Reisen, W.K., H. Lothrop, M.M. Milby, S.B. Presser, J.L. Hardy and M.J. Wargo. 1992. Landscape ecology of encephalitis virus transmission in the Coachella Valley: temporal patterns among mosquito abundance and viral infection rates, and seroconversions in sentinel chickens. Proc. Calif. Mosq. Vector Control Assoc. 60:71-75.

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LANDSCAPE ECOLOGY OF ENCEPHALITIS VIRUS TRANSMISSION IN THE COACHELLA VALLEY: TEMPORAL PATTERNS AMONG MOSQUITO ABUNDANCE AND VIRUS INFECTION RATES, AND SEROCONVERSIONS IN SENTINEL CHICKENS[1,2]

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ABSTRACT

Temporal changes in the distribution of encephalitis virus transmission to sentinel chickens and their relationship to *Culex tarsalis* abundance were studied at 15 sites in the southern Coachella Valley from March to October, 1991. Western equine encephalomyelitis (WEE) virus was active initially in May along the northeastern shore of the Salton Sea and then spread to the west along the north shore of the Salton Sea and to the north along the Whitewater Channel to eventually include 14 of the 15 study areas. St. Louis encephalitis (SLE) virus activity commenced later during July at the same locality, and then followed a similar pattern of dissemination. The seasonal seroconversion rate of sentinel chickens to WEE and SLE viruses was positively correlated with the log of *Culex tarsalis* abundance. Using principal components and correlation analyses, three temporal patterns of *Cx. tarsalis* abundance were recognized among study areas following a south to north progression; A) unimodal spring, B) unimodal fall, and C) continued low abundance. Although vector abundance was correlated spatially with virus occurrence, peaks in vector abundance were temporally asynchronous with virus activity.

Introduction.

In a companion paper, Lothrop et al. (1992) described sampling methodology, the general ecology and distribution of study areas, and attempted to relate seasonal seroconversion rates in sentinel chickens to flock size, habitat type and distance from the Whitewater Channel and the Salton Sea. Seroconversion rates were found to depend primarily on flock location rather than the number of hens in the flock. Seroconversion rates

[1] This research was funded by Research Grant AI-03028 from the National Institute of Allergy and Infectious Diseases, by special funds for mosquito research allocated annually through the Division of Agriculture and Natural Resources, University of California, and by the Coachella Valley Mosquito Abatement District.

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were independent of habitat type and distance from the Whitewater Channel, but decreased as a function of distance from the shore of the Salton Sea.

The purpose of the present paper was to 1) describe the temporal patterns of western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) virus dissemination, 2) compare the sensitivity of sentinel chicken seroconversion rates and mosquito infection rates in detecting virus activity, and 3) relate the intensity of virus transmission to patterns of mosquito abundance and infection over time and space.

Results and Discussion.

Temporal Patterns of Virus Dissemination: The juxtaposition of our study sites 1 to 15 to the Salton Sea and Whitewater Channel are shown in Figure 1. WEE or SLE viruses were considered to be active at a study site on the date that one or more positive pools of *Culex tarsalis* Coquillett were collected or on the date that one or more seropositive sentinel chickens were bled (Table 1).

WEE virus initially was detected during the week of May 29, 1991 when 1 of 17 pools of *Cx. tarsalis* from site 7 at the Salton Sea Recreational Area was determined to be positive by ELISA (Table 1). A second pool was positive at site 7 during early June, but none of the sentinel chickens seroconverted at site 7 until August. However, eight seroconversions were detected at sites 1, 3 and 6 on June 22, 1991. By July, WEE virus also was

Table 1. Seasonal mean abundance of *Cx. tarsalis* (females per CO_2 trap-night) and the percentage of chickens seropositive for WEE or SLE virus at each study site in the Coachella Valley during 1991. Also included are the months when WEE (W) or SLE (S) virus was detected at each site.

Study[a] site	*Culex*[b] *tarsalis*	Percent seropositive[c] WEE	(N)	SLE	(N)	Month virus detected May	Jun	Jul	Aug	Sep	Oct	Nov
GROUP A												
7	33	24	(17)	47	(17)	W	W	WS	WS	WS	S	
8	60	52	(21)	48	(21)			W	WS	S		
GROUP B												
1	106	52	(31)	35	(31)		W	W	WS	WS	S	
2	155	44	(16)	31	(16)				W	WS	S	
3	111	43	(14)	43	(14)		W	W	WS	WS	S	
4	16	10	(10)	90	(10)				WS	S	S	
5	7	10	(10)	60	(10)					S	WS	W
6	10	18	(17)	53	(17)		W		WS	S	S	S
9	39	50	(16)	50	(16)			W	W	WS		
10	8	44	(16)	19	(16)				W	WS		
15	3	41	(17)	0	(17)				W			
GROUP C												
11	1	20	(10)	0	(10)					W		
12	1	36	(25)	0	(25)				W	W		
13	<1	0	(10)	0	(10)							
14	1	17	(23)	0	(23)			W	W	W		

[a] Study site numbers plotted on Figure 1 and grouped by temporal abundance patterns using principal components analysis.

[b] Geometric mean number of *Cx. tarsalis* (females per CO_2 trap-night) from March-October, 1991.

[c] Percentage of seronegative chickens from each flock becoming positive to either WEE or SLE viruses during May-October, 1991 (N= total number of chickens exposed May-October).

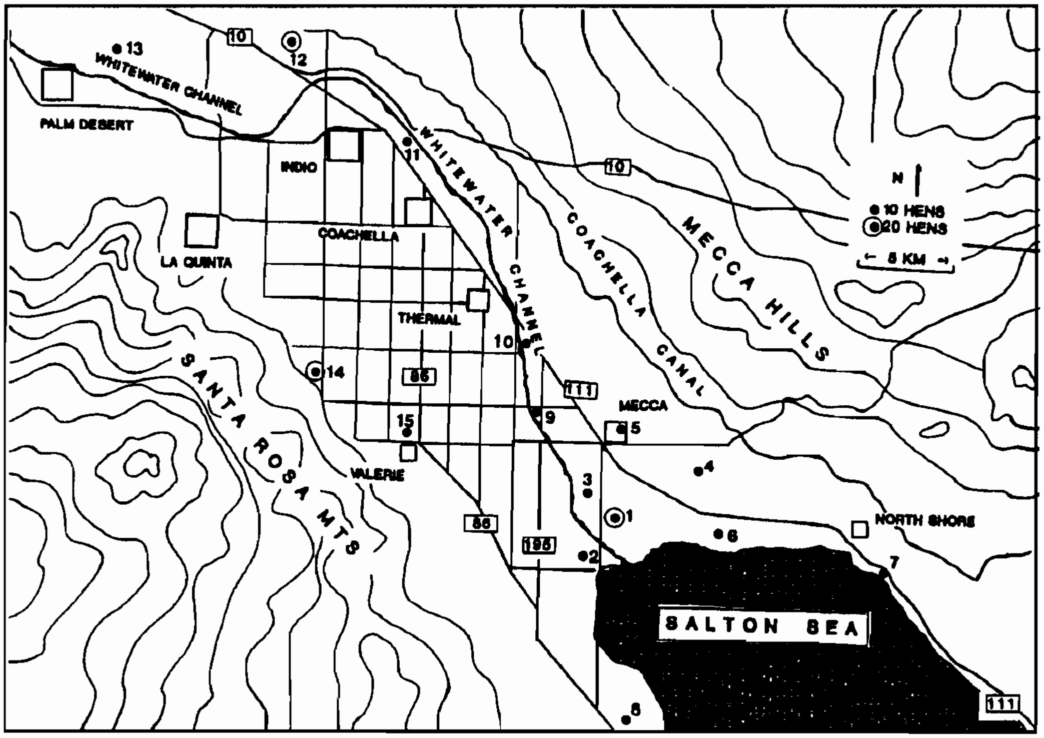

Figure 1. Map of the southern Coachella Valley showing the location of the 15 study sites used in 1991.

detected at site 14 to the west, site 9 to the north, and site 8 to the south, but seemed to by-pass sites 2 and 15. Habitats involved included duck clubs, date groves and sites near seepage along the shore of the Salton Sea. By August, 12 of 15 sites throughout the southern half of the Coachella Valley were involved. Virus still was not detected at sites 13 (a sewage plant in Palm Desert), 11 (a horse pasture near a sewage plant in Indio), and 5 (a house in the town of Mecca). By September, WEE virus was no longer detected at sites 6, 8, and 15 which were previously positive, but now had spread to include site 11. WEE virus then subsided throughout the valley, with the exception of site 5 which was positive during October and November. WEE virus activity at sites 5, 10, and 11 near the towns of Mecca, Thermal, and Indio, respectively, indicated that virus transmission occurred in close proximity to man. However, human cases were not reported from the Coachella Valley during 1991.

A similar pattern of virus initiation and dissemination was observed for SLE virus, with the exception that SLE activity commenced later in the season than WEE virus and was confined to sites south of the town of Thermal (Fig. 1, Table 1). SLE virus activity initially was detected at site 7, when 3 of 10 sentinel white leghorn hens bled on July 22 were seropositive. By August 19, SLE virus had spread to sites 1, 3, 4, 6, and 8. The initial by-passing of site 2 by both viruses was unexpected, since this duck hunting club habitat supported large *Cx. tarsalis* populations and was the site where SLE virus was first detected during 1990. By September, SLE virus was found at all sites along the Salton Sea and north to site 10 in a date grove along the Whitewater Channel just south of the town of Thermal. By October, SLE activity had begun to subside and was restricted to sites along the Salton Sea, but now also included site 5 in the town of Mecca and site 4 in an adjacent citrus/grape plantation. A single chicken seroconverted to SLE at site 6 in November.

In summary, WEE virus was detected at 14 of 15 sites throughout most of the southern Coachella Valley, while SLE virus was confined to 10 sites, mostly along the shore of the Salton Sea and Whitewater Channel. Virus was detected comparatively infrequently by testing mosquito pools. Although 16,876 *Cx. tarsalis* were tested in 379 pools from all sites, only 15 pools from five sites were positive for WEE virus (minimum infection rate per 1000 (MIR)=0.89) and four pools from two sites were positive for SLE virus (MIR=0.24). If sentinels were not deployed, mosquito pools would have provided a very limited picture of virus activity in the Coachella Valley during 1991.

Relationship of Virus Activity to Vector Abundance: The seasonal minimal infection rate of WEE virus per 1,000 *Cx. tarsalis* tested per site was plotted as a function of the log of abundance in females per CO_2 trap-night. WEE virus was not detected or infection rates were low when the geometric mean of trap counts averaged fewer than 10 or more than 80 females per trap-night, respectively. Too few pools were positive for SLE virus for a similar evaluation.

In contrast, the percentage of WEE seroconversions from June to October increased significantly as a linear function of the log of *Cx. tarsalis* abundance (r=0.62, df=13, P=0.013). Only chickens at site 13, which averaged less than 1 female per trap-night, remained seronegative for WEE virus during 1991. A similar relationship was observed for SLE virus (r=0.64, df=13, P=0.01), except that the minimal abundance threshold for sentinel seroconversion was about 5 females per CO_2 trap-night. More striking than for WEE virus, the seroconversion rate also appeared to decrease when *Cx. tarsalis* abundance exceeded 80 females/trap-night. Previous studies by Olson et al. (1979) delineated a bell shaped curve to describe the relationship between seroconversion rates in sentinel chickens and *Cx. tarsalis* abundance. Decreased transmission to birds at sites with elevated abundance was attributed to a high percentage of host-seeking females being diverted from competent avian to incompetent mammalian hosts. Decreased seroconversion rates at sites with low abundance was attributed to the entomological inoculation rate being too low to maintain transmission.

A principal components analysis was performed to group study sites with similar phenologies of *Cx. tarsalis* abundance. Based on seasonal abundance and time series correlations, the 15 sites were segregated into three groups that roughly followed a south to north progression: A (sites 7 and 8), B (sites 1-6, 9, 10, and 15) and C (sites 11-14). The patterns of *Cx. tarsalis* seasonality delineated the temporal and spatial patterns observed for WEE and SLE virus activity (Fig. 2). Sites in Group A to the south exhibited a marked

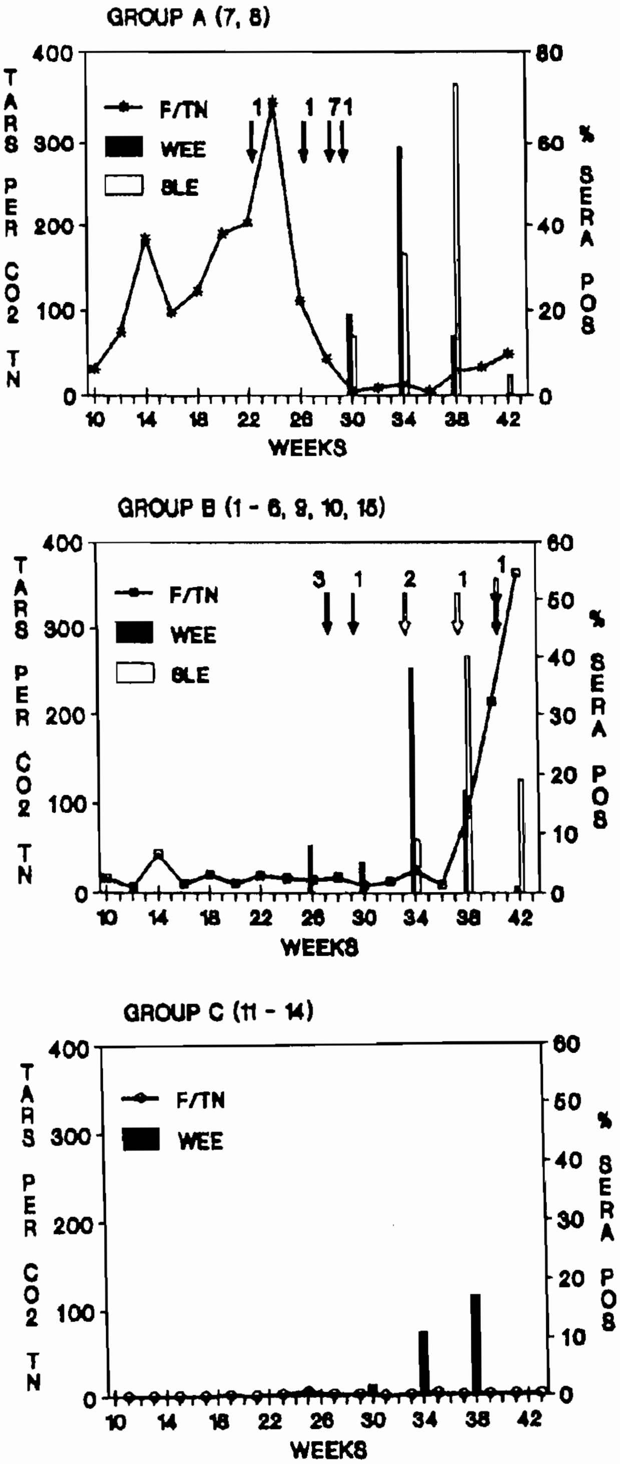

Figure 2. *Culex tarsalis* abundance, positive mosquito pools, and percentage of sera positive for WEE and SLE viruses during 1991 at the 15 study sites in Groups A, B, and C.

increase in abundance during April to June. Although WEE virus was first isolated during this period, most positive pools were detected on the falling edge of this abundance curve. Seroconversions followed concurrently for WEE and SLE viruses. Abundance at Group B sites exhibited almost the mirror image, with few females collected during spring and summer, but with a large peak occurring during fall in association with the flooding of duck hunting club ponds. WEE seroconversions were detected before mosquito infections and SLE virus was first detected almost two months after WEE virus. Few Cx. tarsalis were collected at the northern Group C sites 11 to 14, and virus activity was limited to a few late season WEE seroconversions.

Summary.

Both WEE and SLE virus activity were initiated along the Salton Sea in association with spring increases in *Cx. tarsalis* and then progressively spread westward along the shore of the Salton Sea and northward along the Whitewater Channel. WEE virus was active at lower vector abundance and was more widely distributed than SLE virus. However, increases in virus activity and *Cx. tarsalis* abundance generally were asynchronous, with transmission detected after the spring increase in *Cx. tarsalis* abundance at Group A sites and before the fall increase in abundance at Group B sites.

Sentinel chickens were more sensitive indicators of virus activity than were pools of *Cx. tarsalis* mosquitoes. Collectively, our data indicated that carefully selected "best estimate" sampling sites may be representative of virus activity over relatively widespread areas. However, considerable effort may be required to identify these sampling sites which can vary in sensitivity among sequential years.

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References.

Olson, J.G., W.C. Reeves, R.W. Emmons and M.M. Milby. 1979. Correlation of *Culex tarsalis* population indices with the incidence of St. Louis encephalitis and western equine encephalomyelitis in California. Amer. J. Trop. Med. Hyg. 28:335-343.

Lothrop, H., W.K. Reisen, S.B. Presser, M.M. Milby, J.L. Hardy, and M.J. Wargo. 1992. Landscape ecology of encephalitis virus transmission in the Coachella Valley: spatial patterns of seroconversions in sentinel chickens. Proc. Calif. Mosq. Vector Control Assoc. 60:67-70.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 76-81

SWARMING AND MATING IN *ANOPHELES FREEEBORNI*: PRELIMINARY OBSERVATIONS AND METHODS FOR FIELD STUDIES

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ABSTRACT

The mating and swarming behaviors of *Anopheles freeborni* in the laboratory and in California rice fields were studied to provide a basis for analysing the sexual biology of this species. Mating histories of males were determined by relying on the appearance of male accessory glands and provided the ability to correctly distinguish between mated and unmated males. A power blower (D-Vac) was used to sample swarming mosquitoes, enabling us to collect an average of 232 ± 33.6 mosquitoes per minute. Swarming activity exposes the adult population during a well defined period and in predictable sites which may be exploited for control measures.

Introduction.

The success of genetic control programs will ultimately depend on the ability of altered mosquitoes to mate succesfully with target populations (Asman et al. 1981, Reisen 1985). Indeed, based on this rationale, the sexual biology of *Culex tarsalis* Coquillett in California has received much attention in recent years (Reisen et al. 1983, 1985; Knop et al. 1987; Peloquin and Asman 1988). However, despite a large scale sterile male release in the mid-seventies targeted at *Anopheles albimanus* Wiedemann (Breeland et al. 1974), the sexual biology of new world anophelines has not been studied.

In this paper we report our initial observations on swarming by *Anopheles freeborni* Aitken, and describe techniques we have developed or adapted which we believe will facilitate quantitative studies of anopheline reproductive behavior.

Materials and Methods.

Mating Status of Males: To determine whether males had recently mated we adapted the techniques described by Lum (1961) for several Florida mosquitoes and by Mahmood and Reisen (1982) and Mahmood et al. (1986) for *Anopheles stephensi* Liston and *Culex tritaenioryhnchus* Giles, respectively. Briefly, this technique depends on recognizing the changes which occur in the male reproductive system after mating. Mahmood and her co-workers relied on quantifying the amount of spermatocysts available in the testes, as well as on gross changes in the accessory glands. Counting the spermatocysts is extremely accurate, but has the drawback of being time consuming and not suitable for processing large numbers of field collected mosquitoes. Instead, we relied on the appearance of the accessory glands which become depleted after mating.

We tested this method on colony-grown males. Single virgin males were caged with five virgin females. After 24 hours, females were dissected to determine the number inseminated. Males were then assigned a code number and presented randomly, together with virgin males 1-14 days old, to one author who would attempt to determine their mating history.

Sampling Swarms: Previous studies on swarms have depended on insect nets for sampling, a strenuous method yielding few individuals (Reisen et al. 1983, Marchand 1984). We used a commercially available power blower (D-Vac model

PB-400E; manufactured by Echo Inc., Oakland, IL), which was outfitted with a vacuum attachement. We fashioned collecting cups from 1/2 pint ice cream cartons, which may be replaced in about 10 seconds. Thus, we are able to take discrete samples from either individual swarms or groups of swarms.

Results and Discussion.

Mating Status of Males: Inseminations in females confined with virgin males were detected when the age of males was more than two days old and below 14 days. No males inseminated more than three females in a 24-hour period, and 60% inseminated one or two. Our examination of male accessory glands agreed with the observations of Mahmood and Reisen (1982). The glands of sexually mature virgin males are packed with dense secretions (Fig. 1A). Following one copulation the glands become depleted, and a clear margin becomes apparent (Fig. 1B). After three copulations in a 24-hour period, the glands are massively depleted (Fig. 1C). We also found that the accessory glands of males allowed 3-7 days of rest after mating rejuvenate to some extent but are still distinct from those of unmated males.

Of 92 males examined in the blind study (Table 1), we made 88 correct determinations, an accuracy of over 95%. We examined field-collected males collected and found (as did Reisen et al. 1981) that the appearance of their accessory glands were similar to those of the laboratory-reared males (Fig. 2). We therefore are now capable of correlating the mating history of males in the field to other physiological and behavioral parameters.

Observations on Swarms: We observed swarms near rice fields in Sutter County, California. Swarming begins 5-10 minutes after sunset and ceases 30-35 minutes later, when twilight ends. We observed space and marker swarms which formed primarily near the banks of rice fields, over the center of service roads, near trees or other salient markers. Typically, one to five males would appear and patrol the swarm site five minutes after sunset, following which more males would join until a tight swarm was formed. Most swarms were no higher than 2.5 meters, though some space swarms formed between trees as high as 6 meters. Contrary to the massive top swarms of *Psorophora columbiae* Dyar and Knab seen in Texas rice fields by Peloquin and Olson (1985), we estimate that most swarms numbered fewer than 1,000 mosquitoes.

Throughout their duration, females approached

Table 1. Results of blind tests to determine mating histories of *An. freeborni* males.

Age (days)	No. dissected	Mating History (Determined/Actual) Virgin	Mated
1	7	7/7	-
2	5	5/5	-
4	19	9/10	8/9
5	24	5/6	17/18
6	6	3/3	3/3
7	3	-	3/3
8	7	7/7	-
9	14	6/6	8/8
10-14	7	1/1	6/6
Totals	92	43/45	45/47
(%)		(95.5)	(95.7)

the swarms and mating couples were frequently seen to leave swarms. Though Nielsen and Haeger (1960) doubted the reproductive function of the crepuscular swarms formed by most mosquito species (Downes 1969), students of old world anopheline swarms agree that while composed primarily of males, females approach swarms and are promptly mated (Quarishi 1965, Reisen and Aslamakhan 1976, Reisen et al. 1977, Charlwood and Jones 1980, Marchand 1984). Our observations concur with these published reports. Nevertheless, mating is not neccesarily the exclusive domain of swarms, and may take place elsewhere under certain conditions (Baker et al. 1980, Reisen et al. 1981, Knop et al. 1987). Whether this is the case for *An. freeborni* as well remains to be seen.

Sampling from Swarms: The D-Vac proved to be an extremely efficient sampling tool. Initially, we used it with the engine set to high revolutions. Swarms that were sampled disappeared from view, only their minced remains found in the collecting cage. Henceforward, we set the engine to "idle" and were able to collect intact mosquitoes. We employed two sampling modes. The first consisted of sampling several adjacent swarms in a limited period of time, and the second of sampling one swarm from base to top, until it dispersed. Using the first method yielded an average of 232 ± 33.6 mosquitoes per minute, while sampling a single swarm until it dispersed (approximately 15 seconds) yielded an average of 66 ± 12.6 mosquitoes per

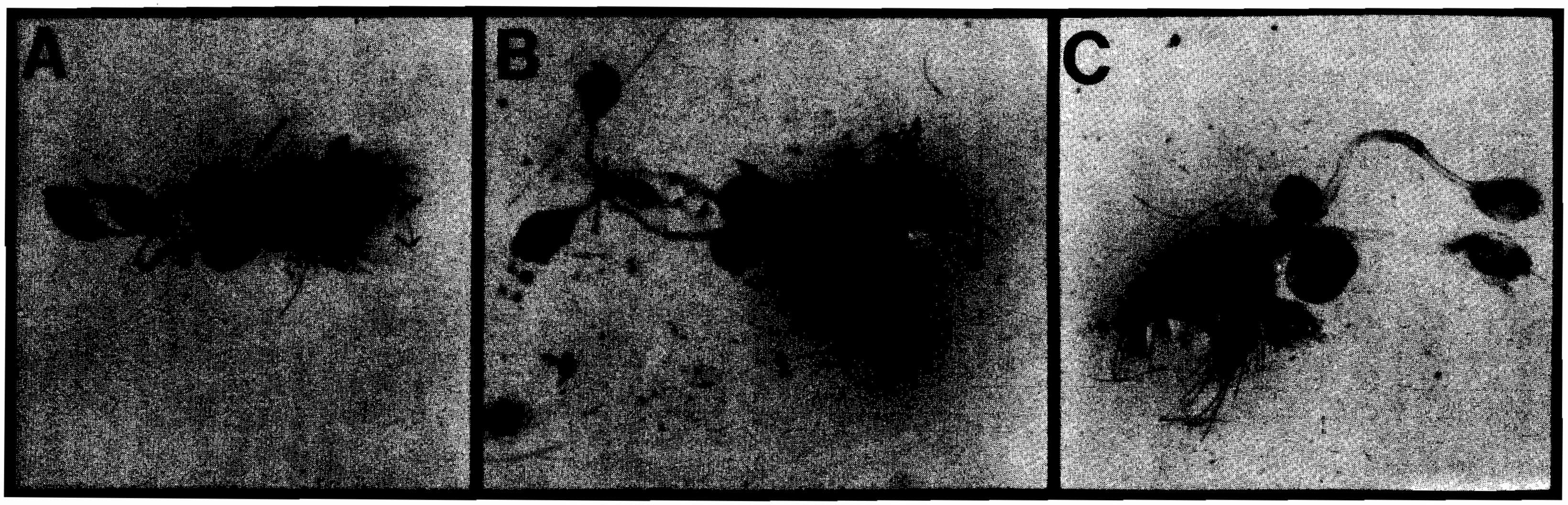

Figure 1. Reproductive system (160X) of laboratory-reared *An. freeborni* males. A. Virgin, 3-day old, showing dense packing of secretions in the accessory glands (arrow). B. Once-mated, 3-day old, showing formation of clear margins within the accessory glands. C. Thrice-mated, 4-day old, showing depletion of accessory glands.

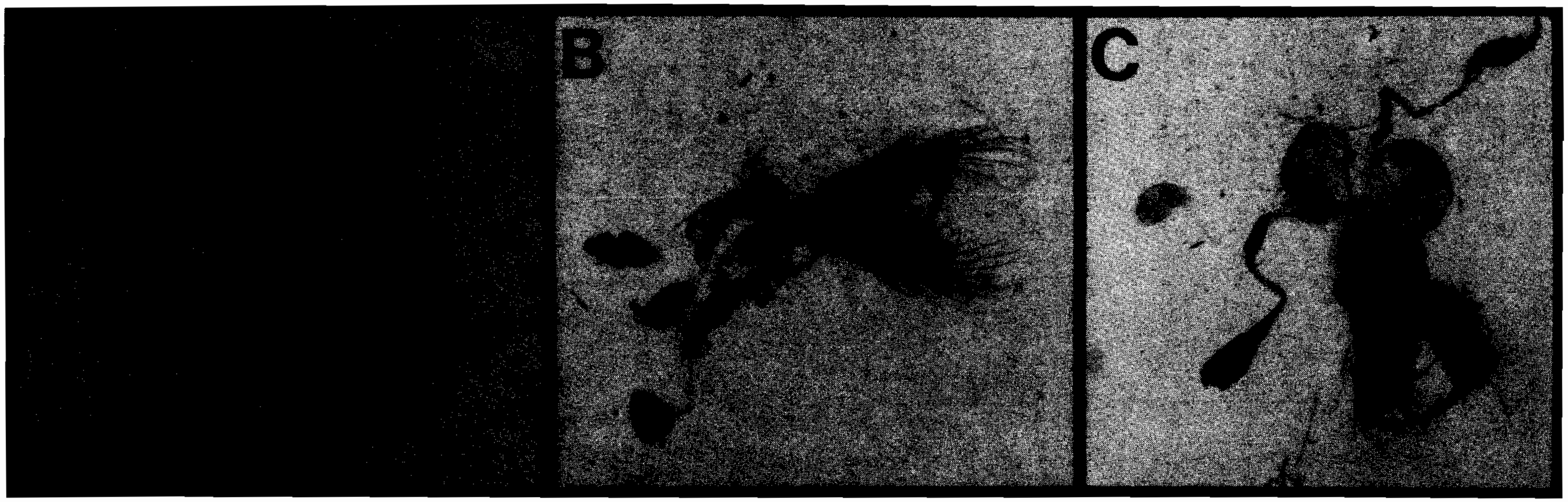

Figure 2. Reproductive system (160X) of field-collected *An. freeborni* males. Determined as: A. Virgin. B. Once-mated. C. Multiply-mated.

minute. This sampling tool will enable us to perform quantitative studies which rely on large samples of swarming mosquitoes.

Many swarms form next to each other so that literally thousands of males are exposed for a brief period of time in a relatively well defined area. This exposure may be exploited for control measures. Ikeshoji et al. (1985) suggested sound trapping to control males in swarms of two species of *Culex*. Other measures, such as ULV spraying (on evenings with moderate wind), may be logistically more effective.

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References.

Asman, S.M., P.T. McDonald and T. Prout. 1981. Field studies of genetic control systems for mosquitoes. Ann. Rev. Entomol. 26:289-318.

Baker, R.H., W.K. Reisen, R.K. Sakai, H.R. Rathor, K. Raana, K. Azra and S. Niaz. 1980. *Anopheles culicifacies*: Mating behavior and competitiveness in nature of males carrying a complex chromosomal aberration. Ann. Entomol. Soc. Amer. 73:581-588.

Breeland, S.G., G.M. Jeffery, C.S. Lofgren and D.E. Weidhaas. 1974. Release of chemosterilized males for the control of *Anopheles albimanus* in El Salvador. Amer. J. Trop. Med. Hyg. 23:272-281.

Charlwood, J.D. and M.D.R. Jones. 1980. Mating in the mosquito *Anopheles gambiae* s.l. II. Swarming behaviour. Physiol. Entomol. 5:315-320.

Downes, J.A. 1969. The swarming and mating flight of Diptera. Ann. Rev. Entomol. 14:271-298.

Ikeshoji, T., M. Sakakibara and W.K. Reisen. 1985. Removal sampling of male mosquitoes from field populations by sound trapping. Japan. J. San. Zool. 36:197-203.

Knop, N.F., S.M. Asman, W.K. Reisen and M.M. Milby. 1987. Changes in the biology of *Culex tarsalis* (Diptera: Culicidae) associated with colonization under contrasting regimes. Environ. Entomol. 16:405-414.

Lum, P.T.M. 1961. The reproductive system of some Florida mosquitoes. II. The male accessory glands and their role. Ann. Entomol. Soc. Amer. 54:430-433.

Mahmood, F. and W.K. Reisen. 1982. *Anopheles stephensi* (Diptera: Culicidae): Changes in male mating competence and reproductive system morphology associated with aging and mating. J. Med. Entomol. 19:573-588.

Mahmood, F., T. Parveen and W.K. Reisen. 1986. *Culex tritaeniorhynchus* Giles: changes in male mating competence and reproductive morphology associated with age and mating experience. Pakistan J. Zool. 18:273-296.

Marchand, R.P. 1984. Field observations on swarming and mating in *Anopheles gambiae* mosquitoes in Tanzania. Neth. J. Zool. 34:367-387.

Nielsen, E.T. and J.S. Haeger. 1960. Swarming and mating in mosquitoes. Misc. Publ. Entomol. Soc. Amer. 1:72-95.

Peloquin, J.J. and S.M. Asman. 1988. Use of a modified Marchand cage to study mating and swarming behavior in *Culex tarsalis*, with reference to colonization. J. Amer. Mosq. Control Assoc. 4:516-519.

Peloquin, J.J. and J.K. Olson. 1985. Observations on male swarms of *Psorophora coloumbiae* in Texas ricelands. J. Amer. Mosq. Control Assoc. 1:482-488.

Quarishi, M.S. 1965. Swarming, mating and density in nature of *Anopheles stephensi mysorensis*. J. Econ. Entomol. 58:821-824.

Reisen, W.K. 1985. Male mating competitiveness: the key to some problems associated with the genetic control of mosquitoes. *In:* Lounibos, L.P., J.R. Rey and J.H. Frank (eds.), Ecology of Mosquitoes. Florida Medical Entomology Laboratory, Vero Beach, FL pp. 348-358.

Reisen, W.K. and M. Aslamakhan. 1976. Observations on the swarming and mating behavior of *Anopheles culicifacies*. Bull. W.H.O. 54:155-158.

Reisen, W.K., Y. Asman and T.F. Siddiqui. 1977. Observations on swarming and mating of some Pakistan mosquitoes in nature. Ann. Entomol. Soc. Amer. 70:988-995.

Reisen, W.K., R.H. Baker, R.K. Sakai, F. Mahmood, H.R. Rathor, K. Rana and G. Toquir. 1981. *Anopheles culicifacies* Giles: Mating behavior and competitiveness in nature of chemosterilized males carrying a genetic sexing system. Ann. Entomol. Soc. Amer.

74:395-401.

Reisen, W.K., M.M. Milby, R.P. Meyer and W.C. Reeves. 1983. Population ecology of *Culex tarsalis* (Diptera: Culicidae) in a foothill environment in Kern County, California: Temporal changes in male relative abundance and swarming behavior. Ann. Entomol. Soc. Amer. 76:809-815.

Reisen, W.K., N.F. Knop and J.J. Peloquin. 1985. Swarming and mating behavior of laboratory and field strains of *Culex tarsalis* (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 78:667-673.

1992 Proc. Calif. Mosq. Vector Control Assoc. **60: 82-84**

OBSERVATIONS ON THE BLOOD FEEDING BEHAVIOR OF *ANOPHELES FREEBORNI* AND *CULEX TARSALIS* IN CALIFORNIA'S CENTRAL VALLEY

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ABSTRACT

Seasonal variations in proportions of blood fed females and blood feeding preferences of *An. freeborni* and *Cx. tarsalis* were investigated from June through September, 1991, in California's Central Valley. The percentage of blood fed female *An. freeborni* decreased gradually through the study period, while *Cx. tarsalis* remained relatively constant over the same period. *Anopheles freeborni* fed predominantly on mammalian hosts: cattle (30.5%), rabbit (24.5%), pig (16.6%), horse (10.6%), and other mammals (17%). *Culex tarsalis* had a 3:1 blood feeding ratio of birds to mammals preferring Passeriformes birds (50.4%). Multiple blood feeding was detected at 1.8% and 1.1% for *An. freeborni* and *Cx. tarsalis*, respectively.

Introduction.

The western malaria mosquito, *Anopheles freeborni* Aitken, and the western encephalitis mosquito, *Culex tarsalis* Coquillett, are pest problems and provide potential threats to human and animal health in California. *Culex tarsalis* is a primary vector of western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) viruses (Reeves 1990). Surveillance efforts for potential disease outbreaks are directed towards sampling populations of *Cx. tarsalis* and *An. freeborni*. Blood feeding habits of *An. freeborni* and *Cx. tarsalis* have been studied extensively for three and a half decades in several California counties (Tempelis et al. 1965, Tempelis and Washino 1967, Washino and Tempelis 1967, McHugh 1989, Reeves 1990).

In this paper we report initial observations on patterns of vector-host contact and discuss the seasonal changes in proportions of blood fed females of *An. freeborni* and *Cx. tarsalis* in California's Central Valley.

Material and Methods.

Mosquito Collection and Sampling: Sampling of mosquitoes was conducted from June through September, 1991. Resting mosquitoes were sampled weekly from walk-in red boxes at 18 sampling sites in Sutter and Yuba Counties. The number of blood engorged females collected was recorded and up to 25 blood fed females of each species from each study site were kept in individual capsules for blood meal identification.

Blood Meal Identification: Abdomens of blood engorged *An. freeborni* and *Cx. tarsalis* were analyzed using the modified-precipitin test of Tempelis and Lofy (1963). Blood meals initially were screened with general antisera to blood from mammals, reptiles, amphibians, and birds. Blood meals reacting with anti-mammalian sera were tested against antisera specific to mammalian orders: primate, marsupialia, perissodactyla, lagomorpha, rodentia, chiroptera, carnivora and artiodactyla. Blood meals reacting with anti-carnivora sera and anti-arfiodactyla sera were screened by family-specific antisera. Blood meals positive for carnivora were tested against anti-sera specific to canidae (dogs), felidae (cats), procyonidae (raccoons), and musterlidae (weasels).

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Blood meals positive for artiodactyla were tested against anti-sera specific to bovidae (cattle), suidae (pigs), and cervidae (deer).

Blood meals that reacted with anti-avian sera were tested against anti-sera specific to avian orders: strigiformes, cuculiformes, columbiformes, gruiformes, anseriformes, galliformes, ciconiformes, falconiformes, charadriiformes, pelicaniformes, and passeriformes.

Results.

Proportions of Blood Fed Females: The proportion of blood fed *Cx. tarsalis* females (mean 19.0%) remained relatively constant throughout the season (Fig. 1). However, the proportion of blood fed *An. freeborni* females (mean 20.5%) was significantly higher in June and July, but gradually decreased through August and September ($Z=71.9$, $P<0.01$). Overall, the monthly blood fed proportions of *An. freeborni* were significantly different between each other ($P<0.05$). Except for July and August ($P>0.05$), the monthly proportions of blood fed *Cx. tarsalis* females differed significantly between each other ($P<0.05$).

Host Selection: *Anopheles freeborni* fed predominantly on mammalian hosts (82% of the 151 blood meals tested): cattle (30.5%), rabbit (24.5%), pig (16.6%), and horse (10.6%). The rest of the identified blood meals (17.0%) were from dog, deer, and rodent. Five blood meals (3.3%) were of mammalian origin, of which two could not be identified beyond the order artiodactyla. Three human blood meals and one passerine blood meal were identified. Four double feedings were detected: 2 cow-horse, 1 rabbit-cow, and 1 deer-rabbit.

Culex tarsalis had a more catholic blood feeding pattern, taking blood meals both from birds and mammals. The most preferred host was passerine birds (50.4% of the 242 positive blood meals). Other bird orders, including pelicaniformes, galliformes, ciconiformes, falconiformes, strigiformes, anseriformes, and charadriiformes, accounted for 18.5% of *Cx. tarsalis* blood meals. Twenty one (8.3%) blood meals were of avian origin but could not be identified to order. Cattle (7.5%), rabbit (6.3%), and other mammalian hosts accounted for 20.7% of *Cx. tarsalis* blood meals. No human-positive blood meals were identified. Three double feedings were detected: 2 passeriformes-pelicaniformes, and 1 passeriformes-cow.

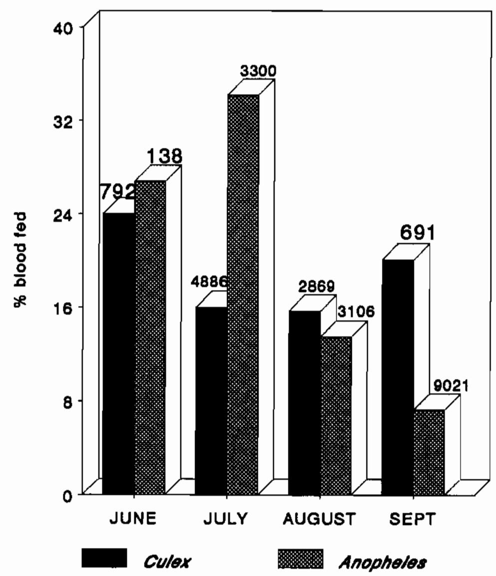

Figure 1. Total numbers collected (above bars) and seasonal percentages of blood fed *Cx. tarsalis* and *An. freeborni* females.

Host determinations were not made for 6 (3.9%) *An. freeborni* and 12 (4.7%) *Cx. tarsalis* blood meals. Four of the undetermined blood meals caused hemastix (Miles Inc., Elkhart, IN) to produce green color, a quantitative indication of adequate antigen for reaction with homologous antisera. Fourteen of the non-reacting blood meals caused hemastix to produce a color ranging from light green to yellow, suggestive of insufficient antigen to give a readable response.

Discussion.

In general, the percentage of blood fed *An. freeborni* females decreased gradually throughout the study season. Similar observations were made by McHugh (1989). According to Bailey and Gieke (1968) and Freeborn (1932), populations of adult *An. freeborni* in the Sacramento Valley reach peak abundance in August and September. In early September, there is a shift from the emergence of gonoactive females to females destined for diapause. These diapausing females can be distinguished by extensive fat body development, immature ovaries and are, for the most part, non-blood feeding (Washino 1970). Thus, as recruitment of blood feeding females decreases there was a concurrent decrease in the percentage of blood fed mosquitoes collected from red boxes.

Culex tarsalis reach peak abundance in July and August (Reeves 1990), a month earlier than *An. freeborni* (Bailey and Gieke 1968). The concurrent decrease in recruitment of gonoactive blood seeking females and general decline of *Cx. tarsalis* population in late summer may probably maintain a constant percentage of blood feeding cohort. Furthermore, continued accumulation of lipids by diapausing females (Schaefer et al. 1971) may suggest a constant host seeking behavior of *Cx. tarsalis* into early fall.

In this study, *An. freeborni* fed on mammals, especially bovids, rabbits, horses and pigs. This is consistent with the findings of Washino and Tempelis (1967) but not with McHugh (1989) who found rabbits among the least preferred hosts.

The mammalian-avian ratio of 3:1 observed for *Cx tarsalis* in this study was consistent with results of Tempelis et al. (1965) in Kern County and Tempelis and Washino (1967) in the Sacramento Valley. *Culex tarsalis* fed more on Passeriformes than other birds. Mammalian hosts represented only 20.7% of *Cx. tarsalis* blood meals with bovids and rabbits being the most common mammals. However, to what extent this pattern reflects the innate host preference of *Cx. tarsalis* or the faunal composition of the area remains to be determined.

Feeding rate on humans was surprising low for both *An. freeborni* and *Cx. tarsalis*, especially so for the former; *Anopheles freeborni* bites man aggressively whenever encountered (Washino and Tempelis 1967). Our results reflect the rural nature of our sampling sites where human population is sparse and where wild and domestic birds and mammals are more accessible.

Multiple blood feeding was detected in 1.8% and 1.1 % of *An. freeborni* and *Cx. tarsalis* blood meals tested. The testing protocol resulted in an inability to detect some double blood feeding (Washino and Tempelis 1983). For instance, blood meals from birds that are in the same order could not be detected. Novel protocols will be used to determine multiple feeding, particularly cryptic blood meals, among field populations of *An. freeborni* and *Cx. tarsalis*.

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References.

Bailey, S.F. and P.A. Gieke. 1968. A study of the effect of water temperatures on rice field mosquito development. Proc. Calif. Mosq. Control Assoc. 36:53-61.

Freeborn, S.B. 1932. The seasonal life history of *Anopheles maculipennis* with reference to humidity requirements and hibernation. Amer. J. Hyg. 16:215-223.

McHugh, C.P. 1989. Ecology of a semi-isolated population of adult *Anopheles freeborni*: Abundance, trophic status, parity, survivorship, gonotrophic cycle length, and host selection. Amer. J. Trop. Med. Hyg. 41:169-176.

Reeves, W.C. 1990. Epidemiology and Control of Mosquito-borne Arboviruses in California, 1943-1987. Calif. Mosq. Vector Control Assoc., Sacramento, CA. 508 pp.

Schaefer, C.H., T. Miura and R.K. Washino. 1971. Studies on the overwintering biology of natural populations of *Anopheles freeborni* and *Culex tarsalis* in California. Mosq. News 31:153-157.

Tempelis, C.H. and M.F. Lofy. 1963. A modified precipitin method for identification of mosquito blood meals. Mosq. News 12:825-831.

Tempelis, C.H., W.C. Reeves, R.E. Bellamy and M.F. Lofy. 1965. A three-year study of the feeding habits of *Culex tarsalis* in Kern County, California. Amer. J. Trop. Med. Hyg. 14:170-177.

Tempelis, C.H. and R.K. Washino. 1967. Host-feeding patterns of *Culex tarsalis* in the Sacramento Valley, California, with notes on other species. J. Med. Entomol. 4:315-318.

Washino, R.K. and C.H. Tempelis. 1967. Host-feeding patterns of *Anopheles freeborni* in the Sacramento Valley, California. J. Med. Entomol. 4:311-314.

Washino, R.K. 1970. Physiological condition of overwintering female *Anopheles freeborni* in California (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 63:210-216.

Washino, R.K. and C.H. Tempelis. 1983. Mosquito host blood meal identification: Methodology and data analysis. Ann. Rev. Entomol. 28:179-201.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 85-86

TEMPORAL OVIPOSITION PATTERNS IN *CULEX* MOSQUITOES INHABITING MANAGED MARSH ECOSYSTEMS

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In natural breeding sites, mosquito larvae are not dispersed randomly, but are found in a clumped distribution. Abiotic and biotic factors such as nutrient levels, presence or absence of vegetation, water depth, and surface area of the water all influence the distribution of larvae. It is hypothesized that a major component of this distributional pattern is a temporal factor; the length of time during which a habitat has been flooded. High populations of mosquito larvae are found 7-10 days following the flooding of a mosquito habitat, then populations begin to decline substantially 2-3 weeks thereafter. Mulla (1990) has hypothesized that this reduction could be due to four factors: 1) an increase in the regulatory force of predators, 2) a decrease in attractiveness of habitat to ovipositing mosquitoes, 3) a combination of factors 1 and 2, or 4) the depletion of the food supply.

In this study we determined the temporal profile of the habitat waters as related to the oviposition behavior of *Culex quinquefasciatus* Say.

In the Prado Basin, a 3,400 hectare flood control basin in Riverside County, California, approximately 240 hectares of land were flooded by four duck hunting club operations in the fall of 1991 to provide waterfowl habitat. Due to the limited availability of water from the Santa Ana River watershed sources in 1991, duck hunting club ponds in the basin were flooded sequentially. As a result of this flooding strategy, on any date during this study there were ponds which were flooded for different durations. These ponds provided ideal conditions studying the temporal larval distribution of *Cx. quinquefasciatus*, *Culex stigmatosoma* Dyar, and *Culex tarsalis* Coquillett. The group of ponds which were flooded most recently supported substantially higher levels of larval populations than did ponds which were flooded for longer periods.

In order to assess the importance of differential oviposition in the distribution of larvae, water samples for these studies were taken from duck hunting club ponds in the Prado Basin which had been flooded for different time periods. These samples were returned to the laboratory, filtered through filter paper (Whatman Qualitative) and stored at 3° C until they could be used in ovipositional experiments. All experiments were conducted within four days of water collection to minimize microbial degradation of the samples.

In the first experiment, water samples from ponds which had been flooded for six weeks were compared for attractancy to a distilled water control. Experiments were conducted in six 23 x 23 x 32 cm cages which were placed in a photo-periodically controlled laboratory insectary (14L:10D including a 2-hour evening twilight period). Each cage contained two randomly placed waxed paper cups (5 cm deep x 7.5 cm diameter), one cup containing 80 ml of water from the pond which had been flooded for six weeks and the other a distilled water control. Twenty laboratory-reared, gravid *Cx. quinquefasciatus* females were placed in each cage and given one night to oviposit. The next morning egg rafts were counted, data square root trans-formed and a paired t-test was used to determine the effect of the pond water on the oviposition behavior of the test mosquitoes. In six replicates of the six-cage assay, the waters from Prado Basin ponds which had been flooded for six weeks received a mean of 9.6 egg rafts per cup while the control cups received a mean of 1.7 egg rafts per cup. Paired t-tests confirmed that the water taken from ponds flooded for six weeks was significantly more attractive ($P<0.01$) than the distilled water controls.

In the second experiment, water samples taken from ponds which had been flooded for less than one week were compared to distilled water controls using six replicates of the six-cage assay described above. Water samples taken from ponds which had been flooded less than one week received a mean of 8.5 egg rafts per cup while the distilled water controls received a mean of 0.3 egg rafts per cup. Paired t-tests again confirmed that the water taken from Prado Basin ponds was more attractive ($P<0.025$) to ovipositing *Cx. quinquefasciatus* females than was the distilled water controls.

In the final and most important experiment, water samples from ponds which had been flooded for less than one week were compared for ovipositional attractancy to water samples from ponds which had been flooded for six weeks. The experiment was replicated six times using six cages per replicate and following the protocol described above. Water samples taken from ponds which had been flooded for six weeks received a mean of 1 egg raft per cup while water samples taken from ponds which were flooded less than one week received a mean of 12.9 egg rafts per cup. Paired t-tests confirmed that the water samples from ponds which had been flooded for less than one week were more attractive ($P<0.01$) to ovipositing *Cx. quinquefasciatus* females than were water samples taken from ponds which had been flooded for six weeks.

These data support the conclusion that the waters themselves from managed marsh ecosystems are not static in their attractancy to ovipositing *Cx. quinquefasciatus*. The marsh waters have a dynamic attractancy profile being most attractive soon after flooding and decreasing thereafter. This dynamic attractancy may prove to be a major factor in the contagious distribution of *Culex* larvae in temporary habitats. A weak attractant shows more attractancy when compared to a less attractive material than when compared to a highly attractive material where it shows little or no attractant activity. Water samples taken from ponds which had been flooded for six weeks were highly attractive to ovipositing *Cx. quinquefasciatus* when compared to distilled water controls, but when compared to waters taken from adjacent ponds which had been flooded for less than one week, this apparently attractive water attracted few ovipositing females. Two-choice laboratory oviposition tests, if not considered in a broad context which incorporates factors which are commonly encountered in the field, may lead to spurious ecological assumptions.

Acknowledgements.

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Reference.

Mulla, M.S. 1990. Activity, field efficacy, and use of *Bacillus thuingiensis israelensis* against mosquitoes. *In*: H. de Barjac and D.J. Sutherland (eds.), Bacterial Control of Mosquitoes and Black Flies. Rutgers Univ. Press, New Brunswick. pp. 134-160.

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CALIFORNIA SEROGROUP VIRUS STUDIES IN CALIFORNIA IN 1991[1]

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Introduction.

We continued our study of California (CAL) serogroup viruses in California in 1991. Studies took place in two distinctly different ecosystems: high mountain regions of the Sierra Nevada and Cascade Ranges, mostly at elevations above 6,000 feet; and coastal salt marshes. Our previous studies have shown that Jamestown Canyon (JC) virus is endemic in alpine areas of the former habitat (Campbell et al. 1991, Eldridge et al. 1989), and that a California encephalitis-like (CE-like) virus is present in at least one salt marsh habitat (Morro Bay)(Eldridge et al. 1991). Since our previous isolations of both JC virus and the CE-like virus came from only a few sites, we sought to learn whether these viruses were restricted in distribution, or if more extensive sampling would show a broader distribution. In addition to field studies, we continued our experimental mosquito transmission studies to determine the vector competence of various California mosquito species for CAL serogroup viruses. This report discusses some of the results of both field and laboratory studies.

High Mountain Studies.

In 1991, we collected and tested over 30,000 mosquitoes (700 pools) for virus infection. Over one third of the entire collection consisted of one species, *Aedes tahoensis* Dyar (13,919 mosquitoes in 294 pools). This species previously was called *Aedes communis* Dyar in California, but a recent paper by Brust and Munstermann (1992) demonstrated that in California, *Ae. tahoensis*, a species described by Dyar (1916) from Fallen Leaf Lake, California, is the most common species in the *Aedes communis* complex. Other species tested in significant numbers included *Aedes hexodontus* Dyar (6,163 in 141 pools), *Aedes cataphylla* (Dyar)(2,768 in 65 pools), *Aedes increpitus* Dyar (2,892 in 66 pools), and *Aedes nevadensis* Chapman and Barr (3,295 in 68 pools). California collections were from Sierra, Alpine, Tulare, El Dorado, Plumas, and Tuolumne Counties. All collections of *Ae. nevadensis* were from the Cascade Range in Oregon. Our preliminary data suggest that this member of the *Ae. communis* complex does not occur in California.

Ten JC virus isolates were made from these collections. Six isolates were from Alpine County in the Hope Valley area, a region which has yielded many JC isolates in past years. One isolate was from Tulare County in the Big Meadow area adjacent to Kings Canyon National Park. Three isolates were from mosquitoes collected in the Gold Lake area of Sierra County. Both the Tulare County and Sierra County isolates of JC virus represent the first such isolates from those counties. All but two isolates were from *Ae. tahoensis*. This species continues to look like the predominant invertebrate host and vector for JC virus in California. We also obtained single isolates from *Ae. cataphylla* and *Ae. hexodontus*.

Adequate sampling of geographic regions and of different snowpool *Aedes* species remains an important future objective. Virus isolation rates continue to range between 1:1,000 and 1:6,000 per year. Thus if you wish to rule out a particular

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species as a vector, an adequate sample would be at least 10,000 individual mosquitoes. Given the difficulties of collecting and processing snow pool Aedes mosquitoes, such a sample is not easy to obtain for each species. The question of sampling adequacy also pertains to geographical representation. Our previous failure to detect virus-infected mosquitoes outside of Alpine County probably was due to under sampling of other areas.

Coastal Salt Marsh Studies.

In 1991, we tested over 40,000 mosquitoes from coastal salt marsh habitats. Over half were collected from the Morro Bay area of San Luis Obispo County. Other counties represented in the collections were Alameda, Contra Costa, Los Angeles, Marin, Monterey, Orange, San Mateo, and Ventura. The collections consisted of approximately two-thirds of *Aedes dorsalis* (Meigen) and one-third *Aedes squamiger* (Coquillett). We also tested about 3,000 *Culiseta inornata* (Williston). The *Ae. squamiger* collections from Morro Bay yielded five more isolates of the CE-like virus which we had isolated in 1989. The questions of adequacy of sampling from various geographical regions discussed above apply here as well. Before we can draw any conclusions about the geographical distribution of this virus we must test many more samples of *Ae. squamiger* from both northern and southern California habitats. In addition to extensive mosquito samples, many blood samples from horses, deer, cattle, dogs, rodents, rabbits, and people have been obtained from the Morro Bay area. These sera are now being tested for antibodies to arboviruses. Data from these tests allow us estimate the public health importance of this virus in the Morro Bay area, and also will suggest which species may serve as sentinel animals to determine the distribution of this virus elsewhere. Interestingly, we failed to isolate any CAL serogroup viruses from the many *Ae. dorsalis* tested, although one still unidentified virus was isolated from this species which is unrelated to the *Ae. squamiger* virus.

Vector Competence Studies.

We have completed the first round of laboratory vector competence testing of several California mosquito species for the CE-like virus from Morro Bay. *Aedes squamiger* is highly susceptible to infection with the CE-like virus and is a very efficient transmitter. *Aedes dorsalis* also is highly susceptible to infection, but is an inefficient vector. *Culiseta inornata* transmitted the virus at a low rate following peroral infection. A number of other species, including coastal populations of *Ae. increpitus*, *Aedes melanimon* Dyar, and *Ae. tahoensis* did not transmit the virus after peroral infection.

We have investigated several human central nervous system disease cases from coastal and mountain areas. In all instances, causes other than mosquito-borne viruses have been implicated, or we failed to obtain adequate serum samples for testing.

Future Studies.

Considerable work lies ahead if we are to predict the occurrence of endemic areas for CAL serogroup viruses, and estimate the public health importance of these viruses. Field and laboratory studies have demonstrated there is considerable variation in vector capacity among even closely related mosquito species for CAL serogroup viruses, and there also is variation in vectorability within different populations of a single species. Complicating the picture is the fact that the taxonomies of mosquito species we are interested in have not been studied extensively. In every instance where we have looked carefully at genetic population structure, we have uncovered patterns of genetic isolation. In the case of *Ae. increpitus*, the isolation is so pronounced that we are in the process of describing two new California species in the complex. Interestingly, these populations also vary significantly in their susceptibility to infection with the CE-like virus. Our results agree with research done on CAL serogroup viruses done elsewhere. Heard et al. (1991) tested Michigan populations of *Aedes provocans* Walker for their vector competence for an Indiana isolate of JC virus and found that this population would not transmit the virus at all, in spite of the fact that JC virus had been repeatedly isolated from this species in Michigan. When they repeated the tests using a strain of JC from Michigan, however, they found the species to be an efficient vector (Dr. Paul Grimstad, personal communication). These results, and ours, underscore the absolute necessity for accurate identification of mosquito samples, and the genetic characterization of mosquito populations. These tasks should occupy significant time in the coming years.

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References.

Brust, R.A. and L.E. Munstermann. 1992. Morphological and genetic characterization of the *Aedes (Ochlerotatus) communis* complex (Diptera: Culicidae) in North America. Ann. Entomol. Soc. Amer. 85:1-10.

Dyar, H.G. 1916. New *Aedes* from the mountains of California. Insecutor Insit. Menstr. 4:80-90.

Campbell, G.L., B.F. Eldridge, W.C. Reeves, and J.L. Hardy. 1991. Isolation of Jamestown Canyon virus from boreal mosquitoes from the Sierra Nevada of California. Amer. J. Trop. Med. Hyg. 44:244-249.

Eldridge, B.F., G.L. Campbell, J.L. Hardy, W.C. Reeves, D.A. Jessup, and S.B. Presser. 1989. California and Bunyamwera serogroup viruses in California. Proc. Calif. Mosq. Vector Control Assoc. 57:13-16.

Eldridge, B.F., G.C. Lanzaro, G.L. Campbell, W.C. Reeves, and J.L. Hardy. 1991. Occurrence and evolutionary significance of a California encephalitis-like virus in *Aedes squamiger* (Diptera: Culicidae). J. Med. Entomol. 28:645-651.

Heard, P.B., M. Zhang, and P.R. Grimstad. 1991. Laboratory transmission of Jamestown Canyon and snowshoe hare viruses (Bunyaviridae: California Serogroup) by several species of mosquitoes. J. Amer. Mosq. Control Assoc. 7:94-10.

DISPERSAL AND LONGEVITY OF *AEDES CATAPHYLLA* AND *AEDES TAHOENSIS* IN THE SIERRA NEVADA MOUNTAINS OF CALIFORNIA

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ABSTRACT

The flight range and direction of two significant pest species of snow pool *Aedes* were investigated to determine if adult immigration from outside control district boundaries was contributing to management difficulties. A mark-release-recapture trial was conducted in El Dorado County using 15 CO_2-baited CDC traps arranged to cover several potential flyways including a transect from an undeveloped area into a housing sub-division.

A total of 13,186 mosquitoes was marked and released, of which 9,705 were *Aedes cataphylla* (Dyar) and 3,481 were *Aedes tahoensis* Dyar. During the recapture period 1.8% (172) of the *Ae. cataphylla* and 17.6% (611) of the *Ae. tahoensis* were recaptured. Longevity of *Ae. cataphylla* and *Ae. tahoensis* was 31 and 37 days, respectively. Daily survivorship estimates using linear regression were 0.91 (R^2=0.47, $P<0.01$) and 0.89 (R^2=0.51, $P<0.01$), respectively.

Aedes cataphylla was found to travel 2.0 km and reached that point eight days after release while *Ae. tahoensis* flew at least 2.3 km to our terminal trap in five days. Results of preferred flyways were inconclusive, but the majority of the mosquitoes dispersed from the natural area toward the housing development. Results indicate that distance and direction of adult flight will have to be considered in establishing boundaries for effective mosquito control in alpine environments.

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THE FIRST RECORD OF *BORRELIA BURGDORFERI* FROM A TICK, *IXODES PACIFICUS*, IN SOUTHERN CALIFORNIA

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Following the outlined protocol for a *Borrelia burgdorferi* Johnson, Schmid, Hyde, Steigerwalt, and Brenner surveillance system as presented by Webb et al. (1990a), small mammals were trapped using Sherman live traps in 1991 in Wood Canyon (Laguna Beach), Skeet Club Canyon (San Clemente), Tonner Canyon (Brea), and El Morro Canyon (Crystal Cove State Park). Sera from 121 cricetid rodents (*Peromyscus, Neotoma,* and *Reithrodontomys* spp.) and four heteromyid rodents (*Chaetodipus* spp.) were analyzed using Indirect Fluorescent Antibody (IFA) techniques. On February 5 and 6, 1991, cricetid rodents were collected in Skeet Club Canyon and Wood Canyon and the sera were tested in the laboratory on February 6 and 7. Two mice (*Peromyscus maniculatus*) from Skeet Club Canyon and two mice (*P. maniculatus, Peromyscus californicus*) from Wood Canyon yielded positive antibody titers (1:32) to *Borrelia burgdorferi* antigen.

As per the *B. burgdorferi* surveillance protocol (Webb et al. 1990a), tick collection trips were made on February 19 and 20 at Wood Canyon and Skeet Club Canyon. *Ixodes pacificus* Cooley and Kohls ticks were collected by flagging at both sites and the tick specimens were tested in the laboratory with dark-field microscopy and Direct Fluorescent Antibody (DFA) techniques. During 1991, a total of 147 specimens of *I. pacificus* was tested for spirochetes. One of the 20 *I. pacificus* specimens flagged at Skeet Club Canyon (San Clemente, see Fig. 1) on February 20 yielded positive results for spirochetes using dark-field microscopy. Cultures of the spirochetes were made in BSK II and a subculture was sent (and received April 5) to the State of California Microbial Disease Laboratory, Berkeley. Confirmation by the State of the *Borrelia burgdorferi* identification was made on April 26.

This isolation of *B. burgdorferi* from *Ixodes pacificus* represents the first State-confirmed report of the Lyme disease spirochete from southern California. Other preliminary information of *B. burgdorferi* isolates from ticks includes a report from Kern County near Ft. Tejon State Park (pers. commun.- P.A. Gillies, EMB, Calif. Dept. Health Services) and a report from San Bernardino County near Rancho Cucamonga (pers. commun.- J.R. Clover, EMB, Calif. Dept. Health Services). Another report includes a *B. burgdorferi* recovery from a wood rat collected in San Bernardino County (pers. commun.- R.N. Brown, U.C. Berkeley). Further, these discoveries suggest that the human, horse, and dog populations of southern California are at a higher risk of contracting Lyme Borreliosis than previously thought.

It seems likely that within the next several years more documented evidence will be generated to demonstrate that *B. burgdorferi* distribution is congruent with the known distribution of *Ixodes pacificus* within California (Fig. 2). In addition to the *I. pacificus* geographical distribution and habitat preferences, the range of hosts for each life stage is also important in assessing pathogen/vector/host factors in the Lyme disease transmission cycle (Table 1).

Also of great importance are the pathogen/

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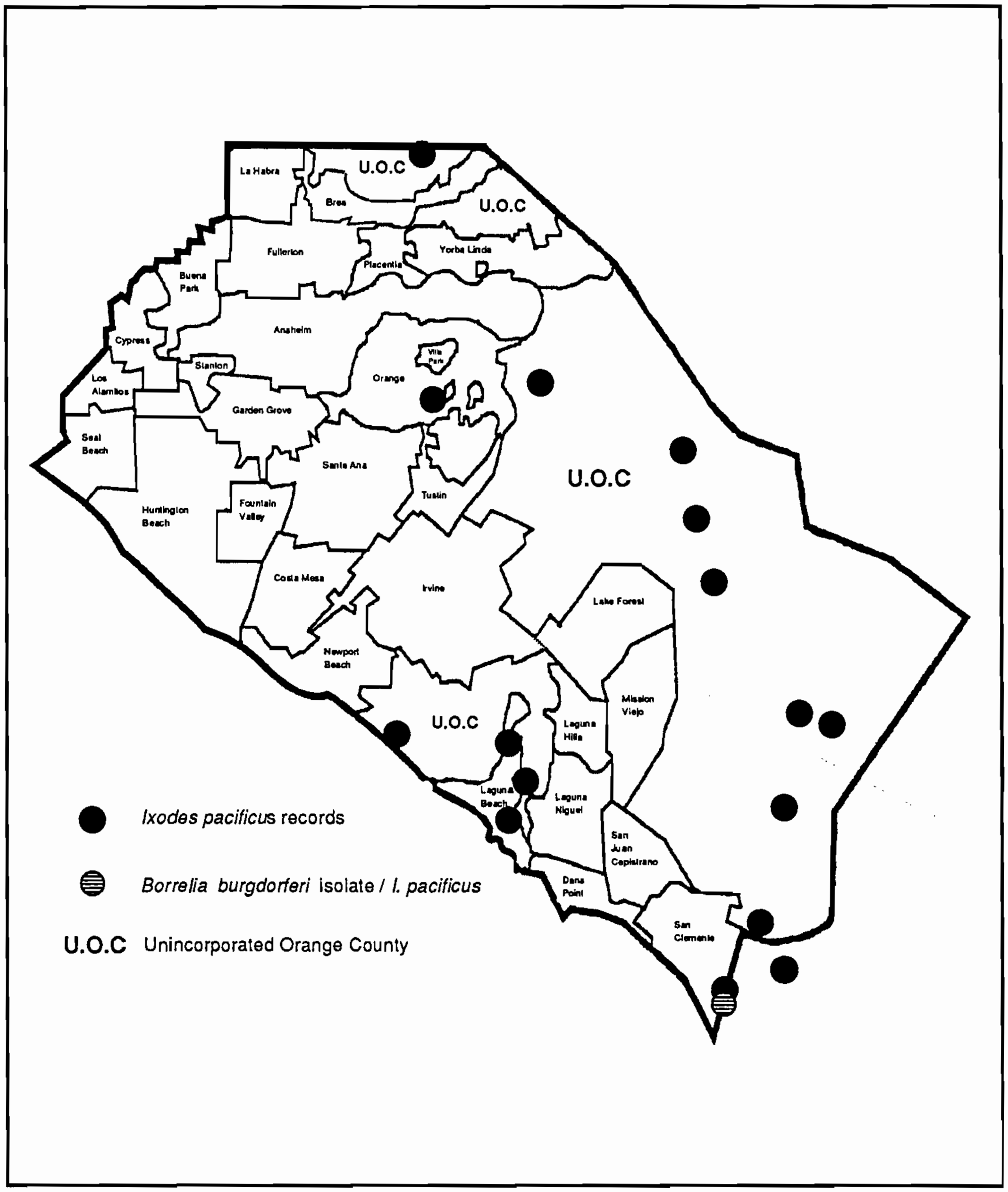

Figure 1. *Ixodes pacificus* collection records in Orange County including the site of an isolation of *Borrelia burgdorferi* from a single *I. pacificus*.

vector/host interactions in the enzootic transmission cycle. Three ixodid species seem to be valid candidates for maintaining the spread of *B. burgdorferi* enzootically in California. *Ixodes spinipalpis* Hadwen and Nuttall (Table 2) and *Dermacentor occidentalis* Marx (Table 3) seem to be the best choices as likely enzootic vectors for *B. burgdorferi* because of their broad base host range for adult and subadult ticks. *Ixodes neotomae* (Table 4) seems the least likely because subadults and adults are found only on *Neotoma fuscipes*. Furthermore, preliminary host/parasite information from Los Angeles County (pers. commun.- G. Van Gordon, L.A. Co. Health Dept.) and Orange

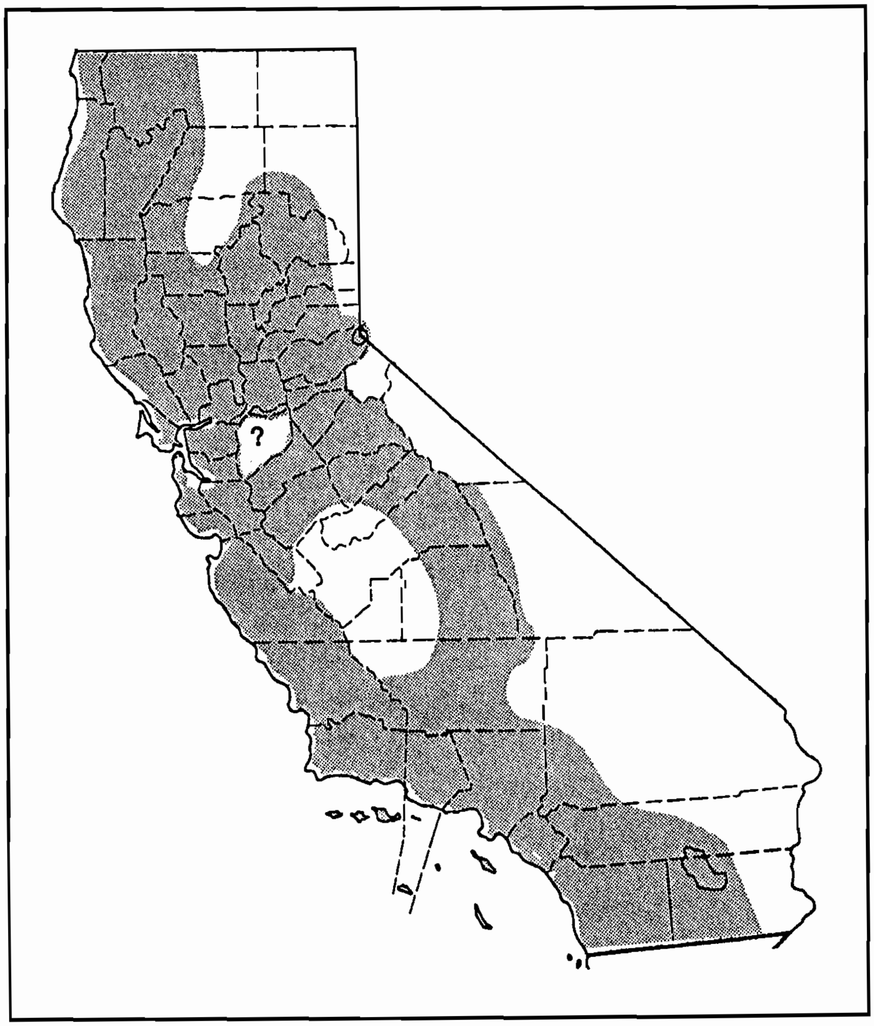

Figure 2. Distribution of *Ixodes pacificus* in California (after Furman and Loomis 1984).

County indicate no records of *I. neotomae* on either *N. fuscipes* or *Neotoma lepida*. Other ectoparasites (e.g., fleas, lice, mites) endemic to the mammalian hosts for *I. pacificus* may also play a role in the enzootic transmission of *B. burgdorferi* spirochetes.

References.

Furman, D.P. and E.C. Loomis. 1984. The Ticks of California (Acari: Ixodidae). Bull. Calif. Insect Survey 25:1-239.

Lane, R.S. 1990. Infection of deer mice and piñon mice (*Peromyscus* spp.) with spirochetes at a focus of Lyme borreliosis in northern California, U.S.A. Bull. Soc. Vector Ecol. 15(1):25-32.

Lane, R.S. and R.N. Brown. 1991. Wood rats and kangaroo rats: Potential reservoirs of the Lyme disease spirochete in California. J. Med. Entomol. 28(3):299-302.

Webb, J.P., Jr., S.G. Bennett, J.I. Curry, C.L. Fogarty, and M.B. Madon. 1990a. *Ixodes pacificus* and Lyme disease in Orange County, California, 1989. Proc. Calif. Mosq. Vector Control Assoc. 58:53-54.

Webb, J.P., Jr., S.G. Bennett, and G.L. Challet. 1990b. The larval ticks of the genus *Ixodes* Latreille (Acari: Ixodidae) of California. Bull. Soc. Vector Ecol. 15(1):73-124.

Table 1. Mammalian hosts for *Ixodes pacificus* in California.

Mammalian Host	*Ixodes pacificus* Larva	Nymph	Adult
Chaetodipus fallax[1]	X	-	-
Dipodomys agilis[1]	X	-	-
Dipodomys californicus[2]	?	X	X
Didelphis marsupialis[1]	X	-	-
Lepus californicus[3]	X	-	X
Microtus californicus[3]	X	X	-
Microtus townsendi[1]	X	-	-
Neotoma fuscipes[3]	X	-	-
Neotoma lepida[3]	X	-	X
Odocoileus hemionus[3]	X	X	X
Peromyscus boylii[3]	X	X	-
Peromyscus californicus[3]	X	-	-
Peromyscus maniculatus[3]	X	-	-
Peromyscus truei[3]	X	-	-
Reithrodontomys megalotis[1]	X	-	-
Scapanus latimanus[1]	X	-	-
Sylvilagus audubonii[3]	-	-	X

[1] Webb et al. 1990b
[2] Lane and Brown 1991
[3] Furman and Loomis 1984

Table 2. Mammalian hosts for *Ixodes spinipalpis* in California.

Mammalian Host	*Ixodes spinipalpis* Larva	Nymph	Adult
Chaetodipus fallax[1]	X	-	-
Chaetodipus formosus[2]	-	X	-
Lepus californicus[2]	-	-	X
Microtus californicus[2]	X	X	-
Neotoma fuscipes[1,2,3]	X	X	X
Neotoma lepida[2]	X	X	X
Notiosorex crawfordi[1]	X	-	-
Peromyscus californicus[1]	X	-	-
Peromyscus eremicus[1]	X	-	-
Peromyscus maniculatus[2]	X	X	-
Reithrodontomys megalotis[1]	X	X	-
Sylvilagus auduboni[1]	X	-	-
Sylvilagus bachmani[2,4]	X	X	X

[1] OCVCD, unpublished data
[2] Furman and Loomis 1984
[3] Lane and Brown 1991
[4] Lane 1990

Table 3. Mammalian hosts for *Dermacentor occidentalis* in California.

Mammalian Host	*Dermacentor occidentalis* Larva	Nymph	Adult
Chaetodipus fallax[1]	X	X	-
Lepus californicus[2]	-	X	-
Microtus californicus[4]	X	X	X
Neotoma fuscipes[3,4]	X	X	X
Neotoma lepida[1]	X	X	-
Odocoileus hemionus[4]	X	X	X
Peromyscus californicus[1]	X	X	-
Peromyscus eremicus[1]	X	-	-
Peromyscus maniculatus[2,4]	X	X	X
Peromyscus truei[2,4]	X	X	-
Reithrodontomys megalotis[1]	X	-	-
Sylvilagus auduboni[1]	X	-	-

[1] OCVCD, unpublished data
[2] Lane 1990
[3] Lane and Brown 1991
[4] Furman and Loomis 1984

Table 4. Mammalian hosts for *Ixodes neotomae* in California.

Mammalian Host	*Ixodes neotomae* Larva	Nymph	Adult
Lepus californicus[1]	-	-	X
Neotoma fuscipes[1,2]	-	X	X
Neotoma lepida[1]	-	-	X
Sylvilagus auduboni[1]	-	-	X
Sylvilagus bachmani[1,3]	-	-	X
Urocyon cinereoargenteus[1]	-	-	X

[1] Furman and Loomis 1984
[2] Lane and Brown 1991
[3] Lane 1990

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TICK ECOLOGY AT WILLOW CREEK STATE PARK

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ABSTRACT

Ecological and distributional relationships of three species of hard tick were investigated at a Lyme borreliosis positive site in Sacramento County. Larval and nymphal ticks were collected by trapping mammals and lizards. Birds and other reptiles were also inspected for immature ticks. Tick associations with floral communities, habitat selection, and climatological effects were observed. The three tick populations at this site have different peak abundance and floral community preferences. Black rats, woodrats, and white-footed mice were hosts for larval and nymphal western black-legged ticks, while birds and reptiles did not seem to be significant hosts. Finally, observations were made of tick diel movement, questing, aggregation, and clustering behavior.

Introduction.

Lyme borreliosis is presently the most common vector-borne disease in the United States. In western North America the disease is vectored almost exclusively by the western black-legged tick, *Ixodes pacificus* Cooly and Kohls. *Ixodes pacificus* occurs in 54 of 58 counties of California. The California population is scattered on the western slopes of the Sierra Nevada Mountains and on both the eastern and western slopes of the Coast Range, being separated by the dry Sacramento and San Joaquin Valleys. It occurs in the northern coastal and Sierra Nevada counties and is by far most abundant in the northwestern portion of the state. With the recent increase of Lyme disease cases in California, there has been a need for field investigators to clearly define *I. pacificus* habitat preferences and host-seeking behavior throughout its range to delineate risk.

Ixodes pacificus populations occur on the eastern edge of Sacramento County in relatively protected riparian habitats. Two general regions exist, the upper eastern portion of the Cosumnes River and the eastern portion of the American River from Folsom Lake to Rancho Cordova. The density of this tick decreases progressively as one travels from east to west. The most abundantly populated sites occur around Lake Natoma just below the city of Folsom. This area was first inspected by J. Bradley of the State Department of Health Services in April, 1990. Of the 101 *I. pacificus* she collected from Willow Creek State Park on the southern shore of Lake Natoma, six of nine pools were confirmed positive for *Borrelia burgdorferi* Johnson, Schmid, Hyde, Steigerwalt and Brenner (CDHS-EMB Unpubl. Records, 1991). The isolation was the first in Sacramento County and prompted this investigation at the Willow Creek site. Important site characteristics include: 1) an established rodent and deer population; 2) occurrence of several hard tick species; 3) vegetation diversity consisting of several different floral communities; 4) undisturbed sites representing a natural setting; and 5) human activity suggesting the potential for vector-borne disease transmission.

The purpose of this investigation was to obtain an understanding of the ecology and behavior of tick species occurring in the park, especially that of *I. pacificus*. This was done by weekly observations and measurements of biotic and abiotic factors that may influence these species. Plant and animal species within the community were identified and inventoried to establish any distinct associations between them and the aforementioned ticks. An ultimate goal was to clearly define the conditions of a central sierran habitat where *I. pacificus* and *B. burgdorferi* coexist.

Materials and Methods.

Willow Creek State Park is an 80 acre, day-use, recreation site located within the Folsom Lake State Recreation Area (Lake Natoma Unit). Willow Creek is a permanent stream on the eastern border of Sacramento County originating in the Sierra Nevada foothills and entering the American River at the park site. The park is a rhomboid-shaped parcel bordered by Willow Creek on the east, the American River on the north, Folsom Boulevard along the south with the western portion tapering toward Highway 50. Lake Natoma is created by the impoundment of the American River at the Nimbus Dam, and is a post-lake reservoir for Folsom Lake. The Park is 2.5 km (1.5 mi.) west of the Folsom City limits and 7.4 km (4.5 mi.) down river from Folsom Dam.

The site exists within the Folsom quadrangle (T.9N, R.7E, S.11). The elevation ranges from 126' at the lake shore to 150' at the upper terrace. At the southwest end of the park steep cliffs occur along the American River.

The climate is mediterranean characterized by mild winters, wet springs, and hot, dry summers. The average annual rainfall is about 20 inches with 99% of this falling in winter and early spring (Anonymous 1991). Between rain storms, a thick low-laying fog usually occurs. A predominantly south wind affects the upper terrace slopes while the lower areas are wind free and are comprised of vegetation that is associated with wetter plant communities. North facing slopes do not receive direct sunlight. Humidity is greater on the north facing slopes, a result of direct contact with the vast waters of Lake Natoma and the protection from wind. These areas support the richest riparian flora and thickest oak forests, while the upland areas have the dryer grasslands and chaparral.

Five floral communities were identified at Willow Creek State Park. They are: 1) open grassland; 2) chaparral; 3) foothill woodland; 4) riparian woodland; and 5) wetland (pers. commun. - F. Hrusa, UCD Arboretum).

Climatological data were collected at the same time each week just prior to dragging. All measurements were therefore taken just after sunrise and probably represent the coldest temperature and highest humidities for the day. Ambient air and soil temperature, relative humidity, wind direction, and weather were gathered and recorded. Humidity measurements were taken at ground level using a Qualimetrics 5245 battery-powered psychrometer and at three feet using a Weksler sling psychrometer. Readings were taken in each floral community. Temperature measurements were made with a 5" stainless steel temperature probe, wind velocity was determined using a Dwyer wind meter, and precipitation and photoperiod information were collected from the National Weather Service Office in Sacramento.

The drag route which passed through each type of floral community followed the roads and footpaths through the park. The route had a combined length of 3.67 km (2.3 mi). The route was followed at the same time each morning for 65 consecutive weeks and the foliage flagged with a standard one meter square cotton flannel cloth. The collection period lasted from two to three hours. Ticks were collected from the flag or directly from foliage.

Mammal traps were set twice a month at established stations along the drag route. At each station, two 3" x 3.5" x 9" aluminum Sherman traps and one 16" x 5" x 5" wire National trap were set within 20 feet of each other. Whole grain with molasses was used to bait the Sherman traps and peanut butter with whole grain was used to bait the National traps. A total of 45 traps was set in the evening and recollected mid-morning (10:00 AM) the following day. The captured mammals were anesthetized with ethyl ether and then carefully combed free of fleas, mites, and lice. Tick collection was done by visual and tactile inspection of the animals with the ears, face, and axial areas being given the greatest attention. Ticks were removed with forceps and placed in labeled containers for later identification. After the combing and inspection, the mammals were sexed, weighed, measured, and ear tagged. Serum samples were taken from mammals via cardiac puncture. Subsequently, all animals were released at their collection site.

Once a week, birds were collected by a modified Australian crow trap designed after Dr. J.A. Gruwell, Orange County Vector Control District. Initially, the 6' x 6' x 4' walk-in trap, baited with mixed bird seed and water, was left open continuously for one month allowing the birds to come and go freely during acclimatization. Over the next seven months, once a week, the trap was closed over one night and part of the next day. Trapped birds were collected twice the next day at approximately 6:30 AM and 1:00 PM. Birds were captured from inside the crow trap with an aerial insect net and transferred to an ether chamber. The chamber was designed similar to the "Fair Isle" apparatus allowing the ectoparasites on the bird's body to be anesthetized and retrieved, while the bird remained fully conscious (Southwood 1966). After mites, lice, and hippoboscids were removed, each bird was visually and tactually inspected for ticks before being released at the collection site.

Whenever lizards were observed, they were captured using a fishing rod and monofilament fishing line tied with a slip noose. Captured lizards were inspected visually in the gular folds, at the base of limbs, between toes, under scale furrows, and around eyelids.

Field observations of questing ticks were also made. Observations included geotaxis, positioning, mating pairs, clustering, aggregations, plant species, presence in each floral community, and diel movements. To gather information on movement, Tanglefoot Pest Barrier was applied to the base of the grass blade or stem. Survey flags were placed at individual questing positions to collect visual and photographic information on clustering. Positions of individual questing ticks were determined by measuring distance to soil, length of stem or grass blade, and distance tick occurred from base and tip of stem or blade.

Results.

Three species of ticks were collected during the survey at Willow Creek State Park; *I. pacificus*, *Dermacentor variabilis* Say, and *Dermacentor occidentalis* Marx. Each species had a distinct peak of activity which was clearly separated by season (Fig. 1). Two other species, *Ixodes neotomae* Cooley and *Ixodes sculptus* Neumann were also collected, but only rarely and only from hosts.

The activity period for *I. pacificus* adults occurred during the winter months with two principal activity episodes or peaks, one in January and one in April. A significant decline in activity was noted during February and March, resulting in a bimodal activity period for *I. pacificus* which has also been observed in Butte County (pers. commun. -S. Monsen, BCMAD) and to a lesser extent in the northern San Francisco Bay area populations (pers. commun. - M. Castro). The initial collection of questing adult *I. pacificus* was made in late October after the first fall rain, and the latest collection was in mid-July. Collection attempts during August and September were entirely unsuccessful over the two year period.

There was some activity peak disparity noticed between the sexes. The fall peak averaged 4.5 more males than females per sample. Males appeared prior to females in the fall and remained more abundant until the beginning of the second peak (Fig. 1). The second peak averaged 18.4 more females than males. Female numbers grew rapidly in April and dominated the second peak with male numbers increasing at a slower rate.

The activity period for *D. occidentalis* overlapped that of *I. pacificus*, but this species was more abundant during the spring months. Initial collections were made in early November and the last were observed in August, giving *D. occidentalis* the longest seasonal activity period and making it the most abundant tick collected at the park. *Dermacentor occidentalis* also showed a bimodal pattern. However, their abundance was strongly skewed toward the late spring months. The major activity episode occurred in May and early June with a rapid decline in collection numbers in early July until it completely disappeared the first week in August (Fig. 1).

The activity period for *D. variabilis* was more narrowly confined to the warmer summer months. The earliest *D. variabilis* adults were collected in early April. Its numbers increased steadily through May and peaked in mid-June and late July. By mid-August, it was the only species collected and its numbers declined after that point until it disappeared in September (Fig. 1). No ticks were collected through most of September and October. All three species were collected in April, May, and June. The seasonal abundance of *I. pacificus* and *D. occidentalis* observed at Willow Creek Park corresponds to those observed at the Berkeley Sierra Field Station (Lane 1990).

Figure 1 also shows the main activity peak for each of the three species of ticks collected in relation to local climatological conditions. When comparing the average ambient temperatures with *I. pacificus* activity peaks, abundance appears to be the inverse of the ambient temperature; i.e., as the ambient temperature declined *I. pacificus* activity proportionally increased to its greatest numbers when temperatures were the lowest. The coldest temperature during which actively questing *I. pacificus* ticks were collected was -3.7° C (25.1° F).

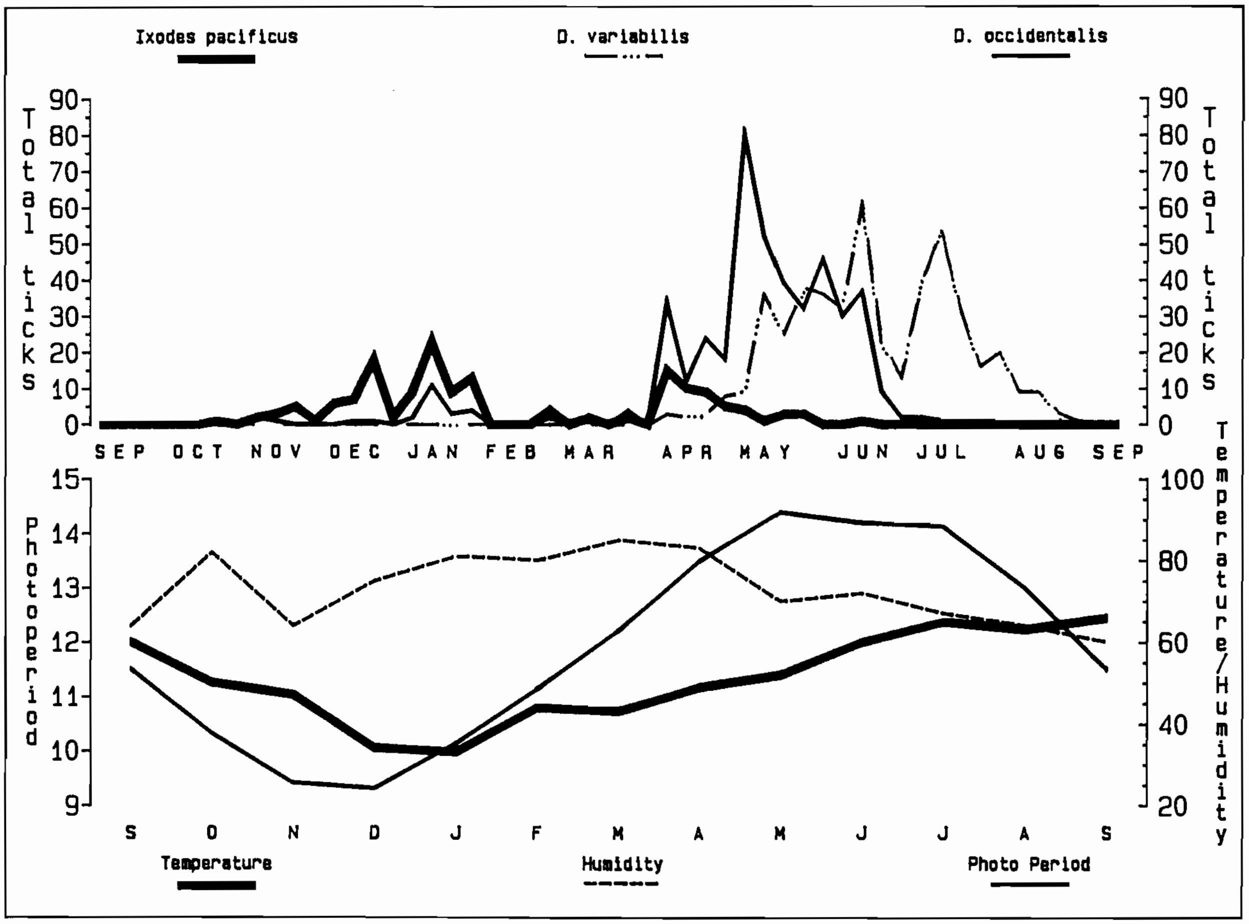

Figure 1. Tick seasonality and climatological effects at Willow Creek State Park, Sacramento County.

In the Spring, as ambient temperature increased, *I. pacificus* numbers proportionally decreased until none were collected at temperatures above 18.3° C (65.0° F). The average temperature of activity was 6.0° C (42.8° F).

Ixodes pacificus showed its greatest activity during the period of the year when rainfall was the greatest, however, the specific activity days were not associated with rainstorms. Peak activity was nearly inverse of the annual shortest photoperiod, increasing as photoperiod declined and decreasing as photoperiod increased. Increased activity was observed when the daily average humidity was 76.8% or greater.

Dermacentor occidentalis had its greatest activity period after the *I. pacificus* began to decline. Ambient temperature and daylength were increasing while rainfall and relative humidity were decreasing. The lowest temperature at which *D. occidentalis* were observed questing was -2.2° C (28.0° F) while the highest was 21.1° C (70.0° F). Throughout the *D. occidentalis* activity period, the average questing temperature was 8.6° C (47.4° F) and the average relative humidity was at 75.2%.

Dermacentor variabilis had their greatest activity period in the late spring and summer months after the *D. occidentalis* had began to decline. Temperatures were on average higher, 14.8° C (58.6° F), rainfall nearly absent, daylength at its greatest (14.5 h), and humidity on the average lower, 68.7%.

The three species of ticks showed some separation by floral community preference. The grassland community exists primarily on the upper terrace slopes and higher elevated locations of the park which are dominated by the valley oak and a mixture of ten different grass species. This community was dominated by the presence of *D. variabilis*, which was found questing from six different grass species (Table 1). *Dermacentor occidentalis*, was found questing on one of the *Festuca* species in the grassland.

Plants associated with a chaparral type floral community are found occurring in the driest portions of the park. *Dermacentor* variabilis was the only tick collected in these regions and it occurred on the brome and rye.

The foothill woodland floral community covers the largest area of the park. It occurs in the low-lying areas and adjacent to the open grasslands. The woodland community is dominated by digger pine, live oak, valley oak, and scrub oak. Thick buckeye and poison oak comprise the understory shading four native annual grasses which include torry melic, California melic, and two blue grasses. This community supported the greatest tick diversity. *Dermacentor* occidentalis and *I. pacificus* both occurred on the shorter native grasses and *I. pacificus* were found abundantly on the hedgehog dogtail. *Dermacentor* variabilis was collected from the taller grasses, ripgut brome, soft chess and barley, that occurred on the fringes of the community (Table 2).

The riparian forest community contains the most diverse plant species in the park. It is densely forested with Fremont's cottonwood, California black walnut, several species of willow, white alder, tree of heaven, and elderberry. The upper canopy is so dense that very little direct sunlight reaches the forest floor. Thick vines of wild grape, wild cucumber, Dutchman's pipe, and poison oak hang from the trees in an intertwined mesh which creates a nearly impenetrable wall of foliage. Wild pea, Miner's lettuce, woodfern, five-finger fern, soaproot and melic grasses grow at ground level. *Dermacentor* occidentalis and *I. pacificus* were abundant in this floral community and were found questing on the vines, low-growing plants and grasses. *Dermacentor* variabilis was not collected in this community (Table 3).

The wetland floral community occurred sporadically throughout the park in low depressions and at an embayment of Lake Natoma. Near the shores abundant cattails, sage, and bulrushes occur. Wild blackberries grow from the shoreline and run up the channels which drain into the lake. Five species of willow occur in the wetland community along with horsetail, rushes, and barnyard Grass. *Dermacentor* occidentalis was the only species collected in the wetland floral community. They were observed questing on the rushes, blackberries, and barnyard grass.

Each of the different floral communities had different temperatures and relative humidities. The average winter morning humidity for each community were as follows: grassland 84%, chaparral 74%, woodland 82%, riparian 92%, and wetland 91%. This factor alone may contribute significantly to some of the tick preference observed.

All three species of tick were observed to remain on their questing substrate throughout the day, but would be observed questing only rarely. At wind velocities above zero mph, ticks would remain on grass blades in a resting position. Due to the protection of surrounding foliage, wind velocities at tick positions rarely registered on the meter. *Ixodes pacificus* and *D. occidentalis* abundance were greatest on north-facing slopes which may be due to less direct sunlight, higher humidities, or less wind exposure. *Ixodes pacificus* and *D. occidentalis* in coastal communities (Hopland) are frequently collected on south-facing slopes (Lane et al. 1985, Lane 1990). It may be that due to the cooler temperature and higher humidity of coastal climate, other factors are able to contribute to tick distribution.

The larvae and nymphs of the three hard tick species showed a similar seasonality as did the questing adults, however, their activity periods started later and then persisted later into the year. Immature ticks were not collected on the drag; *I. pacificus* immatures first occurred on hosts in April and persisted through July, while immature *D. occidentalis* first appeared on hosts in May and persisted through June. Immature ticks of *D. variabilis* were present on hosts in July and August.

Nine species of mammals were collected in the traps at Willow Creek State Park (Table 4). Only five of these species were found to be hosts to one

Table 1. Plant community (grasslands) with tick associations, Willow Creek State Park, Sacramento County.

Major Flora		Density	Tick Association	Tick Species
Valley Oak	*Quercus lobata*	Low	*	*Dermacentor variabilis*
Brome	*Bromus diandrus*	Low-Moderate	*	*D. variabilis*
Chess	*Bromus mollis*	Moderate	*	*D. variabilis*
Rye	*Lolium perenne*	Low	*	*D. variabilis*
	Elymus glaucus	Low		
Oats	*Avena barbata*	Moderate	*	*D. variabilis*
Canary Grass	*Phalaris paradoxa*	Low		
	Festuca spp.	High	*	*D. occidentalis*
Barley	*Hordeum leporinum*	Moderate	*	*D. variabilis*
	Cynodon dactylon	High		
Ragweed	*Ambrosia psilostachya*	Low		
Mustard	*Brassica sp.*	Moderate		
Plantain	*Plantago sp.*	Low		
Bedstraw	*Galium aparine*	Low		
Dill	*Torilis arvense*	Low		
Yellowstar Thistle	*Centaurea sulphurea*	High		

Table 2. Plant community (foothill woodland) with tick associations, Willow Creek State Park, Sacramento County.

Major Flora		Density	Tick Association	Tick Species
Digger Pine	*Pinus sabiniana*	Low		
Live Oak	*Quercus wislizenii*	High	*	*Ixodes pacificus*
Valley Oak	*Q. lobata*	Low		
Scrub Oak	*Q. douglasii*	High		
	Aristolochia californica			
Ripgut	*Bromus diandrus*	Moderate	*	*Dermacentor variabilis*
Soft Chess	*Bromus mollis*	Moderate	*	*D. variabilis, D. occidentalis*
Barley	*Hordeum leporinum*	Moderate	*	*D. variabilis, D. occidentalis*
Torry Melic	*Melica torreyana*	High	*	*D. occidentalis, I. pacificus*
California Melic	*Melica californica*	High	*	*D. occidentalis, I. pacificus*
Hedgehog Dogtail	*Cynosurus echinatus*	High	*	*I. pacificus*
Poison Oak	*Toxicodendrum diversilobium*	High	*	*I. pacificus*
Buckeye	*Aesculus californica*	Moderate		
Blue Grass	*Poa annua*	Low		
	Stipa pulchra	Low		
Plantain	*Plantago lanceolata*			
	P. major			

Table 3. Plant Community (riparian forest) with tick associations, Willow Creek State Park, Sacramento County.

Major Flora		Density	Tick Association	Tick Species
Fremont's Cottonwood	*Populus fremontii*	High		
Interior Live Oak	*Quercus wislizenii*	Moderate	*	*Ixodes pacificus*
Valley Oak	*Q. lobata*	Low		
Scrub Oak	*Q. douglasii*	Low		
N. California Walnut	*Juglans hindsii*	Moderate		
Red Willow	*Salix laevigata*	Moderate		
Green Willow	*Salix goodingii v. variabilis*	Moderate		
White Alder	*Alnus rhombifolia*	High		
Tree of Heaven	*Ailanthus altissima*	Low		
Elderberry	*Sambucus mexicana*	Moderate		
Toyon	*Heteromeles arbutifolia*	Moderate		
Wild Blackberry	*Rubus vitifolius*	High	*	*Dermacentor occidentalis*
Wild Grape	*Vitis californica*	High	*	*I. pacificus, D. occidentalis*
Dutchman's Pipe	*Aristolochia californica*	High	*	*I. pacificus*
Poison Oak	*Toxicodendrum diversilobium*	High	*	*I. pacificus*
Soaproot	*Chlorogalum pomeridianum*	High		
California melic	*Melica californica v. nevadensis*	High	*	*I. pacificus, D. occidentalis*
Torry melic	*Melica torreyana*	High	*	*I. pacificus, D. occidentalis*
Hedgehog Dogtail	*Cynosurus echinatus*	High	*	*I. pacificus*

or more of the three tick species. Immature *Ixodes* were collected from three mammals, the brush mouse (*Peromyscus boylei* Baird), the dusky-footed woodrat (*Neotoma fuscipes* Baird), and the black rat (*Rattus rattus*). A nymphal *I. sculptus* was collected from a California ground squirrel and two larval *I. neotomae* were collected from woodrats. Two hundred and eleven *P. boylei* were captured from the site making it the most abundant mammal collected. However, only seven mice (3.3%) were found parasitized by *Ixodes* and four (1.4%) by *Dermacentor* immatures. There was a total of 12 ticks collected from seven mice, resulting in a tick index (number ticks per animal) for *P. boylei* of 0.057. *Neotoma fuscipes* were less frequently captured as only 23 different individuals were collected during the season, but its *Ixodes* parasitism rate was much higher at 13.0%, and its tick index was 0.17. *Dermacentor* immatures were not collected from the woodrats. *Rattus rattus* was the second most commonly collected mammal. Forty-two *Ixodes* immatures were collected from 95 *R. rattus*, but many rats had multiple ticks. Two were captured that had 14 larvae each. The overall *Ixodes* parasitism rate for *R. rattus* was 8.4%, and its tick index was 0.442, higher than any of the other mammals captured. Six *D. occidentalis* were collected from three *R. rattus* and one *D. variabilis* was collected from a *R. rattus*. Striped skunks were found parasitized by nymphal and adult *D. variabilis* and a single road-killed black-tailed deer, *Odocoileus hemionus* Richardson, was found with three adult *D. occidentalis* ticks. Four opossums, seven California meadow voles, and one western gray squirrel yielded no ticks.

All the ticks collected from the mammals were discovered using visual and tactile inspection. The vast majority of the ticks were attached to the inside of ear pinna. The additional sites of attachment are listed in descending frequency of tick location; 1) back of ear, 2) rostrum, 3) mouth, 4) back of neck, 5) under chin, and 6) anterior axial. The last three locations are represented by only one tick each. Lane and Loye (1991) estimate that such inspections yield between 45-69% of the total ticks parasitizing any one animal.

Serum was collected from three *P. boylei*, 59 *R. rattus* with seven recaptures, 16 *N. fuscipes* with five recaptures, five striped skunks, two opossums, and three ground squirrels. Collected sera were submitted to Dr. James Webb at Orange County Vector Control District for *Borrelia burgdorferi* antibody diagnosis. Laboratory fluorescent antibody tests on sera collected from the mice and woodrats were all negative.

Three species of lizard were captured at Willow Creek; the western fence lizard (*Sceloporus occidentalis* Baird and Girard), the southern alligator lizard (*Gerrhonotus multicarinatus*), and the Gibert's skink (*Eumeces gilberti*). One of 14 *S. occidentalis* captured in late March was found to be parasitized by two *Ixodes* larvae. The other lizards were not found to be parasitized by ticks. The two partially engorged ticks were located in the left gular fold of an adult male. Five species of snake were also collected in the park and inspected but no ticks were found.

Three species of bird were captured at Willow Creek; the house finch, Brewer's blackbird, and the hermit thrush. In total 48 birds were inspected but no ticks were recovered.

Behavioral Observations: *Ixodes pacificus* was

Table 4. Mammals collected at Willow Creek State Park, Sacramento County.

Common Mammal		# Collected	# *Ixodes* L/N	# *Dermacentor* L/N/A	Other Ectoparasites
Brush Mouse	*Peromyscus boylei*	211	11L, 1N	10L, 2N	Fleas, Mites
Deer Mouse	*Peromyscus maniculatus*	8			Fleas, Mites
Wood Rat	*Neotoma fuscipes*	23	4L		Fleas, Mites, Lice, Cuterebridae
Black Rat	*Rattus rattus*	95	42L	6L, 2N	Fleas, Mites, Lice, Cuterebridae
Ca. Meadow Vole	*Microtus californicus*	7			Mites, Lice
Striped Skunk	*Mephitis mephitis*	10		3N, 13A	Fleas
Oppossum	*Didelphis marsipialis*	4			Fleas
Western Gray Squirrel	*Sciurus griseus*	1			
Ca. Ground Squirrel	*Spermophilus beecheyi*	3			Fleas, Mites, Lice

observed to display some interesting consistent questing patterns. Both male and female questing ticks were frequently observed to be concentrated into certain areas. Vast areas adjacent to the concentrations appeared to have few to none. The concentrations were frequently located on north facing topological landscapes that rarely received sunlight, particularly protected under dense oak trees. Aggregations of *I. pacificus* were often found on the same grass blades. The maximum number in a aggregation at Willow Creek was six while the most common was two. Ticks tended to position themselves near the distal end of grass blades and for the most part heads were directed toward the ground, that is, geotactively positive, unless the grass blade was broken or the tick was on a short twig. This orientation is the opposite of what has been reported by other observers (Loye and Lane 1988, Lane and Stubbs 1990). The majority of *I. pacificus* were observed on short grasses and positioned themselves 20-30 cm above the ground. One female was observed 43 cm above the ground. Measurements showed that *I. pacificus* rarely moved when in position on a suitable questing substrate. Of 20 ticks observed, the average time period without moving was six days. One female was observed to remain in place for 22 days. Only one of 20 *I. pacificus* crawled down the grass blade during the observations, the others disappeared over the 22 day period.

Discussion.

The landscape at Willow Creek State Park is highly variable, and when coupled with the availability of water, contributes to the high faunal and floral diversity of the site. A habitat with such a complex canopy and understory with abundant refuge and food resources attracts a wide variety of wildlife. The relatively poor habitat surrounding the Willow Creek site tends to concentrate populations in the park. The wildlife populations at the site are similar to those of much of the Sierra Nevada foothills. This is due to the nearly continuous riparian corridor which follows the American River down from the Sierras. This corridor allows the relatively hidden movement of deer, fox, and coyotes from the higher summer elevations into the lower winter sites such as Willow Creek. The black-tailed deer was occasionally seen at the site and abundant evidence of their presence could be found. Avian diversity at the park is relatively high for the region. Park officials have listed 102 common species (Fregian 1990).

The diversity of this habitat provides abundant host populations for all three stages of tick development. The three tick species, however, show separation by season and by floral community during their host seeking activity periods.

The bimodality of the *Ixodes pacificus* activity periods may represent two different cohorts. Adult *Ixodes* were initially encountered each year directly following the first heavy rain storm of the season, in late October, 1990, and in early November, 1991. This may represent individuals which survived the summer in estivation. The spring peak may be made up primarily of newly molted adults.

The majority of immature *Ixodes* were found on *N. fuscipes* and *R. rattus*. The two species are similar in size and both prefer well shaded, dense cover. *Peomyscus boylei* were also found parasitized, but to a far lesser degree. *Peomyscus boylei* commonly live in the nests of woodrats, and many of the parasitized mice were collected in traps positioned at woodrat nests. *Neotoma fuscipes* have a home range of 10-30 meters and *P. boylei* have a range of 6-17 meters. It is therefore very likely that the *Ixodes* larvae and nymphs are encountered close to the woodrat nests. *Rattus rattus* has a much greater home range, foraging as far as 100 meters from their nest, and therefore, it seems likely that they would encounter more tick larvae during foraging. Despite this behavioral difference, *N. fuscipes* had a higher percentage parasitization. *R. rattus* had a higher tick index, which indicates more ticks were being nourished by their population.

Investigators have indicated that at most locations throughout its range in California *I. pacificus* immatures occur more frequently on lizards than on mammals (Arthur et al. 1968, Lane and Loye 1989). Willow Creek lizards were difficult to find and also to collect, however, those captured had fewer *Ixodes* than mammals captured during the same time.

Thirteen of 14 lizards captured at Willow Creek were without ticks. Rats, mice, and lizards are all suitable hosts for *I. pacificus* immatures. The specific location and abundance of one host versus another will necessarily influence tick parasitism of the host. *Sceloporus occidentalis* displays either rupicolous or arboreal behavior depending upon ambient temperatures and altitude of habitat (Davis and Verbeek 1972). In lower altitudes on the west slope of the Sierras *S. occidentalis* is arboreal which would reduce their exposure to tick populations. In California, *N. fuscipes* are suspected of being enzootic reservoirs for *B. burgdorferi* (Lane and Brown 1991), while *S. occidentalis* may serve as a natural zooprophylaxis, not supporting development of *B. burgdorferi* (Lane 1990). The apparent lack of ground-dwelling lizards and the high *I. pacificus* percent parasitism of woodrats at Willow Creek may suggest an explanation for the detected presence of *B. burgdorferi*.

From tick observations at Willow Creek, there appears to be higher numbers of ticks on specific types of plants, which maybe due to a combination of topological, edaphological, and climatological conditions rather than plant selection. Both ticks and plants may occur together due to some corresponding habitat requisites. What ever the cause, at least at Willow Creek and possibly at other adjacent sites, it seems clear that plants may serve as indicators of *I. pacificus* presence. Plant association has been established for *Dermacentor* species from the Rocky Mountains (Schaalhe and Wilkinson 1985), but have not been observed in *Dermacentor* species from California coastal communities (Lane et al. 1985).

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References.

Anonymous. 1991. National Weather Service Annual Climatological Report, Sacramento, California stations.

Arthur, D.R. and D.R. Snow. 1968. *Ixodes pacificus* Cooley and Kohls, 1943: its life-history and occurrence. Parasitol. 58:893-906.

Davis, J. and N.A.M. Verbeek. *1972.* Habitat preferences and the distribution of *Uta stansbariana* and *Sceloporus occidentalis* in coastal California. Copeia 4:643-649.

Fregien, R. 1990. Resource inventory: old Folsom powerhouse area development plan. CDPR Folsom.

Lane, R.S. 1990. Seasonal activity of two human-biting ticks. Calif. Ag. 44(2):23-25.

Lane, R.S. 1990. Susceptibility of the western fence lizard *(Sceloporus occidentalis)* to the Lyme borreliosis spirochete *(Borrelia burgdorferi)*. Amer. J. Trop. Med. Hyg. 42(1):75-82.

Lane, R.S., J.R. Anderson, J.S. Yaninek and W. Burgdorfer. 1985. Diurnal host-seeking of adult pacific coast ticks, *Dermacentor occidentalis* (Acari: Ixodidae), in relation to vegetational type, meteorological factors, and rickettsial infection rates in California, USA. J. Med. Entomol. 22(5):558-571.

Lane, R.S. and R.N. Brown. 1991. Woodrats and kangaroo rats: potential reservoirs of Lyme disease spirochetes in California. J. Med. Entomol. 28(3):299-302.

Lane, R.S. and J.E. Loye. 1989. Lyme disease in California: interrelationship of *Ixodes pacificus* (Acari: Ixodidae), the western fence lizard *(Sceloporus occidentalis)*, and *Borrelia burgdorferi*. J. Med. Entomol. 26(4):272-278.

Lane, R.S. and J.E. Loye. 1991. Lyme disease in California: interrelationship of ixodid ticks (Acari), rodents and *Borrelia burgdorferi*. J. Med. Entomol. 28(5):719-725.

Lane, R.S. and H.A. Stubbs. 1990. Host-seeking behavior of adult *Ixodes pacificus* (Acari: Ixodidae) as determined by flagging vegetation. J. Med. Entomol. 27(3):282-287.

Loye, J.E. and R.S. Lane. *1988.* Questing behavior of *Ixodes pacificus* (Acari: Ixodidae) in relation to meteorological and seasonal factors. J. Med. Entomol. 25(5):391-398.

Schaalhe, G.B. and P.R. Wilkinson. 1985. Discriminate analysis of vegetational and topographical factors associated with the focal distribution of Rocky Mountain wood ticks, *Dermacentor andersoni* (Acari: Ixodidae), on cattle range. J. Med. Entomol. 22(3):315-320.

Southwood, T.R.E. 1966. Ecological Methods with Particular Reference to the Study of Insect Populations. Methuen and Co., Ltd., London, England. 391 pp.

TEMPORAL AND SPATIAL DISTRIBUTION OF TWO HUMAN-BITING TICKS AND THE PREVALENCE OF *BORRELIA BURGDORFERI* IN CONTRA COSTA COUNTY, CALIFORNIA[1]

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ABSTRACT

The seasonal activity and spatial distribution of adult and immature *Ixodes pacificus* Cooley and Kohls and *Dermacentor occidentalis* Marx were determined along trails and on hillsides at Kennedy Grove Regional Park, in western Contra Costa County, and Lone Tree Park, Alamo, in central Contra Costa County. *Ixodes pacificus*, the western black-legged tick, is the principal vector of Lyme disease in the western United States, and *Dermacentor occidentalis*, the Pacific Coast tick, is known to transmit several viral, bacterial, and rickettsial diseases.

Ticks were collected every other week from December, 1990, through August, 1991, by flagging the vegetation on both sides of a stretch of trail and along transects on a nearby hillside. Immature tick numbers were monitored at both sites by live-capturing small mammals monthly from April through August, 1991.

Ixodes pacificus and *D. occidentalis* adults were most numerous in January and May, respectively. Maximum numbers of 44 *Ixodes pacificus* and 95 *Dermacentor occidentalis* per 100 square meters were found along the trail at Kennedy Grove Regional Park. Adult ticks were significantly more abundant (Student's t-test, $P<0.05$) along heavily vegetated trails than on open grassy hillsides, and on the uphill versus the downhill side of the trails. Five species of rodents were captured. Numbers of *I. pacificus* and *D. occidentalis* larvae were highest during May-June (averaging 2.2 larvae per rodent) and July (averaging 7.2 larvae per rodent), respectively. Few nymphs were recovered either by flagging or from captured rodents.

An average of 2.2 and 2.8% of the *I. pacificus* adults collected from Kennedy Grove Regional Park and Lone Tree Park, respectively, were infected with the Lyme disease spirochete, *Borrelia burgdorferi* Johnson, Schmid, Hyde, Steigerwalt, and Brenner. The greatest risk of contracting Lyme disease from adult *Ixodes pacificus* in these two Contra Costa County parks is therefore during the winter months, especially while hiking near the uphill side of trails where ticks are most abundant.

[1] A manuscript fully summarizing this study has been accepted for publication in the Journal of Medical Entomology.

MOSQUITOFISH REPRODUCTION:

EFFECTS OF TEMPERATURE, PHOTOPERIOD, AND DIET

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ABSTRACT

Accelerated reproduction of mosquitofish (*Gambusia affinis* (Baird and Girard)), a proven larvivore, would benefit mosquito abatement districts' biological control efforts, especially for early season stocking in agroecosystems such as rice fields. Our previous laboratory studies showed that chronic 15L:9D photoperiods stimulated accelerated reproductive development in mosquitofish at 25° C. Fish flake diet supplements (lipid- and protein-rich tubificid worms) reduced female mosquitofish mortality. Our first research objective was to evaluate the 15L:9D photoperiod on TetraMin flake-fed fish and those receiving worm supplements at a more realistic winter temperature (18°C). Our second objective was to assess the value of other dietary supplements on mosquitofish mortality and reproductive development under stimulating temperature (25° C) and photoperiod (15L:9D) conditions.

Two experiments were conducted using 32 replicated glass tanks with aerated, flow-through water in light-tight photochambers. Tanks in the first experiment (18° C, 15 female + 4 male fish, each) were randomly assigned to either a constant 15L:9D or a control (naturally increasing from the winter solstice) photoperiod, on either a TetraMin flakes or TetraMin + live tubificid worms diet (8 replicates of each photoperiod-diet combination) for 24 weeks. Tanks in the second experiment (25° C, 12 + 3 fish, all at 15L:9D) had 1 of 4 diets: TetraMin flakes, TetraMin flakes + tubificid worms, TetraMin flakes + thawed zooplankton, or TetraMin flakes + surplus cheese (8 replicates each). Analysis of variance (ANOVA) showed that all of the temperature, mortality, and reproductive effort data (below) were consistent among replicates in both experiments.

In the first experiment, dietary worm supplements generally decreased mortality and increased reproductive effort. The 15L:9D group on the TetraMin diet showed significantly greater mortality than the control photoperiod group on the TetraMin + worms. The 15L:9D, TetraMin + worms and the control photoperiod, TetraMin groups were intermediate. Reproductive effort was not statistically distinguishable among groups during the first 12 weeks. During the third 6-week segment, the 15L:9D, TetraMin + worms group had significantly greater reproductive effort than either of the control photoperiod groups, which had yet to produce any young. During the last 6-week segment, none of the groups were statistically distinguishable, when production had begun in all of the groups. Overall, the 15L:9D, TetraMin + worms group produced significantly more young than the control photoperiod, TetraMin group. These results generally paralleled our earlier experiment at 25° C, except that mortality and reproductive responses were slower and less pronounced.

In the second experiment, the TetraMin + worms group showed significantly less mortality than the TetraMin group, with the other groups intermediate. Reproductive effort was not statistically distinguishable during the first 12 weeks. During the last three weeks, including all of the remaining females which were overanesthetized and dissected at the end, the TetraMin + worms group showed a significantly greater reproductive effort compared with all other groups, the same result for the overall experiment. Thus, the dietary advantages of supplemental tubificid worms were significantly greater than those of thawed zooplankton or cheese at 25° C in our tanks.

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BACK TO BASICS: A.M.C.A. UPDATE

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Several years ago I went to hear Dr. William Horsfall present the keynote address at an annual meeting of the American Mosquito Control Association (AMCA). I went expecting to be enlightened and to here new pearls of wisdom. As he began speaking, I became aware that I had heard it all before. As he continued, I became concerned that he was becoming senile. And then I became angry. He was reviewing basic mosquito control principals to a group of world renown mosquito researchers and long-time mosquito control workers. I felt that he was talking down to us, lecturing us. As I continued to listen however, I saw the wisdom in what he was doing. I knew the information he was reviewing with us, I had known it for many years. But I was not practicing some of it. And, more importantly, I was not passing the basics on to the people who worked for me. The teacher in Dr. Horsfall had scored again!

I believe it is important to look back at the basics - the who, what, when, where, and why of the AMCA. I believe this approach can help us identify our strengths and weaknesses, help us identify the challenges facing mosquito and vector control, and help us marshall our resources to meet member and association needs.

In looking back at the basics of "WHO was/is/will be the AMCA?", I found an article by Dr. L.O. Howard which Tommy Mulhern reprinted in the June, 1944 issue of *Mosquito News*, which is of course now the *Journal of the American Mosquito Control Association*. Dr. Howard stated that, "someone had told me that the little wrigglers in buckets of rainwater and in horse troughs were young mosquitoes. I had not only studied their transformations out of mere curiosity, but I had found that in this aquatic stage they were readily killed by pouring a few drops of kerosene on the surface of the water. But of course I was only a boy, and mentioned it only to my boy friends." Of course, Dr. Howard later repeated this experiment in the Catskill Mountains in 1882 and kerosene became the first larvicide in our arsenal. In looking at the who of mosquito control I have found that curiosity is a common trait among mosquito control workers. This inquisitive nature puts you in company with great men like Dr. Howard and brings great strength to our association.

Mosquito control workers do their jobs well, grow in their jobs, and freely share information. In the very first issue of *Mosquito News*, Tommy Mulhern reported on the passing of the Bill Erhart, who was the oldest mosquito control worker in New Jersey in 1941 as that issue was printed. Tommy said of Bill Erhart, "Some 37 years ago Bill started mosquito control work in the employ of the Board of Health in the City of Newark. His duties at that time consisted of the installation of ditches on the Newark Meadows with the "true" ditching machine. In 1912 he was employed by the Essex County Mosquito Extermination Commission and served as an Inspector, Foreman and Field Supervisor. Bill Erhart was well known in mosquito circles and participated in many meetings and field trips." Obviously, Bill Erhart was conscientious and did his best at whatever task he had to do. And, Bill Erhart shared his knowledge with others by participation in meetings and field trips over 80 years ago-much as you and I are doing here today.

We are also a very diverse group in the AMCA. In that first issue of *Mosquito News*, Tommy Mulhern also reported on the activities of

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entomologists like Thomas Headlee, with the New Jersey Agricultural Experiment Station; taxonomists such as Alan Stone and W.V. King, engineers with the Tennessee Valley Authority; and mosquito researchers, like Dr. W.B. Hermes at the University of California. AMCA membership continues to include many professions and vocations including industry, operational members, administrators, and researchers. This diversity of expertise and experience brings unusual strength and wisdom to the AMCA. It gives us the expertise to assemble committees to address all the matters which interest and are of concern to AMCA members. And, it gives us expertise from a multitude of backgrounds to publish the *Journal, Mosquito Systematics, Special Bulletins*, and *Wing Beats*.

There were no mosquito geneticists in that first group of AMCA members and we are rapidly loosing engineers from our ranks. But our membership continues to cut across all the disciplines relevant to today's mosquito and vector control programs. We added approximately 100 new associate members this year. This is good because knowledge without applications is useless. We all stand on the shoulder of men like Bill Erhart.

In looking at who we are, I also discovered that we have long been environmentally conscious people. In the March, 1943 issue of *Mosquito News* Gordon W. Mapes, Superintendent of the Matadero Mosquito Abatement District in Palo Alto, California reported that the oils they were using to abate salt marsh mosquitoes were not harmful to "vegetable, fish, or game life". Mosquito control workers were ecologist before ecologists were the in thing.

I have also discovered who we are not. In the June, 1944 issue of *Mosquito News* Tommy said, "With too exclusive preoccupation, one may easily come to assign to one's own special duties a disproportionate importance in comparison with those of one's fellow workers. Like the pendulum, the hands, the face and the works of the fabled clock, the engineer, the medical man and the entomologist are prone each to claim for his own special contribution, pre-eminent importance in mosquito control work."

That, of course, is a very real possibility in a group like ours. But I have not seen it happen during the time I have served on the Board of Directors. Every member of the AMCA board has had opportunity to voice his or her opinion freely. Every other member of the AMCA Board has listened respectfully. It has been a delightful experience in democracy for me. And, the beautiful part is that the members of the board leave their differences inside the board room when the debate ends. Following the vote, winners and losers alike work to move the association in the direction of the vote - basic democracy.

So, the who of the AMCA has not changed. People and personalities have changed but we are still a very diverse group represented by industry personnel, researchers, mosquito control workers, entomologists, managers, etc. We are still very conscious of our stewardship to the environment, and extremely opinionated. But we are also respectful of the opinions of others and all have the best interest of the AMCA at heart. And we have strengthened our association since the forties through the addition of women to our ranks. We may add an industry member to the Board in Corpus Christi, Texas. It may be your own Munzy. I believe that too will strengthen our association even more.

In looking at the question "What was/is/will be the AMCA?", I found the greatest changes and the greatest challenges. They are primarily changes in how mosquito and vector control workers are viewed by the public and those who hold the purse strings. Our perceived worth, or value, to society has changed greatly. Even so, this is not a new challenge. Solomon says in proverbs that what is now has been before and what was before will be again. This is true also for those of us in vector control.

Dr Howard made the following observations about the perceived worth of medical entomologists and other mosquito control workers during World War I: "It seems strange that the possible usefulness of economic entomology in the World War was not at once appreciated. When our country was getting ready, I wrote him (Dr. Gorgas, Surgeon General of the Army) that there were many men, well trained in applied entomology, who could be used to advantage and who were anxious for service. Possibly he never saw my letter, but I received a reply from his office, signed by one of his assistants, stating that what they needed was men trained in sanitary engineering, such as they had employed at Panama, but that they did not need entomologists - men trained to count the spots on a mosquito's wing."

The political and social system is often slow to accept or appreciate the worth of the scientists' discovery and we scientists are frequently not good salesmen.

But by World War II perception of our worth had changed. The June, 1943 issue of *Mosquito News* listed 37 professional entomologists who were commissioned in the U.S. Public Health Service Reserve Corps. They included names like William Bickley and Bernard Brookman of Berkeley, California and Willis W. Wirth, who was stationed in Alexandria, Louisiana at the time. A note in the March, 1943 issue of *Mosquito News* indicated that Dr. William B. Hermes, professor and researcher at the University of California, had been called to active duty by the War Department. By 1943 mosquito control was very popular in many states and California had 34 agencies involved in mosquito control. The public and the politicians recognized the public health role mosquito control played in society. It was also obvious that mosquito control would be even more popular in the United States following the war. In the December, 1943 issue of *Mosquito News*, Tommy Mulhern stated, "With the winning of the war, we may look forward to mosquito control on a much broader scale than heretofore-partly to combat mosquito-borne disease, and partly due to the many who have seen the current effective mosquito control measures and the results thereof being unwilling to return home to live in mosquito infested localities. The possibilities for service by the Association currently are very great; in the future with a broad expansion of anti-mosquito work they would seem to be unlimited."

However, Tommy also warned on several occasions, that public health was not the only role of mosquito control and that we should not lose sight of the importance of pest and nuisance mosquito control. I do not think we lost sight of the importance of pest mosquito control but I do not think we did a good job of selling it to the general public. Now, we are no longer looked upon by the public or by many health care workers as having a public health role. Public health now is AIDS, health care for the indigent, and nutrition for the poor. And, affordable health care for everyone will very likely be the major issue in this presidential campaign. That may make it even more difficult for mosquito and vector control agencies who are already competing with health departments for funds.

If you have any doubt about our perceived role in public health, look at the situation in Florida where there was a St. Louis encephalitis (SLE) epidemic in 1991. The John Mulrennan Mosquito Research Laboratory was recently moved from the State Department of Health and Rehabilitative Services to the Department of Agriculture. That is generally where the public sees mosquito and vector control agencies. We are more closely identified with agriculture than public health. This is a major challenge for mosquito and vector control workers everywhere.

I think we were slow to recognize and appreciate the significance of this shift in public perception and that we were slow to respond when we did recognize it. We are going to have to work hard to play catch up. We must each do more at home to deal with this matter. But we must also ban together to get our message to Washington.

The people serving in the federal government now are largely ignorant of the role that mosquito and vector control has played in our society. Most of the men and women who served in World War II and were influential in getting funding for mosquito and vector control agencies in the fifties and sixties are no longer in office. Many of the baby boomers now serving in local, state, and federal government either do not know what value to place on us, do not know that we exist, or suspect that we are poisoning the environment. And, no matter how effective we may be at home with our public education/public relations programs, many of the federal representatives have been in office and living in Washington, D.C. so long that they do not have the foggiest idea how the majority of their constituents feel on most issues. They respond to the organized, well funded, vocal minorities. And soon the concerns of the baby boomers will command all their attention. We must be more effective in voicing our concerns and getting a hearing for our concerns at the federal level. And we must do it now.

The AMCA spoke effectively for mosquito and vector control during 1991 at the national level. Dr. Bill Hazeltine and the Scientific and Regulatory Liaison Committee represented us very effectively on the minor-use pesticide issue and the wetlands issue. They have not done it alone, however. Industry has helped us know which doors to knock on. And, AMCA members in Texas, Florida, South Carolina, Illinois, and other states made key contacts with the appropriate legislators on behalf of the AMCA. These AMCA members provided the keys to open the door for us to present our message in Washington. We must continue to be proactive as a national association. Our survival depends on it. And, along the way, we need to emphasize the economic importance of mosquito and vector control.

A number of state and regional mosquito and vector control associations have made contributions to a new AMCA Legislative Fund. This fund will be used to expand our proactive efforts on behalf of mosquito and vector control at the national level. The Louisiana Mosquito Control Association (LMCA) donated $500 and several other state associations have donated between $200-$500. South Carolina made $235 on their annual meeting and donated $200 to the AMCA. I challenge the California Association to join with us in this effort.

In looking at the question "WHEN was/is/will be the AMCA?", I noted that there were many state and regional mosquito control associations in existence before the AMCA, including the California Mosquito Control Association which had 180 people in attendance at its 1944 meeting. The organization of the AMCA followed the local, state, and regional associations in the 1940s. And, the AMCA has historically followed the lead of other groups to meet member needs. However, circumstances, public perception, and politics have changed greatly. So, we need to reevaluate our respective roles to determine what will be best for the mosquito and vector control members of AMCA. We will have an AMCA workshop in conjunction with the annual meeting in Corpus Christi, Texas, in March and we can begin to deal with this and other issues. The members of the Board of Directors and the committee chairpersons will meet prior to the Sunday board meeting to set goals and establish priorities for the association, much like you did here in California two years ago. I think this will be very useful and will help us move ahead much more quickly in addressing member needs. So "When?" is a good question. When does the AMCA lead and when does it follow?

In looking at the question of "WHERE was/is/will be the AMCA?", I discovered that the initial membership covered many states and Canada. But now our membership includes a large number of people from Asia, Europe, Australia, and elsewhere. Some AMCA members feel that we should consider expanding our boundaries. This matter is one that needs much discussion, but one AMCA committee is currently exploring the possibility of organizing international regional meetings outside the U.S. If the committee determines that it is feasible, they will report back to the Board for further consideration. So, where is the AMCA? -everywhere.

The next question is "WHY was/is/will be the AMCA?" Why was a national association formed? According to Tommy Mulhern in an 1943 *Mosquito News* editorial, the AMCA was formed to give mosquito control workers: "frequent opportunities to get together to study problems of general concern; opportunities to observe new methods and techniques; and to promote unity of thought and action." The AMCA has done that by working with state associations to host annual meetings and by providing publications to meet member needs.

However, we have begun to realize in the last several years that while we did an excellent job of improving *Mosquito News* and elevating it to the status of a very high quality journal for our scientific members, we neglected an important segment of our association. We no longer had a publication where our mechanics and field personnel could publish short notes or observations or share ideas about improvements in equipment. So, we relied once again on a state association to meet that need and worked with the Florida Mosquito Control Association to publish and distribute *Wing Beats*. It is a great new service but we are not receiving many contributions from California. Please share your information with other AMCA members. As Tommy Mulhern said about *Mosquito News* in Vol. 1, No.1 "The success of this medium for exchanging information of value to all of us will depend entirely on the interest, cooperation and contributions from every possible source. If such contributions of material is not forthcoming, your committee will have nothing to print. From now on, we urge you not to wait for a solicitation from the committee to send material. Write up anything that might be of interest to others in the work and send it on to the committee."

There are AMCA committees working on an accreditation program for vector control agencies, on possible corporate memberships, and other matters. I do not have time to cover those areas now, but I will be glad to discuss them with you later if you like.

I attempted to give some historical perspective as I shared some of the AMCA current activities because I wanted for us to be aware of some of the things which have shaped our current circumstances. Understanding the who, what, when, where, and why of a matter is basic to developing a rational policy to meet today's challenges and needs. We are a strong association, but we must continue to work together and communicate effectively and quickly with each other if we are to meet tomorrow's challenges.

Basic of all basics, I think, is communication. Tommy Mulhern knew this when he helped form the AMCA and *Mosquito News*. I was born in 1944 long after Tommy and others began this work, but I get the privilege of helping to continue the work. I am part of the who of the AMCA and I get to play a role in the future what, when, where, and why of the AMCA. The AMCA does not belong to any one of us but I am proud to be a part of it and to get to work with you to continue a noble work.

If you are an AMCA member, continue to communicate with other members and share your information and knowledge. If you are not an AMCA member, we need you. And you need us. Please join with us now as an associate member or a regular member.

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THE FUTURE ROLE OF THE ENVIRONMENTAL MANAGEMENT BRANCH IN VECTOR CONTROL

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Thank you for the opportunity to address you today and to give you my views on the challenge in the title assigned to my presentation. The timing is superb because just about now I begin my final twelve months in the chair first occupied for a few years by Arve Dahl and then for almost three decades by Dick Peters. I will have held the reins for fourteen years when I leave State service early in 1993, having spent from July, 1959 to February, 1979, on various other assignments within the organization. A third of a century is plenty long enough for anyone to work for a single employer.

When looking ahead it is instructive to look back. You may have heard the art of forecasting defined as driving a car, blindfolded, taking directions from someone watching out of the rear window. Nonetheless, looking back at where we were helps us define where we are now. To review the history of the vector surveillance and control program, we turn to presentations made before your Association at its conferences. Arve Dahl at the 16th Annual Conference of the then-CMCA described the genesis of the then-Bureau of Vector Control (or BVC, as a few may remember it) in the then-Department of Public Health (Dahl 1948). It was formed on July 1, 1947, from the Mosquito Control Section and the Sanitary Inspections Section.

The Department's mosquito control activities originated in 1910 by Dr. William B. Herms in his role as consultant on entomology to the Department of Public Health and remained as a function of the Bureau of Sanitary Inspections until 1919 when it was assigned to the Bureau of Sanitary Engineering. The activities were formalized as the Mosquito Control Section in April, 1946 to administer $400,000 of legislatively-provided subvention funds and also to conduct studies and demonstrations, and to perform emergency control in case of mosquitoborne disease outbreaks. The Section was to provide advisory and/or consultation services on mosquito control to the entire state. It was also to conduct training programs for local mosquito control agencies. The Sanitary Inspections Section, the other entity in making up the new BVC, was established in 1916 with primary responsibility in general sanitation. It was assigned plague control following the urban outbreaks in 1919 and 1925 and performed routine plague and tularemia surveillance starting in 1927. It had emergency control responsibilities as well.

A functional chart presented by Dahl (1948) showed that the new BVC planned to: coordinate closely with the Department's epidemiologists and laboratory services; conduct surveys for plague, tularemia, relapsing fever, encephalitis, and several other diseases; perform studies and demonstrations relating to insecticides for vector control, rice field mosquitoes, mosquitoes produced by sewer farms, and rodent and tick investigations; consult with and advise local agencies; take emergency control measures; and conduct training and other informational services. The foresight of those who shaped the program of the BVC is evidenced by the fact that their plans sound fresh even today.

There is a maxim: "The more things change, the more they stay the same". This is especially true when one reads the names of the members of the newly-constituted Vector Control Advisory Committee as reported by Dr. Wilton Halverson, then the Director of Public Health, at that same 16th Annual Conference (Halverson 1948). The list of the members includes Dr. William C. Reeves. Bill is still on the Committee and has served as its Chair for most of the intervening years.

In 1951, four years after the BVC was founded, Dick Peters became Chief, a post he was to hold until his retirement at the end of 1978. In his first address to your Association after his appointment, he stressed that service in its broad sense was the keynote of the program (Peters 1952). That philosophy has prevailed in our relationship to vector control agencies during the entire existence of the organization first known as the Bureau of Vector Control then in succession, the Bureau of Vector Control and Solid Waste Management, the Vector Control Section, the Vector Biology and Control Branch, the Vector Surveillance and Control Branch, and finally (to date!) the Environmental Management Branch (EMB). Our parent organization has changed its name too, from the Department of Public Health to the Department of Health and now to the Department of Health Services. Nonetheless, and no matter by what name the rose is called, "service" has been our watchword.

Those early plans and consistent philosophy are among the internal factors which shaped our program. Let us now look at some of the external aspects, those over which we have had little or no control. There have been several, and all have had a direct or an indirect effect upon our vector surveillance and control activities. In my perception, the greatest impact has resulted from three very different external influences.

The first is waste management. Over the decades, we have become an administrative repository for waste management functions of the Department which do not fit well anywhere else. There was good logic in assigning to us responsibility for developing the State's solid waste management program beginning in the 1950s because flies and rats were major solid waste-related problems. There was less logic in the 1970s for assigning us the hazardous waste program. Both of these major programs became large enough to depart on their own. However, we now have responsibilities for low-level radioactive waste and medical waste (which have nothing whatsoever in common with vector surveillance and control) and wastewater (only peripherally related to mosquito and aquatic gnat prevention). Having these programs in our organization has been both good and bad. On the plus side, it has kept us in existence. On the minus side, administering and conducting these programs takes a great deal of time and effort from staff who could otherwise be doing vector-related work. For instance, about 50% of my own time over the past 5-plus years has been taken up by the low-level radioactive waste management program.

The second influence is shifting governmental roles and responsibilities, generally driven by political action on the part of the Congress, the Legislature, or both. During the 1950s and until the mid-1960s, the State's major mosquito research program was in our organization. Legislative action transferred the program, its staff, and its support to the University of California. I mentioned the waste management programs, which originated from federal laws and from legislative fiat. Other key federal and state actions which have greatly impacted our program were the creation of the U.S. Environmental Protection Agency in the early 1970s, shadowed by formation of the California Environmental Protection Agency in 1991; the passage of the National Environmental Policy Act and the California Environmental Quality Act in the early 1970s; and the 1972 amendments to the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). There have been myriad other congressional and legislative acts dealing with environmental law and control, for instance endangered species and wetlands protection. The result in many cases has been to increase our workload with little or no increase in resources. For example, the vector control technician certification program was necessitated by the 1972 amendments to FIFRA. We set up a program to certify your staff and we did it with no increase in resources. The continuing education program grew out of concerns that federal and state action would force it upon you. We took on that task with only enough support from you to pay for 50% of a clerical position. In the future, reorganization of State government to increase the scope of the California Environmental Protection Agency may bring about some changes in what currently falls under the purview of the Environmental Management Branch. It could conceivably change the administrative location of the entire organization including the vector surveillance and control program.

The third external influence is fiscal constraints. Proposition 13, the initiative passed in 1978, slashed your income by almost 50%, requiring you to reduce staff, mainly technical support personnel. We were just in the process of gearing up to help you meet your staffing shortages when, early in 1979, we were hit by general fund cuts (general funds are other than fee, contract, or similar special money) which resulted in a 44% reduction in staff. We had to not only drop plans to help you but had to eliminate large portions of our vector surveillance and control program. Ironically, during the next few years, you and we worked together to get legislation enacted which has given you funding options but has left us with no increase. In 1989, additional general fund cuts led to the elimination of a sister branch with its remnants being absorbed by the Environmental Management Branch. This again increased our administrative workload. Finally, or at least most recently, in 1991 we sustained further cuts in our general fund support which resulted in an additional 30% loss of engineers, biologists, and associated staff. Coupled with the reduction was loss of continued funding for a budding Lyme disease surveillance and control program which had been funded using redirected general fund money for two years and two years only. It is apparent that generally funded programs are highly vulnerable in today's fiscal climate.

The foregoing provides part of the basis for looking ahead. Thirty-plus years of participating in the program and watching what has gone on in the state, the nation, and the world also have influenced my thinking. Here are several premises:

1. The Environmental Management Branch will continue to serve. We are in our fifth decade of existence because the public, and you who have come into being to meet the public's desires, want our services. If we are no longer needed, we will disappear. On the other hand, you exist in your present form, and you are able to do what you have been able to do to get your work done, in large part because of the close, active teamwork which has existed between your agencies and the State.
2. Local vector control agencies will continue to do a better job of delivering services to the public than does the State. Therefore, the function of the Environmental Management Branch will nearly always be in support of your work rather than in direct service to the citizens of California. We will in the future as in the past advocate, encourage, and aid in forming local vector control agencies commensurate with the public's need and ability to pay for services.
3. You don't yet completely cover the state, and your agencies vary geographically, demographically, and financially in your ability to provide services to the public. For that reason, our role will also vary. The Environmental Management Branch will continue to have a direct-service role absent your presence, limited, however, in most cases to disease-threatening situations.
4. This is the information age. The role of the Environmental Management Branch will be greater in gathering, processing, and disseminating information, less in taking direct action. To be effective, though, we must retain capability to be in the field, to learn and to experience, in order to have real-world information to impart.
5. "We have always done it that way" is not a valid reason for continuing to do something in a particular manner. Change is often traumatic but may be vital to survival. A biological law states that when faced with adversity, an organism must adapt, migrate, or die. The same law applies to an organization, agency or association.
6. Decentralization is a current trend, but there are some activities which by their nature must be centralized. For example, these include processing surveillance and control information which covers ecological not political areas. Centralization could be modified to be regional, not necessarily state-wide. Some centralized functions need not require involvement of or action by the State but could be done by local agency organizations, notably your Association and the California Conference of Directors of Environmental Health.
7. There are regulatory and quasi-regulatory activities which by their nature are outside of the proper scope of individual or organizations of local agencies, such as standard setting and quality assurance. These are appropriate roles for the Environmental Management Branch and its supporting entities within the State. The cooperative agreement relating to pesticide use and the technician certification program are examples, as is biomedical laboratory support of epidemiological services.
8. There are situations in which one level of government, in your case local government, can best be represented before other governmental entities by another level of government. This includes such functions as the general permit issued by the U.S. Army

Corps of Engineers to the State on your behalf, and the public health exemption for using pesticides for vector control in endangered species habitats, also exercised by the State on your behalf.

9. State programs which depend upon the general fund are highly vulnerable to reduction. State programs which are supported by fees, contracts or other such sources of funds are less vulnerable to reduction. The Environmental Management Branch is actively seeking funding for some activities, such as plague and Lyme disease surveillance and control in recreational areas. There is another maxim which is likely to apply: "He who pays the piper calls the tune". The obvious danger to you is that our staff may not be available to provide to you the services you desire if staff time is taken up in doing contract work for others.

As to the future of the Environmental Management Branch in vector control, given the considerations I have outlined, we will work with you and with other organizations interested in the same question but we cannot completely determine our own fate. You and we together must address some key issues:

1. What are the things that must be done to protect the people of California form attack by vectors and the diseases they transmit? Only after the "must do" needs have been addressed will it become possible to move to the "should do" and "nice to do".
2. Of those things that must be done, what can you do as individual local agencies, what can you do as a state-wide organization or as regional entities, and what cannot you do by and for yourselves?
3. Of those things that you cannot do, what is appropriate for the Environmental Management Branch and its supporting entities within the State to do for you?
4. How can the State's activities be funded? Assistance in obtaining adequate financial support for the Environmental Management Branch must come from the outside. We cannot push a dead bear up a tree.

You asked me to address you today on the future role of the Environmental Management Branch in vector control. I leave you with this question, and charge you to ponder it carefully, for its answer may affect how you do business for many years to come: What is the future role of the Environmental Management Branch in vector control?

References.

Dahl, A.H. 1948. Objectives and scope of the new Bureau of Vector Control. Proc. Calif. Mosq. Control Assoc. 16:8-11.

Halverson, W.L. 1948. California mosquito control strides during 1947; the outlook for 1948. Proc. Calif. Mosq. Control Assoc. 16:2-3.

Peters, R.F. 1952. The scope of California mosquito control. Proc. Calif. Mosq. Control Assoc. 20:7-11.

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PESTICIDE REGULATIONS, THE E.P.A., AND MOSQUITO CONTROL

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Pesticide regulations were initially developed out of concern for the efficacy of products sold to end users, mainly farmers, with little or no concern for a pesticide's possible adverse effects on human health or the environment.

With the advent of DDT in the early 1940s and particularly after WWII when new, generally more toxic, chemical pesticides were developed, it was recognized that these compounds posed a threat to non-target species. While the need for more stringent controls was apparent, it was not until the 1970s that the focus of pesticide registration shifted from a pesticide's possible lack of efficacy to its potential for causing harmful effects to non-target species, human health and the environment.

While the first federal law, "The Federal Insecticide Act of 1910", was enacted early in this century, several states, including California, had already passed laws covering insecticides. These laws were, for the most part, established simply to protect consumers from adulterated products. The recognition of dangers posed to non-target species resulted in the first Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) being enacted in 1947. The United Stated Department of Agriculture (USDA) was initially responsible for administering the Act, but that responsibility was transferred to the United States Environmental Protection Agency (EPA) when it was created in 1970.

FIFRA has been amended several times over the years. Those amendments of 1972, 1975, 1978, 1980, and most recently 1988 are of particular importance to user groups such as those involved in mosquito/vector control. In general, these amendments have provided for stricter control over the uses of pesticides, created a more equitable Special Review process (originally the Rebuttable Presumption Against Registration (RPAR) process), established waiver authority under which the Administrator may set aside data requirements pertaining to efficacy, and allowed greater leeway for the Agency to carry out it's responsibilities.

The basis for pesticide regulations have thus evolved from concerns for product efficacy to the present situation in which environmental and human health factors have become the dominant critical issues. Concerns for the efficacy of pesticide products have greatly diminished. In fact, the waiver authority established by the 1978 amendments to FIFRA were implemented in 1979 for most public health pesticides including mosquito pesticides and that provision is still in place today.

Other relevant changes which have and are now occurring include the reorganization of the EPA Office of Pesticide Programs (OPP), increasing concerns for endangered species and wetlands conservation, and a recognition of the importance of managing pest resistance problems on an international basis.

The OPP reorganization of a few years ago created seven Divisions (from the original four) within the Office and has resulted in an increased emphasis on registration restrictions and on the ecological effects of pesticides in the environment. There was also a name change for the "Benefits and Use Division" to "Biological and Economic Analysis Division" with, what some fear, a diminution of the benefits aspects of the risk/benefits equation. As expected, there has also been an increase in the number of pesticides placed in Special Review.

With the new fee structure mandated in the 1988 amendments to FIFRA, many products that had languished in registration at no cost to registrants, were quickly removed from registration. Many of these products were no longer used or even produced and their loss is of no consequence. Other minor use products are important to users and their loss has created problems.

Before my retirement from the EPA and while working closely with the American Mosquito Control Association's (AMCA) Environmental

Committee, plans were developed assuring that public health concerns will take precedence over endangered species concerns if an occasion arises in which there is direct conflict between the two mandates. That provision remains in the EPA's Endangered Species Protection Program plan.

The Agency is presently sponsoring a major international program on management of pest resistance problems. The program, while concerned primarily with agricultural situations, includes public health pest resistance problems too.

In summary, it is clear that environmental issues have become the dominant factor in action concerning pesticides used for public health and other pest management activities. There is a strong shift toward use of cultural and biological control measures to reduce dependency on the so-called "hard pesticides". The Environmental Protection Agency has always been an advocate of such Integrated Pest Management (IPM) methods and actively supports this change toward the use of measures which are more compatible with environmental protection goals.

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THE ROLE OF INSECTICIDES IN PUBLIC HEALTH VECTOR CONTROL IN CHINA

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There are four groups of pests which are considered as Important Public Health Vectors (IPHV) in China: mosquitoes, houseflies, cockroaches, and rodents. The following goals are emphasized to control these four groups: 1) to maintain populations of IPHV at low levels in cities and towns, 2) to decrease IPHV annoyance activity to humans, 3) to prevent transmission of diseases by vectors.

The policies and techniques for control are:

1. To eliminate vector breeding places, environmental modification is organized by governmental agencies when appropriate.
2. To deal with emergency situations, campaigns on the eradication of vectors are carried out by the Office of National Public Health Committee during vector outbreaks.
3. To manage vector populations as much as possible, with mass population sectors participating in the process of vector control.

Organizations of IPHV Control in China.

The Office of National Public Health Committee in the Ministry of Public Health is in charge of national programs on IPHV control. Its responsibilities are: to formulate national policy and regulation of IPHV control; to monitor, evaluate, and review effects of control programs; to stimulate and plan research dealing with IPHV; and to provide grants to universities, institutes, and other research organizations.

The Technical Advisory Group of Direction, which is a consulting group in the Office of National Public Health Committee, is composed of professors and experts in insect control from universities and institutes of academia, Chinese Academy of Medical Sciences, and the Chinese Academy of Preventative Medicine. This advisory group regularly provides scientific and rationalized suggestions and advice to the Office of National Public Health Committee based on the present problems of IPHV and related diseases in China.

Local Offices of Public Health Committees, which are part of provincial and county governments, organize vector control programs and campaigns to eradicate vectors in local areas. Pest Control Stations, under the leadership of the Local Offices of Public Health Committees, carry out specific and local vector control programs (Fig. 1).

Control Methods.

There are about 400 species of mosquitoes in China. Nine of them are of medical importance (Table 1) and have been the subject of mosquito control in China for over 40 years (Lu 1984). Even though diseases vectored by these mosquitoes are periodically problematic, the more important aspect is their annoyance to people.

Mosquito control by environmental management, biological control, and chemical control are the main methods used in China. Due to lack of time and space, only chemical control of mosquitoes will be discussed here. In chemical control, the commonly employed methods used in China are residual sprays, space sprays, larval control in mosquito breeding places, and pyrethroid-impregnated bednets.

<u>Residual Sprays</u>: For many years residual sprays have been used for the control of adult *Anopheles* mosquitoes in attempts at lowering the incidence of malaria. In the 1950s, DDT was used

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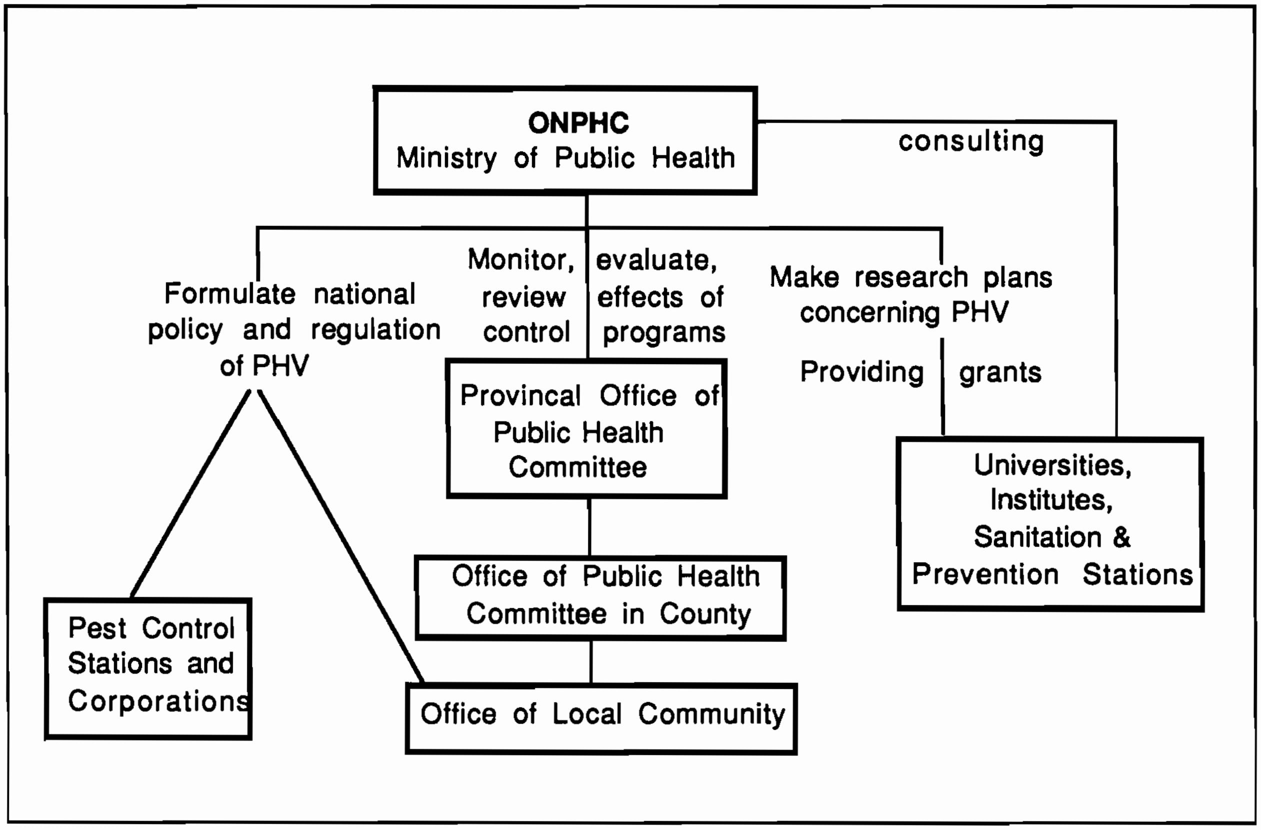

Figure 1. The function and organization of the Office of National Public Health Committee (ONPHC) in the Ministry of Public Health for China.

Table 1. Distribution of and disease(s) carried by the major vector mosquito species of China.

Species	Distribution	Disease(s) vectored
Anopheles sinensis	All China	Malaria
Anopheles anthropophagus	All China	Malaria, Filariasis
Anopheles dirus	Hainan Province	Malaria
Anopheles minimus	Hainan, Yunnan, Guangdong, Guangxi Provinces	Malaria
Culex tritaeniorhynchus	All China	Japanese B encephalitis
Culex pipiens pallens	All China	Japanese B encephalitis, Filariasis
Culex pipiens quinquefasciatus	All China	Japanese B encephalitis, Filariasis
Aedes albopictus	All China	Japanese B encephalitis, Dengue fever
Aedes aegypti	Hainan, Guangxi Provinces	Dengue fever

to control mosquitoes in large-scale programs (Lu and Zhu 1983), but was not effective against *Anopheles sinensis* Wiedemann, which is primarily exophilic (Lu and Zhu 1983). However, during 1955-1958 residual sprays were used on the island of Hainan to successfully control *Anopheles minimus* Theobald. Indoor residual sprays carried out for 3-4 years with BHC (0.2-0.5 grams/m^2), resulted in the almost complete disappearance of *An. minimus* on this island and an overall reduction in malaria transmission (Gao et al. 1958). But this method had no noticeable effects on *Anopheles dirus* Peyton and Harrison populations (another major vector mosquito on the island), because it, too, is exophilic.

Another species, *Anopheles anthropophagus* Xu and Feng, which is a vector of malaria as well as Brugian filariasis, is the dominant species in the southern part of the Yantzi River. This species is susceptible to chemicals, so residual sprays applied 1-2 times per year can successfully control them. Entomologists from the Shanghai Institute of Entomology and Institute of Parasitology have researched this problem for many years in the Zhejiang and Sichuan Provinces.

DDT-resistant mosquitoes were widely found throughout China after using DDT for a number of years (Liu 1979), so DDT residual sprays no longer constitutes the method of choice for control of IPHV in China.

Since 1984, indoor residual sprays with deltamethrin (15 mg/m^2) have been performed in many cities and towns with good results. In addition, space sprays are occasionally used in emergency situations.

Pyrethroid-Impregnated Bednets: Since 1984, bednets impregnated with pyrethroids have been extensively used in China based on World Health Organization's (WHO's) recommendations. The nets have toxic and excito-repellent effects when contacted by mosquitoes. At present, at least five million pyrethroid-impregnated bednets have been used annually in eight provinces with no toxic side effects on humans (Lu 1988). The local residents receive pyrethroid-impregnated bednets enthusiastically because it is a safe, simple, cheap, and effective mosquito control method (Li 1988). In some areas, indoor spraying was replaced with pyrethroid-impregnated bednets as the primary control method. The most common pyrethroid presently used to impregnate bednets is deltamethrin.

A. Deltamethrin-Impregnated Bednets: The utilization of bednets impregnated with deltamethrin (9-25 mg/m^2) is widespread and used to control *An. sinensis, An. dirus* and *An. anthropophagus* in antimalarial programs throughout China (Lu 1991). In 1988, more than 2.25 million deltamethrin-impregnated bednets were used in Sichuan Province. The incidence of malaria in the treated area declined by 50% as compared to the control area. The effect was much greater than that observed with DDT residual sprays (Lu 1991). In Sichuan, Guangdong, Hainan, Guangxi, and Yunnan Provinces, bednets impregnated once with deltamethrin protected residents from biting mosquitoes for more than two months.

Impregnated bednets were effective against *An. dirus*, a major malaria vector in local areas, after the method was extensively employed in Hainan Province, even though *An. dirus* is an exophilic species. For example, deltamethrin-impregnated bednets were employed in the area of Shanganlo (population of 6,407), Hainan Province, during 1986-1987 (Li and Lu 1988). The malaria incidence after treatment and use of the bednets was significantly lower than before treatment (Fig. 2). It is now also proven that this method is efficacious for the control of *Culex pipiens pallens* Coquillett and *Culex pipiens quinquefasciatus* Say.

It is generally thought that the reduction of the incidence of malaria in China since 1988 has been attributable to the successful distribution and use of impregnated bednets.

Recently, deltamethrin-resistant strains of *An. sinensis* have been discovered in Sichuan and Zhejiang Provinces where deltamethrin has been widely used as both residual sprays and for impregnating bednets for a nuber of years. With high dosages of deltamethrin, the knock-down speed of the resistant strains was twice as slow as that of the sensitive strains. This emergence of resistance will affect the future use of deltamethrin.

B. Permethrin-Impregnated Bednets: Permethrin was found to have the same results as deltamethrin through field experiments in Jangsu Province by the Technical Coordinating Groups. Another field survey on the effects of permethrin-impregnated bednets was done in Hainan Province by the Guangdong Provincial Sanitation and Prevention Station. Satisfactory results have been obtained, but at a cost four times higher than that of deltamethrin (Li and Lu 1988).

C. Alphacypermethrin-Impregnated Bednets: At present, the experiments on bednets impregnated

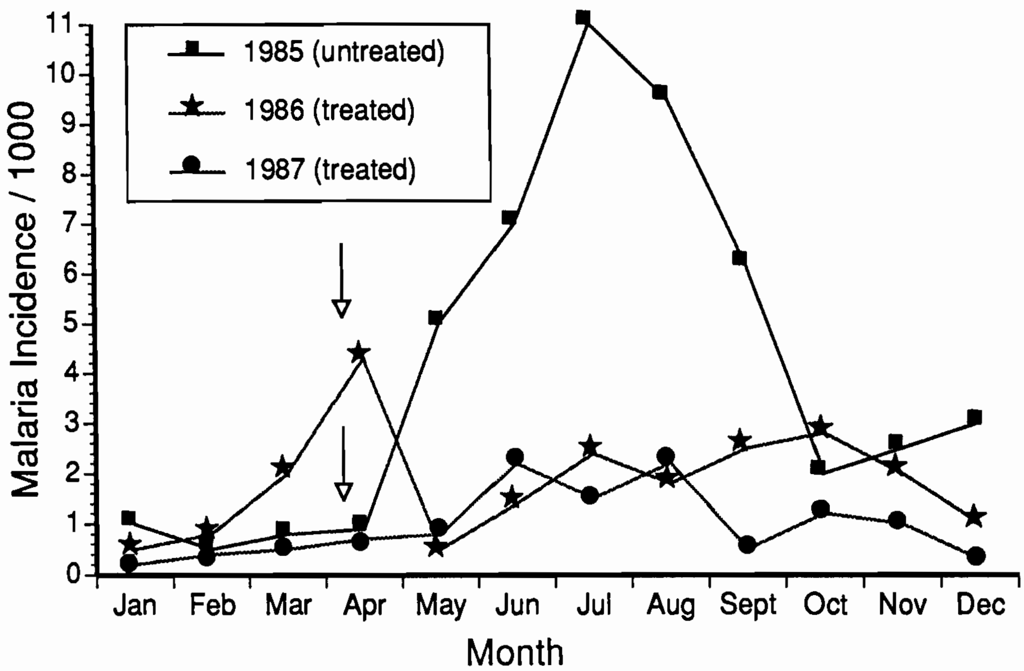

Figure 2. Malaria incidence using deltamethrin-treated bednets in Sanganlo, Hainan Province, China.

with alphacypermethrin are being conducted in the laboratory, as well as the field, against previously mentioned *Anopheles* and *Culex* species. The results show that it is less effective than deltamethrin at the same dosages (Lu 1991). However, it is probable that formulation technology might increase its efficacy.

Larval Control: Rice fields are the major breeding places for *An. sinensis* and *Culex tritaeniorhynchus* Giles, the former is the major vector of malaria and the latter, a vector of Japanese B encephalitis in China. The breeding places are too vast to treat with larvacides, so biological control methods such as wet irrigation and fish planting are adopted in controlling larvae in more than 10 million Mu (about 1.5 million acres) of rice fields.

Culex pipiens breed in sluggish and stagnant parts of streams and canals. This mosquito is controlled by the ditching and dredging of the canals and removal of weeds. Stagnant water mosquitoes are sometimes still controlled with common insecticides such as dipterex and dichlorvos, much as they have been for over 40 years, although resistance has been found at different levels in almost 70% of the cities and towns in China (Liu 1979).

A national surveillance network of resistance and coordination of groups involved in resistance research have been organized to monitor the distribution of resistance and to determine the cause. It was found that resistance to insecticides in some big cities, such as Shanghai, Nanjing, Fuzhow, and Guangzhow, is higher than throughout the rest of the nation. In these situations, *Bti* (*Bacillus thuringiensis* var. *israelensis*) and *Bs* (*Bacillus sphaericus*) are used instead of conventional chemical larvacides. At the end of the 1980s, the production of *Bti* was up to 150 tons per year in China. The application of *Bti* and *Bs* showed that they delayed the development of resistance to other larvacides. Recently, in Hainan Province, the Brateau index of mosquitoes was reduced to 3% from 80.4% in treated fields after application with 10-20 ppm of *Bti* (130-180 ITU/mg) against *Aedes aegypti* (Linnaeus) once every ten days during July and August.

Conclusions.

In the past 40 years, there have been three successful activities in the control of mosquitoes in China: 1) the disappearance of *An. minimus* by residual sprays on the island of Hainan in the 1950s; 2) the adoption and implementation of biological control practices using *Bti* and *Bs* instead of organophosphorus insecticides greatly reduced the development of resistance in the 1980s; and 3) the use of pyrethroid-impregnated bednets decreased population densities of *An. dirus* and *An. sinensis*.

These mosquito control activities have reduced the populations of several species of *Anopheles* to such an extent that incidence of malaria in program areas is decreasing. Development and application of *Bti* and *Bs* have further helped to surmount the difficulties in controlling *Culex pipiens*.

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References.

Gao, J.-Z., B.-A. Zhang, P.-L. Luh and C.-Y. Liu. 1958. The effect of residual sprays of wettable BHC and DDT against *An. sinensis, An. jeyporiensis candidensis*, and *An. minimus*. I. Toxic action. Selected Papers Nat. Congress Parasit. (in Chinese) pp. 329-339.

Li. Z.-Z. and B.-L. Lu. 1988. Application of pyrethroid-treated mosquito nets in anti-malarial program in China. China J. Control Med. Animals (in Chinese) 5(2):105-108.

Liu, W.-D. 1979. The survey of resistance of mosquitoes in China. Scientific Press, Beijing (in Chinese) pp. 114-118.

Lu, B.-L. 1984. The integrated control of mosquitoes. Scientific Press, Beijing (in Chinese).

Lu, B.-L. 1988. Mosquito nets impregnated with deltamethrin against malaria in China. Res. Med. Data in Guangdong (in Chinese) pp. 42-48.

Lu, B.-L. 1991. Bednets treated with pyrethroids for malaria control. *In*: Target, C. (ed.), Malaria-Waiting for the Vaccine. Wiley and Sons, Ltd., England (in press).

Lu, B.-L. and C.-P. Zhu. 1983. Mosquito control in the People's Republic of China. *In*: Laird, M. and Miles (eds.), Integrated Mosquito Control Methodologies. Volume I. Academic Press, Inc., N.Y. pp. 85-103.

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PARADIGMS OF THE MOSQUITO CONTROL COMMUNITY OF CALIFORNIA: PAST AND PRESENT

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Introduction.

Mosquito control agencies of California have conducted remarkably successful environmental health programs, protecting the public from vector-borne disease and pest mosquitoes for over eighty years. Today, in the midst of the "environmental era", many feel these agencies are facing their most serious challenge. The challenge, simply stated, is to bring the activities of mosquito control into balance with the natural systems. The task is our share of the larger task of bringing our whole socio-economic system into balance with natural systems.

Nowhere is the challenge to the mosquito control community of California (MCCC) greater than in meeting public demand to restore, enhance, and manage wetlands. Since in state and federal law the responsibility for the regulation and management of the environment has been fragmented into parts and distributed to a number of public agencies, all agencies are required to work effectively together to steward these complex environmental systems.

Fritjof Capra (1982) speaks to the issue of fragmentation in his book "The Turning Point" and in the 1991 movie "Mindwalk" which was based upon his book. He finds the mechanistic world view of Cartesian-Newtonian science inadequate. He feels we live in a globally interconnected world needing a new holistic perspective, a new vision of reality. Capra believes we are facing a crisis of perception.

Daniel Botkin, Professor of Biology and Environmental Studies at the University of California at Santa Barbara, offers a similar message. He believes that, more than any other factor, the major challenge in interpreting nature and dealing with the environmental issues is recognizing and confronting our deep seated assumptions about nature. Botkin (1990) believes that before we reach a point where our role in the environment is positive we will have settled upon a new set of metaphors, images, and symbols of nature.

The purpose of this paper is to explore our perceptions of reality and nature in the MCCC. This, I believe, is slippery business and I expect my efforts to be of more value as a force to stimulate reflection rather than a presentation of facts. I concur with the above authors, however, in believing that the process is an essential first step in meeting the environmental challenges facing the MCCC.

Mental Models.

Why are metaphors, images, and symbols of primary importance? First and foremost, because they influence what we see and do. They shape the development and provide a frame for a complex cognitive structure that has only in the past few decades become recognized and studied. The structure has been alluded to by various investigators as "assimilatory schemata" (Piaget 1954), "image" (Boulding 1961), "tacit infrastructure" (Bohm and Peat 1987), "theory-in-use" (Argyris et al. 1985), and "mental models" (Senge 1990). There has been a wealth of knowledge developed about these highly abstract cognitive structures which shall be referred to in this paper as mental models. Following is a compilation of some of that knowledge provided by the above cited authors:

1. Mental models begin developing at birth and continue to serve the individual throughout life by interpreting the world and influencing behavior.
2. Mental models are deeply ingrained assumptions, generalizations, even images that influence how we understand the world. They take a subliminal and unconscious form as

time passes (habitualization).

3. When a message reaches a mental model, three things may happen: the message may be ignored; the message may change in a well defined way; or it may be changed in a revolutionary way as in a religious conversion.
4. Mental models determine what see and therefore what we do. Perhaps more importantly, they also determine what we do not see.
5. There is a powerful natural tendency for individuals to resist changing their mental models. In fact, individuals develop elaborate "defensive routines" designed specifically to defend them. The resistance to change can be a severe impediment to learning that affects individuals and their organizations.
6. Mental models are not reality and therefore fall short of completely describing reality. In the vernacular: "mental models are maps not the territory". Yet, we tend to confuse the map with the territory.
7. Techniques have been developed to manage mental models by conversing in a manner which balances inquiry and advocacy, where people expose their thinking to make it open to the influence of others.

The crisis of perception can be fully appreciated in light of our knowledge of mental models. The metaphors, images, and symbols of nature that are communicated in the MCCC influence our individual mental models. They, in turn, influence what we see and do. Learning about the dynamics of mental models, and reflecting on our individual mental models, can help us to improve them as necessary to establish a solid foundation for judicious and effective environmental action by the MCCC.

The Kuhnian Paradigm.

Exploring the mental models of the mosquito control community of California could be a most slippery endeavor were it not for the historic work done by Thomas Kuhn. In his seminal work "The Structure of Scientific Revolutions", Kuhn (1962) introduced the concept of a scientific "paradigm". It is a premise of his paper that paradigms operate in a scientific community to generate and reinforce the metaphors, images, and symbols of a scientific community and that paradigms are instrumental in shaping mental models. Therefore, by identifying and examining the paradigms of the MCCC, we can learn about the quality of prevailing images of nature being communicated in our community, and can also gain insight into the structure of mental models.

A paradigm was defined in a variety of ways in Kuhn's work. In this paper it is distilled to: "... universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (Gutting 1980) creating "... an entire constellation of beliefs, values, and techniques that bind the community together" (Horgan 1991). Upon close examination of Kuhn's work (1970), a paradigm can be seen to have a life-cycle of five stages:

STAGE ONE (Discovery Phase): The discovery phase starts with an "archetypical experiment", or by new models of law, theory, application, or scientific achievements that become the basis for further practice (Kuhn 1970). The achievement usually focuses on critical problems (anomalies) that cannot be solved by the old paradigm.

STAGE TWO (Demonstration Phase): During this stage scientists who are privy to the archetypical experiment enlist converts by lectures, publications, or applied demonstrations. Adherents to the old paradigm tend to resist the new approach even though the new paradigm solves problems that have led the old paradigm to crisis.

STAGE THREE (Paradigm Shift): The shift has occurred when a preponderance of scientists shift professional allegiances to the new paradigm. Scientists then re-interpret and give new meaning to the same pool of data they saw prior to the paradigm shift. Some, however, remain unconverted, cling to the old paradigm, and are assigned to a form of scientific oblivion.

STAGE FOUR (Productive Phase): High productivity is attained by way of "normal science". Debate subsides, efficiency and effectiveness increase, and the vexing problems of the previous paradigm are solved. Paradigmatically-induced blindness prevails. When anomalies are detected, scientists attempt only to modify their theory or practices.

STAGE FIVE (Crisis Stage): The crisis stage occurs when anomalies have accumulated to the level that they can no longer be ignored.

"Extra-ordinary science" is now allowed to create novel solutions outside paradigmatic boundaries. Scientists, usually young and ignoring the prevailing paradigm, focus on anomalies. The result is a proliferation of competing, non-traditional, approaches and new discoveries. Incommensurability prevails as different scientists describe and interpret the same phenomena in different ways.

The Paradigms of Mosquito Control.

Search for Paradigms: The written proceedings of the California Mosquito and Vector Control Association provide a rich history of mosquito control in California. Its pages have served to communicate vital information to vector control personnel in California since 1930. Not surprisingly, the proceedings also contain the story of the rise and fall of the paradigms of the MCCC. Analysis of the proceedings revealed that two successive paradigms have emerged to dominance during the history of mosquito control in California. Both paradigms were found to have passed through the five previously defined stages. Interestingly, it appears that the MCCC is currently in a prolonged crisis stage of the second paradigm, with four incipient paradigms vying for dominance (Fig. 1).

The Permanent Mosquito Control Paradigm: The first paradigm of MCCC might be called permanent mosquito control. Its origins can be traced to the discovery made by Ross in 1898 that malaria was caused by a particular genus of mosquitoes (Jones 1931). Malcolm Watson, a British scientist, along with others in many parts of the world, developed a "species sanitation" approach where a selective attack would be aimed at the species of mosquito that was known to be transmitting malaria (Gray and Fontaine 1957). The development of a species-specific malaria control program, based upon the discovery by Ross, was the compelling "tricky idea" or first stage of the permanent control paradigm.

The second stage of the permanent control paradigm, the demonstration phase, was conducted primarily by William Herms, a medical entomologist at the University of California. He implemented a remarkably successful demonstration of permanent control measures in Penryn, California in 1910. The project effectively broke the malaria cycle, eradicating it from the area by 1912 (Gray and Fontaine 1957). The essence of permanent control approach can be summarized as: "To the greatest extent possible the places where mosquito control larvae were found should be eliminated by either

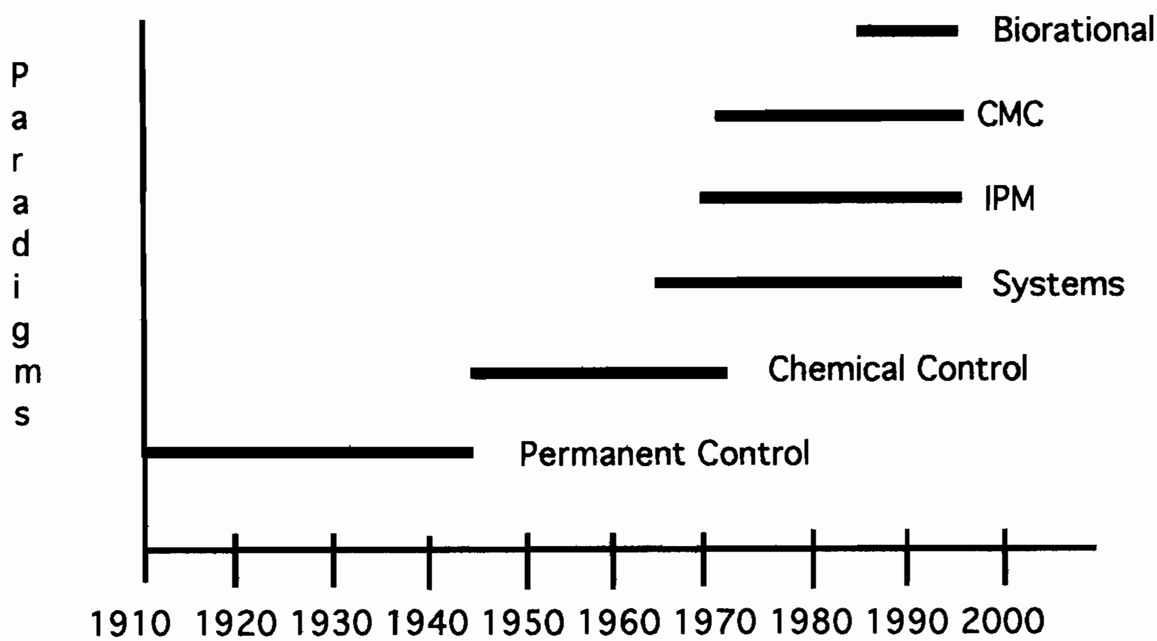

Figure 1. Prevalence of paradigms in the mosquito control community of California (MCCC) over the last 80 years. (IPM =integrated mosquito control, CMC =comprehensive mosquito control).

drainage or filling, to minimize the need for repetitive applications of oil as a larvicide" (Gray and Fontaine 1957). The demonstration phase of the paradigm continued after the Penryn Campaign when Professor Herms traveled the length of the Central Valley spreading the word on how malaria control could be accomplished (Gray and Fontaine 1957).

Perhaps the first evidence of stage three, the paradigm shift, was passage of the Mosquito Abatement Act in 1915. It institutionalized the permanent control approach by providing agencies with the authority to eliminate larval breeding sites. In order for there to have been a typical Kuhnian paradigm shift, however, there had to be a paradigm to be replaced. A scientific paradigm did not really exist at that time, although the public at large held the empirically derived idea that malaria was caused by the "bad air", or miasmas, that emerged from the swamps (Jones 1931). In the face of such tenuous theory, Ross' discovery and Herms' demonstration at Penryn, found fertile ground.

Stage Four of the permanent control paradigm, the productive phase, is very evident in the literature. After the Mosquito Abatement Act had passed, increasing numbers of agencies were formed to accomplish mosquito control. By 1945 there were 24 mosquito control agencies in California, all practicing their particular version of permanent control. Kuhn calls this period "puzzle-solving" and much of the literature from 1930-1937 demonstrated solutions to practical problems that had been encountered. During that period, there was a fairly even balance between papers presented on larviciding and those on drainage techniques.

The final, or crisis stage, of the paradigm began to appear in the later half of the 1930s as anomalies increased. In 1937, the proceedings listed "particular handicaps to work" that were experienced by the 23 mosquito control agencies in California. The agencies experienced: invasions of mosquitoes from outside the boundaries of the control agency (8 agencies), lack of funding (6 agencies) and lack of cooperation from land owners in their water management (8 agencies). Even more serious problems appeared in 1938 when there was a decided increase in malaria cases to 368, the greatest number in over twenty years (Dommes 1939). Another serious assault upon the paradigm came in 1941 when researchers found that some viral encephalitides were transmitted by mosquitoes, and that there were hundreds of previously undiagnosed human cases of mosquito-borne encephalitis in the Central Valley of California (Howitt 1941). A paradigm that had proven itself by painstaking, longterm efforts aimed at elimination of mosquito sources was now faced with the need to provide instant success.

The crisis stage of permanent control had been reached, providing fertile ground for a new paradigm. The discovery, or archetypical experiment of a new paradigm was provided by a new "miracle" insecticide that was developed and used during World War II. Its introduction was destined to have enormous benefits as well as incalculable liabilities for man and nature throughout the world. In California, it was the perfect tonic to cure the anomalies of permanent control. Ironically, it was William Herms, pioneer of the permanent control paradigm, that presented the first paper in the proceedings on the use of DDT as a mosquito larvicide. He had tested DDT against mosquito larvae with great success in 1943 and presented his findings in 1946 (Herms 1946). Stage one of a new paradigm had been launched.

<u>The Chemical Control Paradigm</u>: Shortly after Professor Herms' announcement, his colleague, Harold Gray, another pioneer of permanent control, presented a paper on the successful use of DDT (Gray 1946). In fact, the proceedings of 1946 contained an unprecedented 12 articles on DDT ranging from its use in mosquito control to potential public health and environmental hazards. The second, or demonstration stage, of the chemical control paradigm had begun, and the MCCC was poised for a paradigm shift: the permanent control paradigm was in crisis; a competing paradigm was in its early stages; and a great number of new, unindoctrinated professionals were entering the MCCC.

The increase in the unindoctrinated can be traced to state subvention funds made available to mosquito abatement districts (Dahl 1946). Spurred by subvention funding, the number of districts would climb from 24 to 44 in the space of a few years. Those agencies receiving state subvention funds were compelled to employ professionally trained and experienced men (Dahl 1946). The State's large pool of "unconverted" professionals provided fertile ground from 1946 to 1950 for the paradigm shift from permanent to chemical control.

Surprisingly, and in seeming violation of Kuhnian principles, the proponents of the shift were the aging pioneers of the previous paradigm, Herms and Gray. Where was the rigidity and resistance to paradigm change that Kuhn suggests (Kuhn 1970). Where, as Kuhn would have us believe, are the young, new, and unindoctrinated proposers of the new paradigm that are expected to stand on the shoulders of the giants of the field, bashing them over the head (Horgan 1991). The answer to the puzzle lies in the permanent control paradigm itself, which proposes draining and filling of mosquito sources to the greatest extent possible to minimize larviciding. Herms and Gray must have felt they were only adding another, more powerful, larviciding tool to their permanent control armamentarium when they proposed DDT. To the sea of unconverted, however, a different perspective was yet to be fashioned by the use of DDT in the field. The remarkable field successes in the early days of DDT became a most powerful indoctrination into the chemical control paradigm for those young, and often inexperienced, professionals. The shift to chemical control occurred quite rapidly. The proceedings in the years 1948 and 1949 were dominated by presentations on the successful use of DDT in various circumstances.

The productive phase (stage four) of the chemical control paradigm had been reached. Meanwhile, the permanent mosquito control paradigm continued to function. The fact that it did not disappear immediately is wholly consistent with the Kuhnian view which suggests that it would only completely disappear when the last hold-outs die (Kuhn 1970). The permanent control paradigm, however, had more than stubborn adherents. It had been institutionalized in law (the Mosquito Abatement Act), institutionalized in the policy of the State Health Department (Dahl 1946), prescribed in text (Herms and Gray 1940), and etched in the minds of the proponents who still held powerful positions in the State and the University. Their presence and advocacy continued to be felt throughout the life of the chemical control paradigm. This period of time, roughly from 1946 to 1960, was characterized by "incommensurability" between the adherents of the two paradigms. Gray epitomizes the resultant conflict best in his lecture of 1953:

> "I stated (in 1949)...over the past forty or more years, both experience and logic have indicated that the basic function of mosquito control is to eliminate or minimize the production of mosquitoes . . . The introduction of new insecticides of greater toxicity has not changed this basic postulate . . . Well, what happened? Nothing! You were all bemused in the phantasmagoria of DDT - wonderful stuff!"

The appearance of an anomaly in the chemical control paradigm began in 1952 with the advent of resistance to DDT in mosquitoes (Gjullin and Peters 1952, March 1952). The resistance problem spread rapidly as did the solution to the problem, the substitution of a new insecticide.

The productive phase of the chemical control paradigm was sustained by simply using a new chemical on the resistant mosquitoes. The chemical control records of the period illustrate the seductiveness of the paradigm, showing a continuing increase in chemical use until it peaked in 1958 to begin a slow and gradual decline (Eldridge 1988). By 1966, however, it had become apparent that the rate of production of new insecticides was falling behind the rate at which resistance was being developed. The crisis stage of the chemical control paradigm had been reached. Later in 1972, Dr. Charles Schaefer said it clearly:

> "No new compounds are currently under commercial development that would be effective in controlling our highly resistant strains. This means MADs cannot expect to have any new larvicides available for a minimum of several years."

Dr. Schaefer's speech marked the end of the predominance of the chemical control paradigm that, for the most part, had provided effective mosquito control in California since World War II. The crisis was not caused by pesticide resistance alone. Other anomalies included secondary pest outbreaks (Dahlsten et al. 1969), killing of non-target species (Lusk 1971), water contamination problems (Bissel 1988), and human safety considerations (West 1964). Without doubt, however, the recurring phenomena of resistance was the major factor to bring down the chemical control paradigm. In 1966, the tone of the annual meeting of the California Mosquito Control Association was one of novelty. The shift from normal science to extra-ordinary science was evident in the presentations that year as a variety of competing paradigms emerged. Permanent control measures were being discussed anew (Reginato and Meyers 1966). New ideas in genetic (McClelland 1966) and biological control (Hokama and Washino 1966) were being offered as solutions. The keynote speaker at the conference envisioned a new and promising era for the MCCC brought about by a the use of the rapidly developing "systems approach" (Stead 1966). The 1966 conference was a watershed. The seeds of new paradigms had been planted.

The Current Paradigms of Mosquito Control - Paradigm Wars.

Analysis of the proceedings of the California Mosquito and Vector Control Association revealed the absence of a dominant paradigm from the mid-1960s to the present. Instead, it suggested that at least four paradigms are currently in active competition, none having been accepted by a clear majority of the MCCC. The four competing paradigms are comprehensive mosquito control, the systems approach, integrated mosquito control, and bio-rational control (Table 1). What follows is an examination of the four paradigms with particular emphasis on identifying the metaphors, images and symbols that are evident in each paradigm to represent nature.

Comprehensive Mosquito Control: Comprehensive mosquito control (CMC) is a candidate paradigm formally presented to the MCCC in numerous presentations (Kimball 1973; Mulhern 1971, 1973, 1980). It is defined as:

> ". . . applying all of the available technology of naturalistic control, prevention or source reduction and, chemical control, each in appropriate situations. "

The roots of comprehensive mosquito control can be traced to the old permanent control paradigm. Both paradigms feature engineering-entomological approaches focusing on modifications of aquatic sources. The primary proponent of CMC, Thomas Mulhern, declared in 1973, that the "era of comprehensive control had already begun but it is only in the transition stage". In that year, Mulhern and other staff of the California State Health Department's Bureau of Vector Control created a training manual for the mosquito control agencies of California (Mulhern 1980). The manual institutionalized the paradigm and made it required reading for personnel wishing to be certified to conduct mosquito control in California. CMC had a powerful mechanism by which to gather its fold. The fact that comprehensive mosquito control has not become the dominant paradigm may be traced to the fact that the paradigm is largely a collection of rules and guidelines that have been derived from historically successful approaches to mosquito control (Mulhern 1973). The knowledge generated by the paradigm is a body of un-connected, yet practical techniques which have been collected by practitioners who may be guided by other paradigms. The bottom-up, ad hoc approach provided by CMC may be highly practical in some circumstances, but it fails to provide the practitioner any explicit theoretical framework with which to guide his activities. When facing new or novel circumstances, he is limited to searching for descriptions of successful approaches that most closely match those he faces. The paradigm is effective when the methods developed are applied to relatively simple mosquito sources. In complex systems, however, such as wetlands, there is significant ecological variation from region to region as well as different defined purposes for the wetlands. The paradigm fails here in that there is not one success model for wetlands that provides a set of specific rules for mosquito control.

The influence of engineering on CMC suggests that the machine metaphor of nature may be lurking at its core. For the most part, however, this paradigm seems devoid of powerful symbols. The strength of this paradigm has been based upon continuous updating of the body of knowledge of practical applications of mosquito control. In fact, since the State of California appears unlikely to upgrade the training manual in the near future, and since there are currently no outspoken proponents for this paradigm, it seems highly unlikely that the paradigm can be responsive to the changing needs of the MCCC.

Systems Paradigm: Frank Stead (1966) formally introduced the systems paradigm to the mosquito control community at their conference in 1966, calling it the "Systems Analysis Era". He characterized the approach as encompassing the totality of a problem by drawing boundaries which would capture:

> "All the effects of these acts, all of the costs, all of the benefits, all of the penalties and all of the rewards assigned to different people. . ."

The author felt that a systems view offered

Table 1. Paradigms in the mosquito control community of California (MCCC).

	PERMANENT MOSQUITO CONTROL
Definition:	"to the greatest extent possible the places where mosquito larvae were found should be eliminated by either drainage or filling, to minimize the need for repetitive applications of oil as a larvicide" (Gray and Fontaine 1957).
Discovery:	Ross finds in 1898 that malaria is carried by anophelines.
Demonstration:	Herms and Gray demonstrate in Penryn, California, 1910.
Evidence of Shift:	Mosquito Abatement Act of 1915.
Productive Phase:	1915-1937.
Anomalies (Crisis Stage):	Increase in malaria cases -1938. Evidence that some viral encephalitides were carried by mosquitoes demanding rapid action -1941.
Images of Nature:	Machine.
	CHEMICAL MOSQUITO CONTROL
Definition:	Apply larvicides and adulticides to suppress mosquito populations. Substitute new insecticide when resistance occurs.
Discovery:	DDT is successful as a larvicide in the lab (Herms 1946).
Demonstration:	Gray demonstrates use of DDT as larvicide (Gray 1946).
Evidence of Shift:	High percentage of papers in Proceedings in 1948-49 were describing successful use of DDT.
Productive Phase:	1948-1966.
Anomalies (Crisis Stage):	Resistance, secondary pest outbreaks, killing non-targets, ecosystem disruptions, water contamination, safety.
Images of Nature:	Nearly devoid. Target, "arms race" or co-evolution.
	SYSTEMS SCIENCE
Definition:	Encompass the totality of the problem by drawing conceptual boundaries that capture all the effects of the acts, all of the costs, all of the penalties and all of the rewards (Stead 1966).
Discovery:	Introduced to MCCC by Stead (1966).
Demonstration:	Computer modeling of wetlands (Schooley 1983).
Productive Phase:	Not attained.
Anomalies (Crisis Stage):	Too soon.
Images of Nature:	Nature as an "open system", a homeostatically self-regulating system, as "artificial life", chaos, etc.
	INTEGRATED MOSQUITO CONTROL (IPM)
Definition:	A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury (Smith 1970).
Discovery:	Introduced by Smith 1970.
Demonstration:	Demonstrated in saltmarshes (Telford and Rucker 1973).
Productive Phase:	Probably not attained.
Anomalies (Crisis Stage):	Too soon.
Images of Nature:	Nature-in-balance, GAIA, chaos, and others.
	COMPREHENSIVE MOSQUITO CONTROL (CMC)
Definition:	Applying all of the available technology of naturalistic control, prevention or source reduction and, chemical control, each in appropriate situations (Mulhern 1971).
Discovery:	Synthesis and Introduction by Mulhern in 1971.
Demonstration:	All successful projects are subsumed. Concepts incorporated into training manual for mosquito control technicians.
Productive Phase:	Not distinguishable.
Anomalies (Crisis Stage):	Avoided by definition.
Images of Nature:	Probably nature as machine, otherwise devoid.
	BIO-RATIONAL MOSQUITO CONTROL
Definition:	Customized and bio-engineered insect-specific materials to control larval mosquitoes (Eldridge 1988).
Discovery:	Altosid and *Bti* discovered and became available in 1980s.
Demonstration:	Successful experimental and field trials of biorationals (Mulligan and Schaefer 1984).
Evidence of Shift:	Since 1970s conventional pesticides have declined while biorationals have increased. This may portend a paradigm shift or simply use as a component of one of the integrated paradigms.
Productive Phase:	If it has reached status of paradigm, it may be in the productive phase.
Anomalies (Crisis Stage):	Too soon.
Images of Nature:	"Target" or "co-evolution" or "arms race".

great hope to the field of mosquito control. He touted the record of successes that occurred in its application to space and weapons technology. In spite of Mr. Stead's enthusiasm, the systems approach only began to surface in the proceedings in the late 1970s. The approach appeared as models to predict mosquito dynamics and abundance (Gilpin et al. 1979, Milby 1984); computer modeling of mosquito sources (Collins et al. 1986, Schooley 1983, Fry and Taylor 1990); research projects aimed at supporting systems models (Cech and Linden 1985, Mead and Conner 1987, Milby and Meyer 1985, Orr and Resh 1987); and computer system development (Rusmisel et al. 1983).

The systems approach, in spite of its formal introduction in 1966 and numerous demonstrations of the approach citations, has not captured the imagination of a sufficient number of adherents in the MCCC to prevail over the other paradigms. The development of this paradigm may be hindered by the almost total absence of systems courses in curricula taken by professional biologists of the MCCC.

The systems approach appears to be the most expansive of all of the competing paradigms of the MCCC. The paradigm is based upon a premise that the world as we know it is an organizing cosmos and inherently unified, integrated, and harmonious (Reckmeyer 1982). More simply, the systems view suggests everything is connected to everything else. It leads to recognition that we deal with an extremely complex, dynamic world in which our actions are expected to have a variety of consequences, and those consequences may often be counter-intuitive. The practitioners of the systems approach in the MCCC tend to rely heavily upon ecological theory to inform their applications while excluding a vast portion of the domain of systems science. Today, system sciences offer a number of "hard" and "soft" approaches to solving problems in a range of system contexts (Flood and Jackson 1991), yet the MCCC has only barely ventured into computer modeling of mosquito populations and wetlands. As a result, the expansiveness provided by systems thinking has not been fully realized. When it has, mosquito and vector control will be viewed as an organizational system connected to and interacting with the human and natural systems. The systems paradigm, in its broadest context, is capable of generating a wide range of images of nature including: nature as an "open system" (Odum 1983), a "homeostatically self-regulating system" (Odum 1983), as "artificial life" (Langton 1989), and others. Recently a metaphor has emerged that depicts the earth as a single, interacting system, alive and self-safeguarding (Myers 1990). Simultaneously, studies of "chaotic systems" suggest that the cherished "equilibrium" or "balance-of-nature" metaphor of nature must be reconciled with new knowledge concerning the chaotic behavior of non-linear, dynamical systems (Gleick 1987). The developing metaphor seems vaguely consistent with the illusive metaphor sought by Botkin and hinted at in the title of his book "Discordant Harmonies".

<u>Integrated Mosquito Control</u>: Integrated mosquito control emerged primarily from the applied academic community, designed specifically to overcome the anomalies associated with chemical control. It has been named variously "pest management", "integrated pest control" and "integrated pest management" or IPM. For convenience, this paradigm is called IPM in this paper. An early proponent to integrated control concepts, Ray Smith, discussed the proposed paradigm to the MCCC in 1970. He formally defined it as:

> "A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury . . . (integrating) all suitable management techniques with the natural regulating and limiting elements of the environment . . . (applying) the principles of population ecology toward the goals of pest population management (Smith 1970)."

In 1970, when Ray Smith introduced integrated mosquito control, he felt that the MCCC was not yet desperate enough to go into something as difficult and intellectually challenging as IPM. Since that time, however, a number of mosquito control projects can be cited that fall within the framework of the integrated mosquito control paradigm (Garcia and Des Rochers 1984; Pelsue 1984; Miura et al. 1986, 1989). IPM stresses a number of up-front rules dealing with monitoring the pest population, balancing control activities with development of insecticide resistance (spray thresholds), and minimizing impact on natural enemies of the mosquitoes as well as non-target organisms.

The IPM paradigm, once past the initial rules, is primarily informed by ecological theory and practice. Indeed, the practitioners of this paradigm have done much to advance the knowledge of ecological systems in the course of their mosquito control research and practice. In theory, this paradigm also espouses a systems approach and computer modeling, yet current adherents to this paradigm in the MCCC have not used much in the way of system approaches. The relatively limited application of the IPM paradigm by the MCCC suggests it does not clearly dominate other competing paradigms at this time.

The IPM paradigm defines a world where mosquito species and other organisms are connected and behaving dynamically in a natural environment. IPM, however, has not yet adequately illuminated the important interactions between the public, the socio-economic environment, the natural environment, and the mosquito control organization. It appears that the paradigm could overcome much of its limitations if it were to incorporate more systems methodologies into its approach.

IPM, informed by both ecological and systems theory, presents a wide range of metaphors to represent nature. This paradigm, along with the systems paradigm, is being influenced by our increased knowledge of chaos theory (Gleick 1987).

Bio-Rational Paradigm: In his presentation to the MCCC in 1988, Dr. Bruce Eldridge, Director of the Mosquito Research Program in California, reported a declining use of pesticides and predicted an end to uses of "conventional" pesticides for mosquito control in "our professional lifetime". He felt, however, that, in the short term, the conventional pesticides would probably be replaced by insect-specific materials such as insect growth regulators and bacterial insecticides. He lauded these materials because of their specificity to target vectors and because of low human toxicity. According to Eldridge, the advent of bio-engineering had created a "vast untapped potential for customizing present insect-specific materials, as well as the possibility of creating new materials".

Already, a number of the bio-rational products have proven effective in both experimental trials and actual usage (Mulligan and Schaefer 1984, Mulla et al. 1988, Kramer 1989). In fact, the use of both bacterial insecticides and insect growth regulators (bio-rationals) has increased markedly since the mid-1970s, while conventional pesticide use has declined (Eldridge 1988).

The use of bio-rationals hardly seems worthy of paradigm status, since it would seem to serve as just one narrow component to be integrated into one of the more expansive competing paradigms. Yet some factors suggest it could become a "paradigm-by-default" in the same manner as the chemical control paradigm. A compelling force operating for a bio-rational paradigm is its simplicity, a major factor that also operated for the chemical control paradigm. If, as some fear, the future holds an insufficiency of graduating professionals in vector control (Scudder 1988), the likelihood increases that the bio-rational approach will become a paradigm-by-default.

It is quite apparent that the bio-rational control paradigm provides a limited perspective. Knowledge accumulated in the MCCC by the bio-rational control paradigm would be generated primarily by the field experiments conducted by way of actual applications of bio-rationals. The technologies of larval detection and identification, biocide applications, larval susceptibility testing, as well as research and development of bio-rational products, would be highly developed in this paradigm. The paradigm would be largely blind, however, to the complexity of the natural and human world; a major failing.

This prospective paradigm is quite limited in its ability to generate metaphors to provide a broad view of nature. One metaphor that comes to mind is that of an "arms race". The target population is pressured with a bio-rational pesticide; it adapts genetically to survive; the bio-rational is bio-engineered and applied again; and the cycle continues. Nature at its simplest in this metaphor would simply be a target or the "enemy". A more complex interpretation of the metaphor might depict the target mosquito as an co-evolving organism, capable of ultimately producing the "Red Queen Effect," where, in spite of reciprocal escalation on both sides, neither the mosquito control agency nor target population make any relative progress (Dawkins 1987). This metaphor can provide a powerful perspective on the dynamics relationship between the mosquito control agency and the target mosquito population. It does little, however, to help us enrich our understanding of the relationship between the target and the environment, or the mosquito control agency and its environment.

It is obviously not the intention of Dr. Eldridge (1988) that bio-rationals be used excessively or to the exclusion of other appropriate physical/biological approaches. Yet the simplicity of this powerful approach may well lead to an over-dependence on bio-rationals, just as occurred with chemical pesticides after World War II. Excessive and singular use of these powerful tools could give them paradigm status in the mind of the users. The result could be a limited perspective for the MCCC and missed opportunities for sound environmental management.

Findings and Implications.

Since the decline of the chemical control paradigm in the mid-1960s, four competing paradigms have influenced the MCCC by shaping mental models and generating images of nature. Both the bio-rational and CMC paradigms generate limited perspectives of nature. The CMC paradigm, emphasizing an engineering approach, appears to have the machine metaphor lurking at its core. The bio-rational paradigm does little to generate useful images of nature. One metaphor, that of an "arms race", portrays the target population and the mosquito control agency as co-evolving organisms. The metaphor is useful in that it shows the possible development of the "Red Queen Effect" where, in spite of reciprocal escalations on both sides, neither the target population nor the mosquito control agency have made any relative progress (Dawkins 1987). The two paradigms appear limited, however, and seem to offer little hope in solving the crisis of vision in the MCCC.

The IPM and systems science paradigms are both informed by ecological theory and systems theory, promising the infusion of rich and varied images of nature. They also are capable of incorporating bio-rational approaches as a component of the paradigm. An important contribution of systems science is that it provides a framework that can encompass the socio-economic system as well as the natural system. A major shortcoming of systems science appears to be the lack of access to curriculum by the MCCC. The primary image generated by IPM is of "nature-in-balance", unfortunately a failing myth (Botkin 1990). The major advantage of the systems science paradigm is that it provides a framework which connects the socio-economic systems with ecological systems. If the MCCC is to attain the broad vision prescribed by Capra (1982) and Botkin (1990), it is vital that both of these paradigms be further developed by increased infusion of ecological and systems theory.

Managing Paradigms and Mental Models in the MCCC.

The current climate in the MCCC suggests that forces are operating to prevent any one paradigm from obtaining dominant status. The Universities are cutting back on graduates trained in vector ecology and IPM; access to systems science curriculum by students of vector ecology seems limited; the vector control programs of the state have been cutback dramatically in the last decade, reducing the ability to promulgate the concepts of comprehensive mosquito control in their certification and training programs; and finally, the bio-rational approach does not yet seem in danger of being perceived as a paradigm.

There are both negative and positive consequences associated with the continued competition of the paradigms. One positive benefit is that it is unlikely in an atmosphere of competing paradigms that an anomaly would escape detection due to paradigm blindness. When anomalies are not seen by adherents to a paradigm that produce them, they may be easily seen and emphatically identified by adherents of other paradigms. A problem associated with the continued paradigm competition would be that adherents would tend to actively suppress novelty and innovation when it is outside the boundaries of their paradigm. Yet today, the MCCC is much in need of new and novel solutions. Bohm and Peat (1987) say it most succinctly:

> "The cycle of perception and action cannot be maintained in a totally arbitrary fashion unless we collude to suppress the things we do not wish to see while, at the same time, trying to maintain, at all costs, the things we desire most in our image of the world. Clearly the cost of supporting such a vision of reality must be paid."

Perhaps the most serious problem of continuing competition between the paradigms is caused when adherents to different paradigms ascribe different meanings to the same words. For example, the word "mosquitoes" spoken to a member of the MCCC will conjure up different images depending upon his or her paradigm. If he were an adherent to bio-rational control, he would focus on knowledge of mosquitoes centering around their range of behavior as immature and susceptible larvae. An adherent to IPM would likely visualize a population of mosquitoes managed to maintain susceptibility to insecticides. Those in comprehensive mosquito control would likely focus on mosquitoes as they are inextricably tied to a particular type or types of aquatic sources. Finally, an adherent to the systems paradigm might visualize the mosquito as an information processor capable of a determinant number of states. When the word "mosquito", or any other of the paradigmatically defined terms, is communicated to a typically heterogeneous group of individuals of the MCCC, the message intended to be sent by the speaker may be very far from what is received by the listener.

In a scientific community, such miscommunication may be divisive. Flood and Carson (1988) have described the possible outcomes of transparadigm discussion:

> "First, that the opposing camps literally ignore each other and carry on maturing their own paradigms by in-house debate. Second the transparadigm debate leads to further entrenchment in a battle between paradigms. Third, and last, that an individual may change camps adopting in its entirety the whole set of philosophical beliefs and rejecting wholly the set of beliefs previously subscribed to."

In the face of today's environmental challenges, the MCCC can ill-afford the inherent inefficiencies of the above described options. A fourth option would be for individuals in the MCCC to be trained in techniques to surface test, and improve their mental models. Once the skills of managing mental models have been developed, and an ethic of openness has been established, the forces working for a paradigm shift may be blunted. In effect, the MCCC might seek to prolong the crisis stage, thereby providing the advantages of innovation and novelty associated with extra-ordinary science. The MCCC could use the images generated from any of the competing paradigms as temporary epistemological devises by which to obtain a differing view of the world. The result could be a giant step toward meeting the crisis of perspective posed by Botkin and Capra.

Conclusions.

1. There are currently two competing paradigms (systems and IPM) in the mosquito control community of California that appear capable of generating a variety of powerful and useful images of nature. Both paradigms need further development in the MCCC. The bio-rational paradigm should be subsumed within the framework of systems or IPM.
2. No single paradigm is currently predominant in the MCCC. Instead, at least four are in competition with both negative and positive consequences. The natural propensity to advocate the principles of ones paradigm, to suppress novelty, to be blind to phenomena outside paradigmatic boundaries, and to resist conversion can generate divisiveness in the MCCC. Incommensurability between adherents of different paradigms confounds communication and reinforces the divisiveness. On the other hand, the fact that the MCCC is composed of adherents of more than one paradigm offers the opportunity to generate more novel approaches and to reduce the problem of paradigmatically-induced blindness in the scientific community.
3. The MCCC now has a unique opportunity to manage the dynamics of the paradigm competition to obtain a high level of productivity of the kind associated with the operation of normal science, while allowing the innovation and resultant creativity associated with extra-ordinary science.
4. It is essential that appropriate, well-planned action be taken immediately to sustain and enhance the period of extra-ordinary science. The objective should be to learn methods to avoid cognitive traps commonly associated with a dominant paradigm while utilizing paradigms as "useful and temporary perspectives". Senge (1990) has provided a synthesis of a great deal of work aimed at that goal.

References.

Argyris, C., Putnam R., and D.M. Smith. 1985. Action Science. Josey-Bass Publishers, San Francisco.

Bissel, G.E. 1988. Pesticide disposal practice of the 60s haunts vector control district in the 80s. Proc. Calif. Mosq. Vector Control Assoc. 56:99-100.

Bohm, D. and F.D. Peat. 1987. Science, Order, and

Creativity. Bantam Books, New York.
Botkin, D.B. 1990. Discordant Harmonies: A New Ecology for the Twenty-First Century. Oxford University Press, New York.
Boulding, K.E. 1961. The Image. Univ. Michigan Press, Ann Arbor.
Capra, F. 1982. The Turning Point. Bantam Books, New York.
Cech, J.J., Jr. and A.L. Linden. 1985. Comparative larvivorous effects of mosquitofish and Sacramento blackfish in experimental rice fields. Proc. Calif. Mosq. Vector Control Assoc. 53:93-97.
Collins, J.N., S.S. Balling, and V.H. Resh. 1983. The Coyote Hills Marsh model: calibration of interactions among foating vegetation, waterfowl, invertebrate predators, alternate prey and *Anopheles* mosquitoes. Proc. Calif. Mosq. Vector Control Assoc. 51:69-73.
Dahl, A.H. 1946. State subvention in California mosquito control. Proc. Calif. Mosq. Control Assoc. 15:73-84.
Dahlsten, D.L., R. Garcia, J.E. Prine and R. Hunt. 1969. Insect problems in forest recreation areas. Calif. Agr. 23:(7)4-7.
Dawkins, R. 1987. The Blind Watchmaker. W.W. Norton and Company, New York.
Dommes, S.F. 1939. Observations of mosquito problems throughout the state. Proc. Calif. Mosq. Control. Assoc. 10:57-66.
Eldridge, B.F. 1988. Conventional chemical pesticides for mosquito control: past and present. Proc. Calif. Mosq. Vector Control Assoc. 56:207-213.
Flood, R.L. and M.C. Carson. 1988. Dealing with Complexity. Plenum Press, New York.
Flood, R.L. and M.C. Jackson. 1991. Creative Problem Solving. John Wiley and Sons, New York.
Fry, J. and C.E. Taylor. 1990. Mosquito control simulation on the connection machine. Proc. Calif. Mosq. Vector Control Assoc. 58:207-213.
Garcia, R. and B. Des Rochers. 1984. Towards an integrated mosquito control strategy for Gray Lodge Wildlife Refuge with emphasis on the floodwater species: *Aedes melanimon* and *Ae. nigromaculis*. Proc. Calif. Mosq. Vector Control Assoc. 52:173-180.
Gilpin, M.E., W.R. Thomas and G.E. McClelland. Modifications of an *Aedes aegypti* systems model for *Aedes sierrensis*. Proc. Calif. Mosq. Vector Control Assoc. 47:86-87.
Gjullin, C.M. and R.F. Peters. 1952. Abstract of recent studies of resistance to insecticides in California. Proc. Calif. Mosq. Control Assoc. 20:44-45.
Gleick, J. 1987. Chaos. Viking Press, New York.
Gray, H.F. 1946. The control of mosquito breeding in street inlets (catch basins), underground utility vaults and similar structures by DDT residual spray. Proc. Calif. Mosq. Control Assoc. 14:61-64.
Gray, H.F. 1953. Temporary control measures vs. mosquito source reduction. Proc. Calif. Mosq. Control Assoc. 21:46-47.
Gray, H.F. and R.E. Fontaine. 1957. A history of malaria control in California. Proc. Calif. Mosq. Control Assoc. 25:19-39.
Gutting, G. 1980. Introduction. *In:* C. Gutting (Ed.) Paradigms and Revolutions: Appraisals and Application of Thomas Kuhn's Philosophy of Science. Univ. Notre Dame Press, Notre Dame. pp. 1-7.
Herms, W.B. 1946. Some comparative laboratory tests with minute dosages of DDT, 666, and DDD on mosquito larvae and pupae. Proc. Calif. Mosq. Control Assoc. 14:3-6.
Herms, W.B. and H.F. Gray. 1940. Mosquito Control. The Commonwealth Fund, New York.
Hokama, Y. and R.K. Washino. 1966. Potential invertebrate predatory-prey relationships in rice field habitats. Proc. Calif. Mosq. Control Assoc. 34:59.
Horgan, J. 1991. Profile: reluctant revolutionary. Sci. Amer. 5:40-49.
Howitt, B.F. 1941. Relationship of the St. Louis and the western equine viruses of encephalitis to man and animals in California. Proc. Calif. Mosq. Control Assoc. 12:3-23.
Jones, G.P. 1931. A Short History of Malaria in California. Proc. Calif. Mosq. Control Assoc. 2:42-54.
Kimball, J.H. 1973. A changing emphasis of mosquito control in California: planning, persuasion, negotiation, cooperation and legal action. Proc. Calif. Mosq. Control Assoc. 41:83-84.
Kramer, V.L. 1989. Efficacy and persistence of *Bacillus sphaericus*, *Bacillus thuringiensis* var. *israelensis*, and methoprene against *Culiseta incidens* in tires. Proc. Calif. Mosq. Vector Control Assoc. 57:139-140.
Kuhn, T.S. 1962. The Structure of Scientific Revolutions. Univ. Chicago Press, Chicago.
Kuhn, T.S. 1970. The Structure of Scientific

Revolutions, 2nd Edition (enlarged). Univ. Chicago Press, Chicago.

Langton, C.G. (Ed.) 1989. The Proceedings of an Interdisciplinary Workshop on the Synthesis and Simulation of Living Systems Held September, 1987 in Los Alamos, New Mexico. Addison Wesley Publishing Co., New York.

Lusk, E.E. 1971. Environmental conflicts. Proc. Calif. Mosq. Control Assoc. 39:26-28.

March, R.R. 1952. Aspects of insecticide restistance. Proc. Calif. Mosq. Control Assoc. 39:26-28.

McClelland, G.H. 1966. Genetic control. Proc. Calif. Mosq. Control Assoc. 34:29-31.

Mead, S.E. and G.E. Conner. 1987. Temperature-related growth and mortality rates of four mosquito species. Proc. Calif. Mosq. Vector Control Assoc. 55:133-137.

Milby, M.M. 1984. Predicting *Culex tarsalis* abundance in Kern County. Proc. Calif. Mosq. Vector Control Assoc. 52:153-155.

Milby, M.M. and R.P. Meyer. 1985. The influence of constant versus fluctuating temperatures on larval *Culex tarsalis*. Proc. Calif. Mosq. Vector Control Assoc. 53:117.

Miura, T., D.E. Reed and R.M. Takahashi. 1986. Efficiency and cost analysis of chemical vs. integrated *Culex tarsalis* control in central California rice fields. Proc. Calif. Mosq. Vector Control Assoc. 54:22-25.

Miura, T. and R.M. Takahashi. 1989. A model of population dynamics of *Culex tarsalis* on rice fields in Fresno, California. Proc. Calif. Mosq. Vector Control Assoc. 57:61-66.

Mulhern, T.D. 1971. Little used technology valuable in a program of comprehensive mosquito control. Proc. Calif. Mosq. Control Assoc. 39:93.

Mulhern, T.D. 1973. The third era of mosquito control in California has just begun. Proc. Calif. Mosq. Control Assoc. 41:75-78.

Mulhern, T.D. 1980. Mosquito control: past, present and prospective future. Proc. Calif. Mosq. Vector Control Assoc. 48:20-23.

Mulla, M.S., H.A. Darwezeh and H. Axelrod. 1988. Activity of slow release formulations of IGRs fenoxycarb and altosid against mosquitoes and non-target aquatic organisms. Proc. Calif. Mosq. Vector Control Assoc. 56:184-191.

Mulligan, F.S. and C.H. Schaefer. 1984. Field trials of *Bacillus thuringiensis* H. 14 commercial formulations. Proc. Calif. Mosq. Vector Control Assoc. 52:80-84.

Myers, N. 1990. The GAIA Atlas of Future Worlds. Anchor Books, New York.

Odum, H.T. 1983. Systems Ecology. John Wiley and Sons, New York.

Orr, B.K. and V.H. Resh. 1987. Interaction between mosquitofish (*Gambusia affinis*), sago pondweed (*Potamogeton pectinatus*), and the survivorship of *Anopheles* mosquito larvae. Proc. Calif. Mosq. Vector Control Assoc. 55:94-97.

Pelsue, F.W. 1984. Integrated pest management of an urban swamp. Proc. Calif. Mosq. Vector Control Assoc. 52:60-61.

Piaget, J. 1954. The Construction of Reality in the Child. Balantine Books, New York.

Reckmeyer, W.J. 1982. The Emerging Systems Paradigm: An Historical Perspective. Unpubl. Ph.D. dissertation, The American University.

Reginato, R.J. and L.E. Myers. 1966. Recent water management research. Proc. Calif. Mosq. Control Assoc. 34:19-22.

Rusmisel, J.R., R.O. Abriam and P.S. Turney. 1983. A computerized database and simulation system to support decisions in the Alameda County Mosquito Abatement District. Proc. Calif. Mosq. Vector Control Assoc. 51:67-68.

Schaefer, C.H. 1972. Mosquito control crisis in the Central Valley. Proc. Calif. Mosq. Control Assoc. 40:76-80.

Schooley, J.J. 1983. The Coyote Hills Marsh model: calibration of the interactions among fish and floating vegetation. Proc. Calif. Mosq. Vector Control Assoc. 51:74-76.

Scudder, H.S. 1988. Medical entomology manpower: an analysis and a plan. Bull. Soc. Vector Ecol. 13(2):323-331.

Senge, P.M. 1990. The Fifth Discipline: The Art and Practice of the Learning Organization. Doubleday Currency, New York.

Smith, R.F. 1970. The application of integrated control principles to mosquito control problems. Proc. Calif. Mosq. Control Assoc. 38:28-30.

Stead, F.M. 1966. Changing program perspectives in environmental quality management. Proc. Calif. Mosq. Control Assoc. 34:9-14.

Telford, A.D. and J.D. Rucker. 1973. Successful source reduction on tidal salt marshes. Proc. Calif. Mosq. Control Assoc. 41:70.

West, I. 1964. Safety considerations in mosquito control operations. Proc. Calif. Mosq. Control Assoc. 32:64-65.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 135-141

"INVITED", UNWELCOME GUESTS?

THE VECTOR AS CITIZEN IN THE NEW TOWNS:

A PLANNER'S PERSPECTIVE ON VECTOR CONTROL

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ABSTRACT

Sutter County is planning to add four New Towns in the southern part of the county, one of the largest planning projects ever considered in California. Over the next 40 years, the Plan is expected to add about 143,000 new residents, 92,000 new jobs, and 58,000 new dwelling units. The Sutter-Yuba Mosquito Abatement District expressed its concerns regarding vector control, which resulted in the adoption of vector control mitigation measures which will enable the Mosquito Abatement District to become fully integrated into the planning process as development occurs.

In 1990, Sutter County began the process to amend its General Plan to allow development of four New Towns in the southern part of the county (Fig. 1). This is one of the largest planning projects ever considered in California. Over the next 40 years, the Plan is expected to add about 143,000 new residents, 92,000 new jobs, and 58,000 new dwelling units. The four New Towns are intended to be "sustainable" communities, where the planned mix of land uses would reduce dependence on other parts of the region (Sutter County).

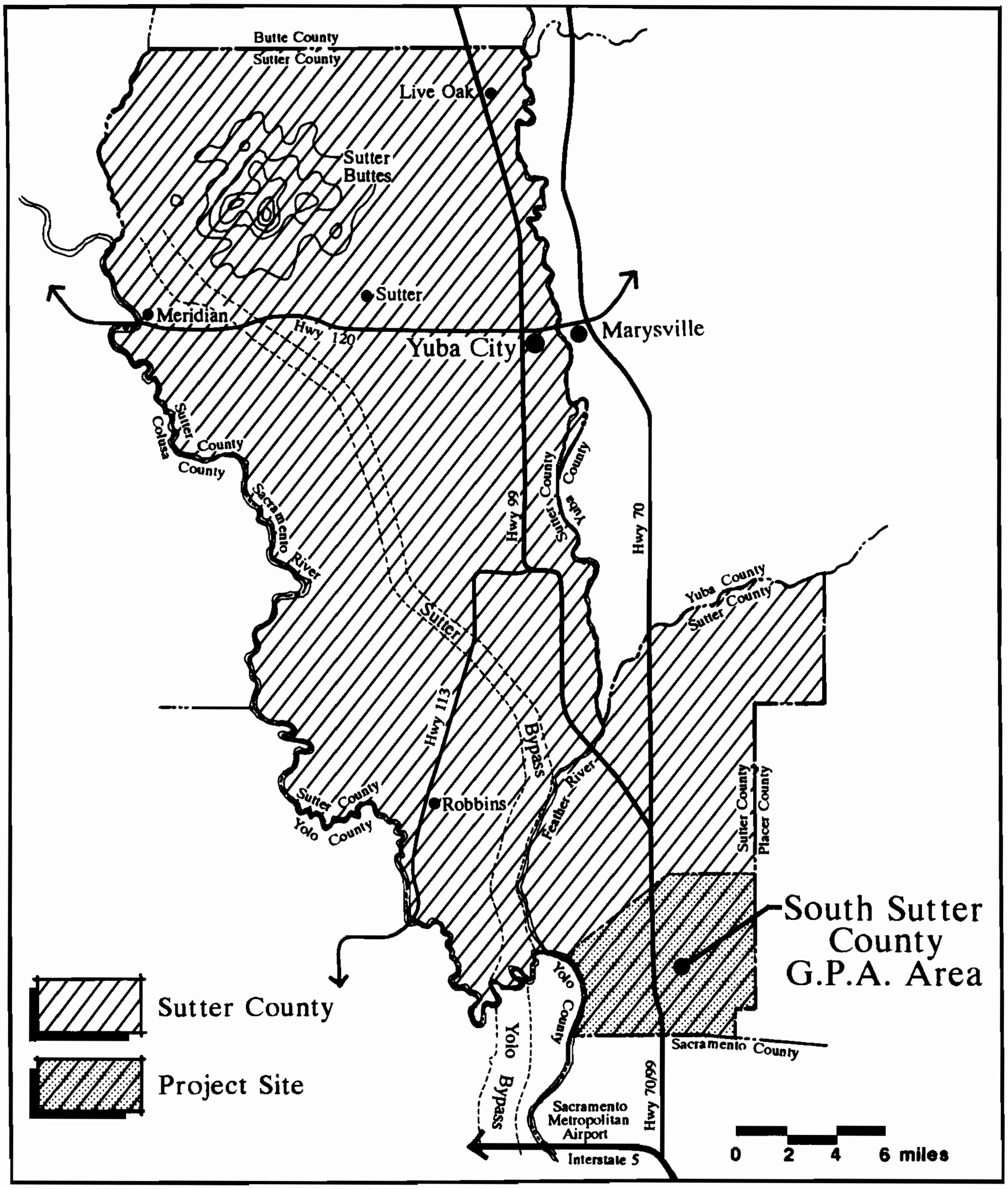
The proposed development and changes in land use were naturally of great concern to the Sutter-Yuba Mosquito Abatement District (SYMAD). The County recently agreed to provide the District with an opportunity to become fully involved in the planning process. I am here today to tell you how this came about, as I know many of you face similar problems within your own District.

Currently there are only about 1,000 people living within the project boundaries, 36 square miles overall. South Sutter County averaged 28,411 acres of land in rice production during 1989 and 1990, providing an immense habitat for *Anopheles freeborni* Aitken and *Culex tarsalis* Coquillett production. As you know, *An. freeborni* and *Cx. tarsalis* are vectors of malaria and encephalitis, respectively. Since 1974, there have been six cases of locally transmitted malaria in the Sutter-Yuba area. In 1978, two horses were determined positive for western equine encephalomyelitis (pers. commun.- R.L. McBride and D.A. Lemenager, SYMAD).

Existing water management facilities include levees along the Sacramento River, a regional canal system providing both supply and drainage of agricultural irrigation water, and limited flood control. Local storm runoff is controlled through a drainage system consisting of unlined canals, ditches, and two pumping plants.

With implementation of the General Plan Amendment, about 13,000 acres of riceland will be converted to urban uses. An Environmental Impact Report (EIR) was required to evaluate the potential for adverse environmental impacts resulting from this proposed development.

In the "conceptual" layout for these New Towns (Fig. 2), residential and employment-generating land uses will be clustered together with nearby open space, recreational, civic, and cultural areas planned to discourage use of the automobile. An extensive network of regional bikeways,



Source: Prepared by The Planning Center for Sutter County, 1991. Final Environmental Impact Report, South Sutter County General Plan Amendment, SCH #90030904.

Figure 1. Regional Location of the proposed South Sutter County General Plan Amendment Area.

Source: Prepared by The Planning Center for Sutter County, 1991. South Sutter County General Plan Amendment.

Figure 2. Land Use Diagram of the proposed South Sutter County General Plan Amendment.

pedestrian walks, and a transit system is an important part of the plan.

Protection from flood hazards is a major concern to planners in South Sutter County, which is subject to periodic significant flooding from heavy rainstorms. There is also concern about catastrophic flooding, since failure of the man-made regional flood control facilities could result in covering parts of South Sutter with as much as 40 feet of water.

About 7,000 acres of open space are planned throughout South Sutter, in an effort to provide drainage throughout the project area. The Drainage Plan (Fig. 3) shows key features included in the new drainage system which will replace the existing local drainage system. The project's planners recently expressed strong concerns regarding control of nuisance-producing mosquitoes in the open space areas.

In Multi-Purpose Corridors located along major arterials and the Multi-Use Open Space, there will be numerous small detention ponds. Two miles of unlined drainage canals are planned. In addition, a 1,200-acre regional park is planned in the northeast part of the site, to serve a dual function as the regional stormwater and treated effluent detention basin following infrequent, major flood events (Fig. 4). The drainage system will be consistent with the recently issued Federal water quality regulations, EPA's new National Pollutant Discharge Elimination System stormwater requirements.

Multi-Purpose Corridors (formerly referred to as "Environmental Corridors") are planned along main roads. These areas are intended to provide visual amenities along the circulation system and intended to accommodate local storm runoff. Multi-use Open Space is intended to provide visual amenities and opportunities for recreation, continued space for agriculture and the preservation of local sensitive habitats and species. Both local storm runoff and infrequent major flooding would drain into the Multi-use Open Space areas. Biological resources in South Sutter include existing wetlands, the Giant Garter snake, Swainson's Hawk, the Tricolored Blackbird, and the Valley Elderberry Longhorn Beetle.

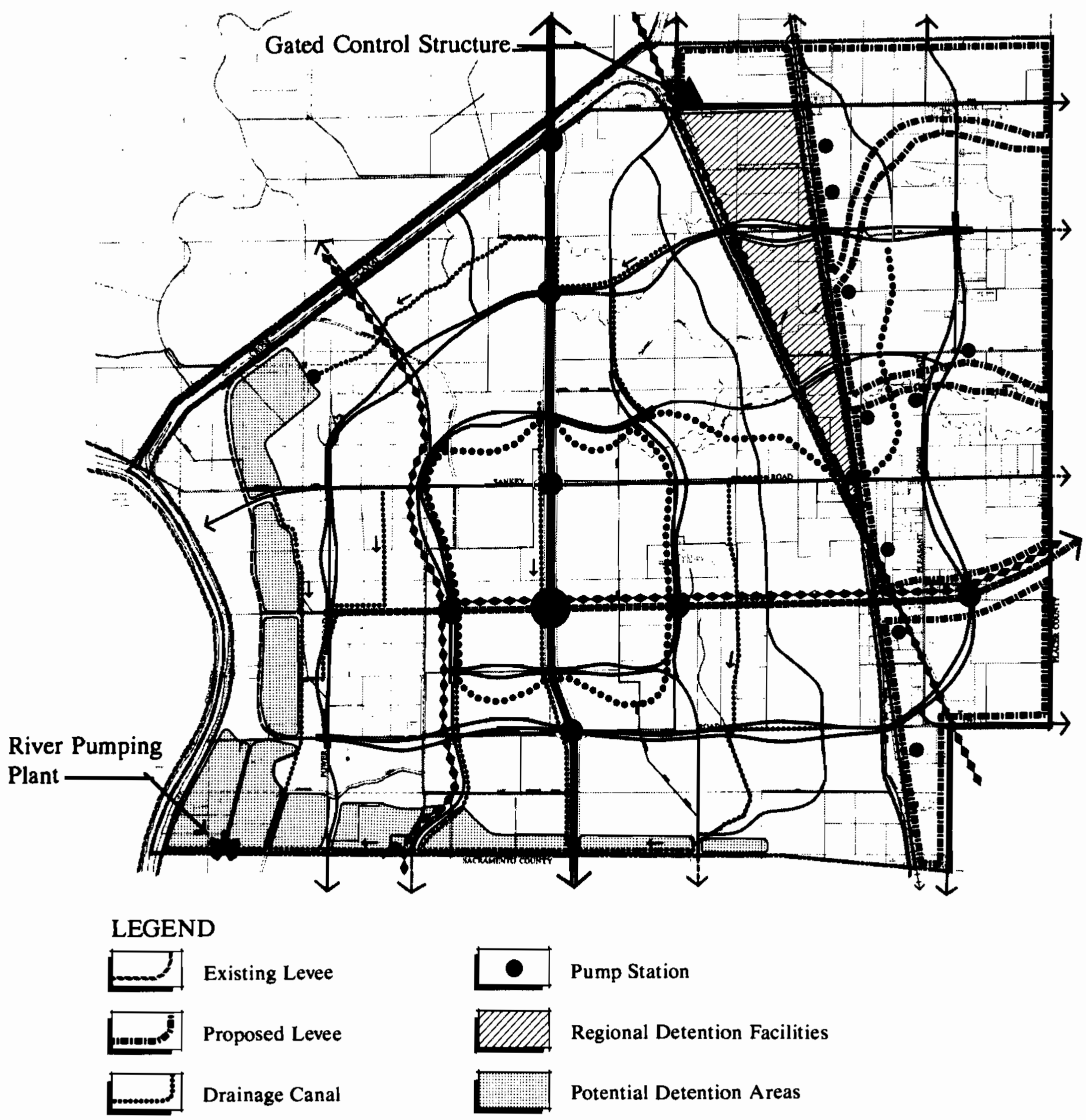
In an effort to mitigate adverse environmental impacts on vector control, Ronald McBride, Manager of the Sutter-Yuba Mosquito Abatement District, asked that the following issues be included in the Final EIR:

1. Proper design of proposed water retention facilities, which have potential to become a major breeding source for mosquitoes in the project area.
2. Careful reconstruction and revegetation methods in water retention facilities in order to allow access by mosquitofish.
3. Consideration of increased costs associated with mosquito and disease control due to the significant increase in the population at risk.

As a response to these concerns, I prepared an addition to the EIR, which summarized the existing conditions regarding vector control, identified the potential for adverse environmental impacts, and recommended that the County adopt certain mitigation measures to reduce those impacts. This was fully coordinated with the both the SYMAD and the California Department of Fish and Game, to avoid potential for conflicts.

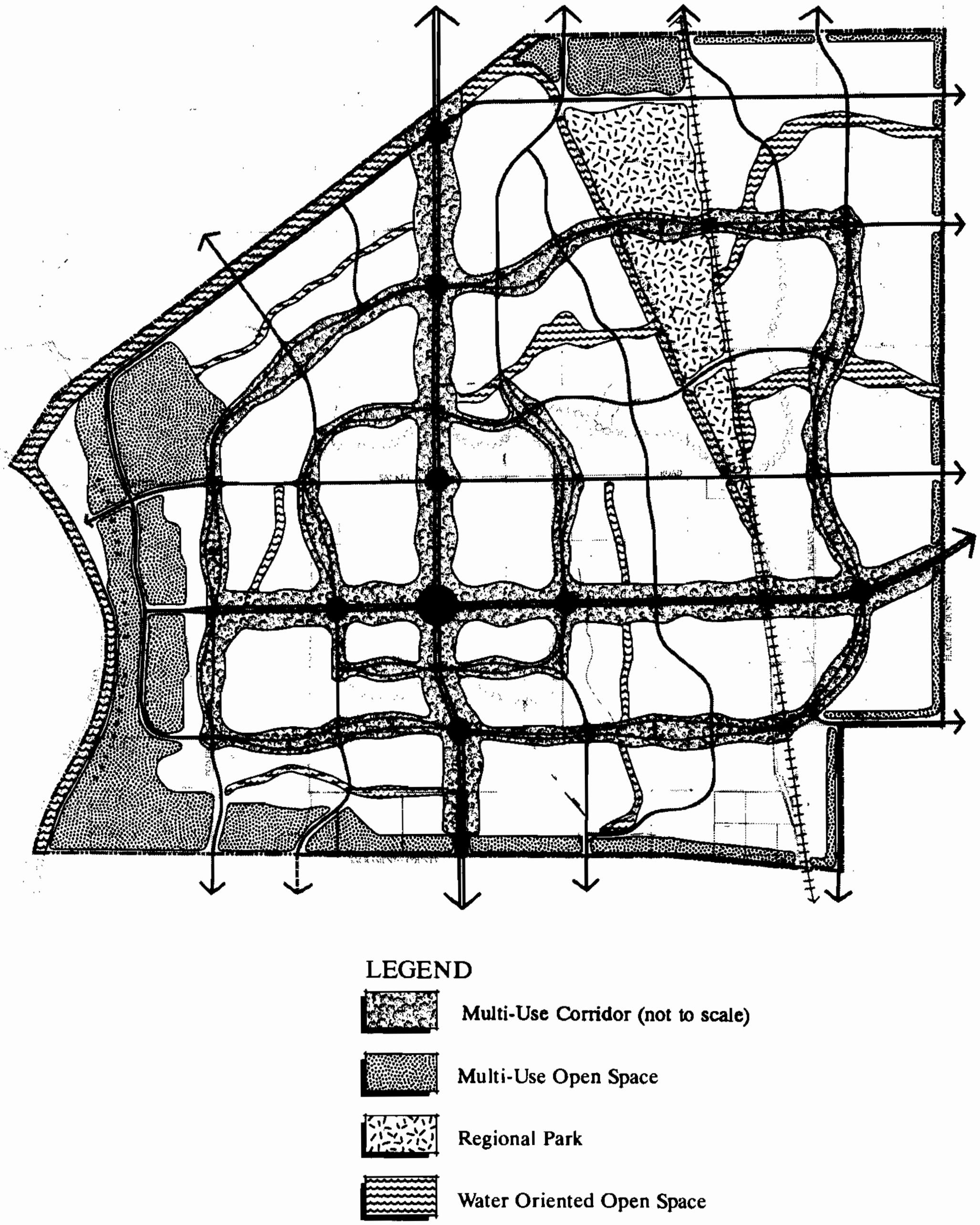
Sutter County agreed to accept a number of mitigation measures, which I will summarize. The County is also responsible for developing an implementation program for the General Plan and a Mitigation Monitoring Program to ensure that the District remains involved in the planning process:

1. The County will be responsible for coordination between representatives of the SYMAD and Calif. Dept. Fish and Game to identify their concerns and potential for conflicts between vector control methods and habitat conservation.
2. The County, the Sutter-Yuba Mosquito Abatement District, and California Dept. of Fish and Game will establish a formal Memorandum of Agreement, which identifies the terms of their joint corporation in development of final recommendations for vector control in conjunction with habitat preservation.
3. The design of all water retention facilities will be reviewed by both the SYMAD and California Dept. of Fish and Game. No drainage ponds, retention ponds, canals, or other water retention facilities will be developed unless these meet with the approval of both agencies, in accordance with the Memorandum of Agreement.
4. A funding mechanism will be developed by the County to provide for the on-going costs of vector control associated with implementation



Source: Prepared by The Planning Center for Sutter County, 1991. South Sutter County General Plan Amendment.

Figure 3. Drainage Plan (approximate locations)of the proposed South Sutter County General Plan Amendment.



Source: Prepared by The Planning Center for Sutter County, 1991. South Sutter County General Plan Amendment.

Figure 4. Open Space Plan (not to scale) of the proposed South Sutter County General Plan Amendment.

of the General Plan.

5. All owners and operators of the proposed detention ponds, detention basins, and drainage canals will be informed that if mosquito populations are produced as the result of this development, they will be liable for mosquito abatement at these sources, in accordance with State Health Code.
6. The County will hire a qualified vector biologist or medical entomologist to prepare an Integrated Pest Management Plan (IPMP) for disease vectors, utilizing the State's "Vector Prevention in Proposed Development: Guidelines, Standards, and Checklists." This plan will be required to meet with the approval of both the SYMAD and California Dept. of Fish and Game.
7. The County will also consider incorporating Mosquito Prevention Standards in its future implementation programs, based on the recommendations of the SYMAD in conjunction with the California Dept. of Fish and Game. Alternative mosquito prevention standards may also be recommended by those agencies.

The adoption of these mitigation measures proves that the planning process in California can be used to address vector control issues effectively, since without the Sutter-Yuba MAD's formal comments on the Draft EIR, these mitigation measures would not have be adopted. The planning system is a formal system. After issuance of a Notice of Preparation of a Draft Environmental Impact Report, a Responsible Agency typically has 45 days to respond. The formal Public Review Period for a Draft EIR must be for no less than 30 days following the date of notice, or forty-five days where Draft EIRs are submitted to the State Clearinghouse, after which your comments may not be considered (Pub. Resources Code §21091(b); CEQA Guidelines, §15087(c), §15205(d). In the final EIR, the lead agency will evaluate and respond to all the comments on the Draft EIR it receives.

An important factor is to develop one-on-one working relationships with groups or agencies responsible for land use decisions. Another important contact is the local Public Works Director. Public Works is responsible for approving final designs for stormdrain facilities and establishing design standards for water management facilities. Certainly, vector control is an issue which requires our joint cooperation.

In conclusion, this type of coordination between vector control agencies and planning agencies is expected to become increasingly critical. Potential for land use conflicts and vector control practices will increase as biological resource mitigation requirements are being strengthened at a time when the human population is projected to increase significantly in the State. As development in the South Sutter area proceeds, the Sutter-Yuba MAD will become fully integrated into the planning process, and will be able to limit future problems with mosquito production in an area where the potential for tremendous growth exists.

Acknowledgements.

The author gratefully thanks Ronald L. McBride, D.A. Lemenager, and other staff of the Sutter-Yuba Mosquito Abatement District for information on vector control efforts in this District and the staff of the Newport Beach and Sacramento offices of The Planning Center for information regarding the South Sutter County General Plan Amendment and EIR, and for graphics support and funds for travel to the conference.

References.

Sutter County. 1991. South Sutter County General Plan Amendment; and Final Environmental Impact Report, South Sutter County General Plan Amendment, SCH #90030904.

Remy, M.H., Thomas, T.A., and Moose, J.G., 1992. Guide to the California Environmental Quality Act (CEQA) - 6th Edition. Solano Press Books, Point Arena, California 647 pp.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 142-146

STATUS AND TRENDS OF WETLANDS IN THE SAN FRANCISCO ESTUARY[1]

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The San Francisco Estuary, which includes the San Francisco Bay, the Suisun Marsh, and the Sacramento-San Joaquin River Delta, is the largest estuary on the west coast of North and South America. Wetlands and related habitats are some of its most valuable natural resources. These wetlands are critical habitat for hundreds of species of fish, birds and other wildlife. They are also now recognized for their importance as they improve water quality and provide flood control, open space, recreational opportunities, and many other benefits.

The majority of the Estuary's historic wetlands have been significantly altered or no longer exist, and there are continuing threats to many of the remaining wetlands. The original 545,375 acres of tidal marshes have been reduced to approximately 44,371 acres with a drastic reduction in the wildlife populations that depend upon them. Uses that have lead to these modifications include hydraulic mining, farming, urbanization, waste disposal, salt production, and transportation systems such as airports, bridges, and roadways. More than any other habitat type related to the Estuary, wetlands have been adversely affected by development.

"The Status and Trends Report on Wetlands and Related Habitats in the San Francisco Estuary" describes the values and functions of wetlands, traces the loss and conversion of these habitats, projects trends in their distribution, and discusses some issues related to their regulation and management. It is the product of more than two years of effort by the San Francisco Estuary Project (SFEP). SFEP is a broad-based planning effort working to develop a comprehensive management plan by November, 1992 to restore and maintain the chemical, physical, and biological integrity of the Estuary. Today, I will present some of the findings from this report, particularly focusing on wetland distribution, future trends and regulation.

Wetlands Classification and Distribution.

Wetland habitats for the United States have been classified by the U.S. Fish and Wildlife Service (FWS) according to a system developed by Cowardin et al. This system was chosen for use in the Status and Trends Report (STR) because of its "ecological", as opposed to "regulatory", approach to defining and classifying wetlands. It is important to note that wetlands legally regulated by agencies, such as the U.S. Army Corps of Engineers ("jurisdictional wetlands") are defined differently. Generally, the jurisdictional definition used by federal regulatory agencies is less inclusive, thereby encompassing fewer wetland acres and excluding certain habitat types.

The FWS defines wetlands as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water, with one or more of the following attributes: 1. supports hydrophytes (water-loving vegetation) part of or all of the year; 2. contains predominantly undrained hydric (water-saturated) soil; 3. contains predominantly non-soil and is saturated with water or covered by shallow water for some time during the growing season.

Wetland habitats of the San Francisco Estuary were mapped by the FWS as part of the National Wetlands Inventory (NWI) Project. The purpose of the NWI is to develop and disseminate comprehensive data concerning the distribution of wetlands. The most recent data for the Estuary was based on interpretation of aerial photography taken in April, 1985 (Table 1).

According to the 1985 NWI data, Bay and

[1] Copies of the published report on which this paper is based, entitled "The Status and Trends Report on Wetlands and Related Habitats in the San Francisco Estuary", may be obtained at the above address or by contacting (510) 464-7990.

Delta tidal marsh acreage was estimated at 44,371 acres. This represents a loss of 92% of the Estuary's historic tidal marsh acreage. Other wetland habitats that exist today are primarily seasonal wetlands which were historically tidal marshes. These converted wetlands retain vital wetland characteristics and provide potential for enhancement; however, their wetland functions and values have been significantly altered and in most cases reduced. The existing seasonal wetlands are comprised primarily of farmed wetlands (82%) and the overwhelming majority of the farmed wetlands (350,347 acres) are in the Delta. Other seasonal wetlands include diked marsh, abandoned salt ponds, and vernal pools.

In the San Francisco Bay, the predominant wetland type is intertidal mudflat (57,776 acres) and salt ponds (36,603 acres). The majority of the salt ponds are in southern San Francisco Bay. In northern San Francisco Bay, intertidal mudflat and farmed wetlands predominate. Suisun Bay is dominated by diked salt and brackish marsh.

Historic Wetlands.

The Estuary historically (1850s) supported an estimated 545,375 acres of tidal marshes (Table 2). San Francisco Bay accounted for approximately 200,375 acres and the Delta accounted for approximately 345,000 acres. This extensive wetlands provided extraordinary fish and wildlife habitats, major spawning grounds for finfish and shellfish, and a key stopover for wintering area migratory birds.

Not surprisingly, these resources attracted human settlement and the loss and conversion of wetlands correspond to the history and settlement patterns of the region. Major conversion of swamplands to agriculture in the 19th and early 20th centuries accounts for the largest loss of wetlands. In the Delta, wetlands rich with thick layers of organic soil were diked and drained to make productive farmland. Around the Bay, some marshes were converted to agricultural uses, while a significant portion was converted to salt production basins. Beginning in the 1920s, the

Table 1. Wetland and open water habitats (acres) within the San Francisco Estuary based on the 1985 National Wetlands Inventory figures.

Habitat type	San Francisco[5] Bay	Suisun Bay	Delta	Total
WETLANDS				
Tidal Mudflats[1]	57,776	5,994	322	64,092
Tidal Marshes[2]	25,466	10,682	8,223	44,371
Seasonal Wetlands[3]				
- Farmed Wetland	27,344	8,064	350,347	385,755
- Other Seasonal Wetlands[4]	21,150	47,482	16,502	85,134
Riparian Forests	2,322	403	9,788	12,513
Salt Ponds	36,603	27	54	36,684
TOTALS	170,661	72,652	385,236	628,549
OPEN WATER				
Perennial Lakes & Ponds	13,361	3,526	12,482	29,369
Open Water	192,109	28,247	45,802	266,158
TOTALS	205,470	31,773	58,284	295,527
ALL HABITATS TOTALS	376,131	104,425	443,520	924,076

[1] Estuarine intertidal (includes rocky shores) [2] Estuarine intertidal (salt/brackish/freshwater)
[3] Palustrine [4] Palustrine (diked marsh, vernal pools, abandoned salt ponds)
[5] Includes South/Central Bay & San Pablo Bay

Table 2. Tidal wetlands trends (acres) in the San Francisco Bay Area.

Year	San Francisco Bay	San Pablo Bay	Suisun Bay	Bays Total	Delta
1850	62,890	60,290	71,100	200,375	345,000
1940	-	-	-	65,375	-
1957	12,800	13,890	22,980	49,660	-
1978	6,400	17,280	13,760	37,440	-
1979	-	-	-	30,890	25,204
1980	6,993	13,670	9,340	30,003	-
1985	25,466	a	10,682	36,148	8,223
1987	8,861	17,959	10,084	35,287	-

[a] Included in the San Francisco Bay acreage

increasing pace of urban development started to significantly alter wetland areas.

Future Wetland Trends.

Future wetland trends will be determined largely by government policies and population growth, as well as natural events that reach beyond the Estuary. The Estuary region continues to be one of the most rapidly developing areas in the U.S. with pressure for expansion being applied to outlying areas surrounding San Pablo Bay, Suisun Bay, and the Delta. Expansion of facilities such as airports, roadways, and housing represent threats to the remaining wetlands. The conversion of tidal marshes have led to the reduction in contiguous acreages and habitat fragmentation. Urbanization of the adjacent upland surrounding these smaller and smaller wetland parcels further reduces the values and functions of these areas.

Estimates of future trends in abundance and distribution of wetland habitats are difficult, since these predictions are based on a variety of conditions, many of which are uncertain or even unpredictable. For example, regulatory programs may change, mitigation requirements vary, the success of restoration and acquisition projects is uncertain, and future land use patterns will be influenced by numerous factors. Nevertheless, the Wetlands STR did take a stab at this to provide an indication of the level of risk wetlands will face in the future. The analysis looked at current wetland mapping data, local land use designations and projected urban land needs.

In the analysis, over 12,000 acres of wetlands in the Bay and over 78,000 acres of wetlands in the Delta would be subject to moderate-to-high development pressure due to intensified or expanding land uses. This would affect 5% of existing Bay Area wetlands and 14% of Delta wetlands. When considering low-to-moderate development pressure, an additional 16% of Bay and 20% of Delta wetlands would be exposed. This analysis does not imply that all these wetlands will be converted, but rather that these lands are vulnerable. Because they may be wet only part of the year, seasonal wetlands are considered by some to be the most vulnerable to development.

Wetlands Regulation and Management.

Over 20 federal and state agencies operate under more than 60 laws, regulatory guidelines, and policies that affect wetlands within the Estuary. In fact, this regulatory framework for managing and protecting wetlands is one of the most intricate bodies of environmental law, relying on an elaborate system of checks and balances, with roles for permit applicants, public commenters, all levels of government, and ultimately the courts. The emergence of this framework to protect wetlands was driven largely by the environmental movement that began during the late 1950s. In 1959 the Save San Francisco Bay Association and the Sierra Club rallied the public to save San Francisco Bay from excessive fill. The most important result was the passage of the McAteer-Petris Act in 1965, which formed the Bay Conservation and Development Commission (BCDC). Concerns nationally for the protection of important water bodies resulted in the passage of the Clean Water Act in 1972, which among other things, established a permit process for wetlands.

Briefly, federal agencies provide the most comprehensive wetlands regulations applied throughout the Estuary, through the Section 404 program administer jointly by the Corps and EPA. NMFS and FWS both play key roles through commenting and the FWS is responsible for major acquisition efforts.

On the state level, there is currently no comprehensive wetlands program, but agencies that directly and indirectly manage wetlands include the State Water Resource Conservation Board (SWRCB), the Regional Water Quality Control Boards (RWQCB) and the Department of Fish and Game (DFG). Most significant on the state level is BCDC, who is charged with preventing unnecessary filling of the Bay and protecting Suisun Marsh. The California Coastal Conservancy (CCC), along with other state agencies oversees an active program to protect, restore and enhance wetlands.

On the local level, municipalities, county governments, and special districts are responsible for a variety of policies that affect wetlands. Presently, only 16 percent of the regions local jurisdictions have specific ordinances for stream and wetland protection and California's General Plan law does not require local governments to protect these or other estuarine resources. Private organizations, such as the Nature Conservancy, Ducks Unlimited and Audubon Chapters are playing an increasingly important role to protect and preserve wetlands.

While the existing laws and agencies provide a relatively intricate regulatory framework for wetlands, numerous shortcomings exist. These shortcomings are in part exemplified by the continued decline of certain wildlife populations dependent on wetland habitats, such as the clapper rail. While some of the harshest criticism has been directed at the federal Section 404 program authorized under the Clean Water Act, regulatory improvements are most likely needed at all levels of government. It is not surprising that the final report of the National Wetlands Forum in 1988 concluded that "(t)he United States urgently needs a better system for managing and protecting its wetlands." Since no single agency has complete or final authority over wetland-use decisions, there is a great need for having a more coordinated framework to protect and manage the Estuary's wetlands.

Next Steps.

So where do we go from here? The Estuary Project is trying to develop a comprehensive action plan for wetlands with the goals of not only protecting existing wetlands, but also increasing the quantity and quality of wetlands throughout the Bay and Delta. It is likely that full protection of the remaining wetlands will not, in itself, be sufficient to maintain many of the existing functions and values. Rather, extraordinary measures to preserve, restore and create functional wetland systems will be required to help maintain the long-term health of the Estuary.

Admittedly this will be a difficult task. In fact, wetlands preservation will continue to be one of the most challenging environmental issues of the 1990s, testing private property rights, political clout, legal powers, the limits of regulations and science and policy. Though politically complex and technically challenging, there are many recent developments and trends that may facilitate protection and management;

1. Strong political support for protection of wetlands is emerging. People want a better quality of life and that includes abundant fish and wildlife, vistas of open space, parks, access to the Bay, clean water, and enjoyment of natural habitat areas.

2. Better planning tools, such as GIS systems, are becoming available to local jurisdictions, state and federal agencies that may facilitate wetlands protection and management.

3. More entities are undertaking proactive planning efforts. For example, the State's Resource Agency is preparing a State Wetlands Conservation Plan that will work towards articulating a comprehensive state wetlands program. The SFRWQCB is increasingly undertaking watershed planning efforts and EPA has recently established a wetlands planning section.

4. Local jurisdictions and special districts are increasingly preparing hydrologic studies on a watershed basis for multi-objective planning for water quality, flood control and stormwater management.

5. There are an increasing number of successful cooperative efforts such as the acquisition of nearly 1,500 acres of diked historic baylands at Cullinan Ranch or the ongoing efforts to establish the Stone Lakes National Wildlife

Refuge in Sacramento. At Stone Lakes, for example, the FWS has recognized the need to cooperate with many entities including the Sacramento-Yolo Mosquito and Vector Control District to define standard operating procedures.

6. Increasingly developers are willing to spend money on impact reduction and restoration. So if managed well, through the implementation of good regional planning coupled with policies to raise increased resources for acquisition and restoration, growth could indirectly benefit critical habitat areas.

Conclusions.

Clearly new efforts are needed if the objective of increasing and improving our wetlands is to be achieved. Our ability to effectively achieve this goal may serve to demonstrate whether or not, or how, we can protect and enhance our valuable natural resources, while we continue to grow and develop. Given the large number of players and the broad range of alternatives for wetlands in the Estuary, perhaps the most important single need, as asserted by Kusler in "Wetland Creation and Restoration" (1989) is the "formulation of common goals for protection and management and multi-objective, cooperative implementation." SFEP is providing a basis for a coalition of environmentalists, regulators and the regulated community to agree on goals and develop actions to achieve these goals. But clearly more is needed such as continued and expanded political support, clear legal authorities, thoughtful consideration of private property rights, adequate funds for acquisition, and many cooperative efforts among all entities involved with wetland resources.

Thank you for the opportunity to talk with you this morning and I look forward to working with you in the future.

BARRIERS TO MOSQUITO CONTROL OPERATIONS IN DEVELOPED WETLANDS

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Washoe County was named after a tribe of American Indians which inhabited the area. On September 9, 1850, Congress created the Territory of Utah which included the present day Washoe County. In March of 1861, Congress created the Territory of Nevada. With the discovery of the Comstock Lode came the human populations to inhabit the state of Nevada and Washoe County. Washoe County's present population is approximately 250,000 with 130,000 of those in Reno and 60,000 in Sparks.

Washoe County District Health Department is located in Reno. The inception of our current interlocal agreement was September 27, 1972, although we have had a bona fide city/county health agency as far back as 1902.

Washoe County encompasses 1,195 square miles of which approximately 58,500 acres are under surveillance and control for mosquito activity. Plague and rabies surveillance and treatment is mostly confined to populated and adjacent areas, but does not exclude rural camping and hunting sites.

Most people envision Reno as a very populated resort community consisting of cement, asphalt, and tourists. It is also a place where people live and conduct business. Many of these homes and businesses are situated adjacent to agricultural and wetland areas. Because of a booming increase in population, open lands are giving way to housing and the once safe interface between humans and the wild animal population is diminishing.

Washoe County District Health Department's Vector Control Program works in four main areas; plague, rabies, ticks, and mosquitoes. Our program consists primarily of three facets; surveillance, control, and education, with our basic purpose being that of disease prevention.

Plague surveillance is accomplished through host rodent population monitoring; rodent and flea sampling and testing; and responding to citizen service requests. Control measures are directed against the vector fleas. Rodent burrows in identified problem areas are dusted, special emphasis being given to "high use" areas; e.g., parks, schools, and campgrounds. Education is implemented through public service announcements; community and school presentations; in-service workshops for Health Department personnel, animal control officers, park rangers and aides, and Humane Society personnel; and individual public inquires.

Rabies surveillance is conducted primarily in response to citizen requests. Specifically, specimens of high risk species are picked up and tested with the cooperation of our State Animal Disease Laboratory. Also, known bat populations are monitored. Our role in rabies control is the investigation and quarantining of domestic animals that have been exposed to a high risk species. We also investigate any reported human exposure to a high risk animal as well as certain bites by domestic animals that the animal control agencies do not handle. Once again, education is accomplished via public service announcements, school presentations, in-service workshops, and on an individual basis.

Our activities in the area of ticks have been somewhat limited due to a lack of funding and personnel. Minimal surveys of tick species present in the area have been conducted and the Nevada Department of Wildlife has been very cooperative in helping with deer hunter check station surveys. We also identify specimens submitted by the public and advise on associated tick-borne diseases. Education is through individual contacts, literature, and our hunter awareness program.

Additionally, we respond to citizen requests for a wide variety of other arthropod-related problems; e.g., cockroaches and identification of various unknown specimens.

In all of these areas we maintain a close working relationship with our Epidemiologist, Pam Young. In suspected human exposures she is our liaison to the medical community.

In mosquito control we have a unique situation, at least to us. It involves the modified use of wetlands for community and recreational development. Have you noticed that we rarely use the word "swamp" these days? Today the buzz word is wetland. Some have slightly different ideas of just exactly what these terms mean. Actually, these words have legal definitions. A wetland consists of an area which supports specific plant species and is covered by water for definite periods of time.

Attitudes have changed towards these areas. In Nevada we seem to have a fascination with water, probably because it is such a rare commodity here. Our recreational activities tend to focus around it, from fishing to waterskiing to bird watching. This fascination has extended into where we choose to live. Our most costly homes are located on creeks, rivers, and lakes (consider Lake Tahoe). And, where there is no water we go to extreme lengths to put some; i.e., ornamental ponds, streams, etc.

Up until about 1989 this area was a healthy marsh. Today we have an 18-hole golf course and surrounding planned community built on this existing 180-acre wetland. This area has provided ideal habitat for both migratory and local waterfowl and various shore birds by offering feeding, nesting, and resting sites. It has also supported a wide variety of predator species; e.g., hawks, owls, and coyotes. It has also been used for cattle grazing (along the drier margins), waterfowl hunting, and as a natural filtration system for agricultural irrigation tail water and runoff.

We have made ourselves a part of this marsh community. Of the original 180-acre tract, some 100+ acres have become golf course. To the east is Hidden Valley and to the west and south is Donner Springs, both residential areas. Together these areas have a population of approximately 15,000 people. The area to the west is currently being developed for multiple family housing. The areas to the south and east are being prepared for single family housing. When complete, these new residential areas will add another 1,800 people to the community.

This marsh receives water from several creeks and one major irrigation ditch. There are several control structures on the main channels. When closed, they can flood a considerable amount of ground. Also, the water level fluctuates with upstream usage. Thus we have several *Aedes* species present including *Aedes melanimon* Dyar, *Aedes nigromaculis* (Ludlow), and *Aedes dorsalis* (Meigen). Also present are a number of permanent water species with the most prevalent being *Culex tarsalis* Coquillett, *Culex erythrothorax* Dyar, and *Culiseta inornata* (Williston).

Even prior to regulatory constraints and development our agency has maintained an attitude and commitment toward preservation of sensitive ecosystems. This has extended throughout all our activities from surveys to pesticide applications. Physical controls such as channeling, while a very real option in the early years, was not implemented in order to preserve this great waterfowl habitat. Biorational materials have been in use since their registration. We selected vehicles that would have the least negative impact on the terrain. Further, we have always tried to use them in an environmentally conscious manner. These methods worked. We were able to achieve adequate control without significant damage to the wetland. With the new golf course, housing, and community attitude enters a new factor - appearances.

While these methods inflicted little or no real damage to the marsh, today they are visually unacceptable. The fact that golf course rules prohibit retrieval of golf balls from anywhere beyond posted wetland boundaries illustrates the degree of scrutiny that the area is now under. Thus, even foot traffic is considered aesthetically detrimental. The golf course meanders around and through the marsh. One can no longer exist without the other.

Where does all this put mosquito control? Certainly control is even more critical now. People are now living and playing in an integrated marsh community. The marsh is fairly typical in vegetation with cattails, tules, willows, various marsh grasses, and sedges. It is atypical, however, in its abundant growth of white top (*Lepidium latifolium*). This noxious weed occurs in those areas only flooded intermittently, is very invasive and a great colonizer. One species grows to a height exceeding five feet, and is dense enough to prohibit penetration of virtually all chemical formulations excepting sand, dense pellets, and briquets. Even walking through it is nearly impossible. It is also, obviously, quite tolerant of intermittent flooding and has become so well established as to constitute an integral part of this plant community. Thus the appearance of even this weed is something that must now be considered.

We have been forced to resort to frequent aerosol applications of adulticide to achieve even minimal control because of these real and imposed barriers to larvicide techniques. The larval options are: ground application using all terrain vehicles, hand application (backpacks and briquets), aerial applications, and *Gambusia* transplanting.

Ground treatments have given acceptable control levels, but have drawn criticism for disturbing the appearance of the vegetation. Hand treatments have resulted in less disruption of the vegetation, but have been impractical for adequate control due to personnel limitations and the nature of the terrain.

Aerial applications are currently a viable technique. But, this too has its drawbacks. As we do not have local helicopter agricultural services, we must contract with out-of-state companies. This often means three to five days to get the pilot and equipment to the site. Obviously, during the very warm weather, this delay could mean missing a mosquito hatch altogether. Further, as buildings go up around the wetland, helicopter access will be reduced. Finally, helicopters are very expensive. Of the remaining 80 acres of wetland, it might be necessary to treat only a small portion at a given time. Thus, the expense is often not justified.

Gambusia have been established for a number of years. While they do offer some control in the ponds and channels, their effectiveness has been limited in the denser vegetation. Also, we have fairly cold winters and the year-to-year survival has been minimal.

Physical controls, at this point in time, are not an option. This project has been planned, engineered, and is well on its way to being implemented. Few changes can be made now.

It is up to you to be involved in all planning stages of similar developments. Establish communication, if it does not currently exist, with whatever regulatory agency or agencies review and approve plans for development. Get your two cents in while the project is still only on paper. Also, be prepared. Familiarize yourself with the area in question and identify your needs. Know what you want before you go into the meetings. Make sure your board members and administrators are educated, you need their support. Do not forget the basics: easements, access, and hydrology. We have a "mitigated" area which now is a static backwater. It fills when the water level rises but never really flushes, a simple problem that was overlooked.

Consider alternative methods to offset budget problems. With increased human population comes increased demands for control. Developers and recreational property owners can be a source of additional funding, especially when faced with unhappy customers and the resulting loss of income. One can also gain other forms of cooperation from the developer. For example, we did get three permanent, hard-wired light trap sites installed at their expense as well as the purchase of the traps. Aerators were installed and are being maintained at the golf course's expense. We also had input regarding the grading of the slopes of the pond margins. While the course management is extremely cooperative, the basic design problems remain.

Future problem areas locally include the Spanish Springs Valley located north of the Truckee Meadows which has 3,000+ acres of agricultural and wetlands. Development plans here include three golf courses, 2,300 acres of parks and wetlands, 200+ acres of business and offices, and 4,000 acres of residential areas. Another project is the Double Diamond Ranch development with 270+ acres of mitigated wetland.

It would probably be prudent for all of us to be aware of similar projects in our own regions and take full advantage of being involved in the planning process.

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COMPUTER MODELING AS A TOOL TO DEVELOP WETLAND DESIGN AND MANAGEMENT STRATEGY

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Introduction.

In yesterday's plenary session a panel of scientists from environmental and vector control agencies discussed the need for coordination of efforts to develop and manage wetlands. We found that the issue was critical because over 100,000 acres of wetlands is scheduled to be created or enhanced in the near future in California. A good deal of effort was expended on the part of the vector control panelists to make a case to assure that vector control interests would be involved at the early stages of wetland design. If we succeed in becoming involved with a multi-disciplinary planning team on wetlands, however, other very serious problem arise that need to be addressed. It is our experience that the team members have great difficulty communicating effectively together because they operate in different paradigms. The result could be serious conflict that can develop into an adversarial rather than a cooperative relationship between team members. This paper discusses a tool that may help resolve the problem: STELLA modelling. Properly used, it can help illustrate to each team member the consequences of his recommendations on the wetlands.

The objective of this paper is two-fold. First, it discusses the use of computer simulation as a tool to aid in design and management of wetlands. Secondly, and perhaps most importantly, it raises the question of how to best solve the planning problems that arise when experts from various disciplines come together to plan wetlands. The intent of the presentation is not to introduce a valid or robust new model of wetlands. We intend to present a case history of the development of a simulation model which has been designed for use as a planning tool.

It is important to state early in the discussion that the wetland model developed by the authors was not utilized officially by the wetland planning team in their decision or policy making. The authors developed the model simultaneously as the planning progressed, involving only five of the team members directly in model development. The authors feel, however, that the exercise provided sufficient positive benefits to warrant recommending the approach be incorporated into wetland planning processes.

Background.

Wetland restoration, creation, and enhancement has been occurring in Alameda County, California, since the early 1970s. It is driven by public policy, supported by environmentalists, and carried out by governmental agencies. Salt marshes that were once "reclaimed" by levees are being restored to tidal action, restoring their function ecologically and providing for the recovery of wildlife populations. More recently, these "diked marshes" have been recognized by wildlife specialists as important as "seasonal wetlands" providing valuable habitat for additional species of wildlife. These wetlands, with levee systems in place, are now being preserved and enhanced to maximize their wildlife value. Both the tidal and the seasonal wetlands represent an extremely valuable resource, supporting wildlife, and protecting endangered species, as well as providing aesthetic, educational, and recreational benefits to man. The salt marshes of Alameda County make up a vital portion of the total San Francisco Bay ecosystem, much of it belonging to the San Francisco Bay Wildlife Refuge.

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These wetlands are all the more valuable because they are adjacent to highly urbanized cities in the San Francisco Bay area, totalling millions of residents.

Problem.

The authors have recognized that a major problem occurs in the process of planning wetlands because of conflicts arising from policies and objectives of various governmental agencies. The authors recognize that conflicts also arise because of the influence of differing paradigms on the participants. The clash of paradigms creates different "realities" different "blind spots" and an inability to communicate effectively (Horgan 1991). Often representatives of agencies take positions that may have severe consequences to other agencies and seem blind to consequences of their proposed actions. They also, at times, are unwilling to give serious consideration to alternative approaches. The authors felt computer simulation could be a valuable tool to be used in the planning process by showing participants the consequences of their positions and by testing alternative approaches to reaching stated objectives. In general, the authors felt that a properly developed model would assist all participants in replacing linear thinking patterns with systems thinking. We are reporting on our first attempts at developing a computer simulation as a tool to wetland planning.

STELLA.

STELLA is computer simulation software developed for the Apple MacIntosh computers. It has emerged from the system dynamics paradigm developed at M.I.T. in the 1950s by Jay Forrester and others. STELLA has features that make it particularly suitable as a planning tool:

1. The simulated systems are represented by easy to understand graphical representations of the parts: Stocks (state variables) depicted by a rectangle which evokes the image of liquid accumulating in a container; flows depicted by a pipe with a valve to regulate the rate of flow through the pipe; converters represented by a circle which convert input to output; connectors depicted by curved arrows that connect stocks to connectors and connectors to connectors.
2. STELLA requires only the first two steps of the typical fours step modelling process (conceptual, diagrammatic, mathematical and computer programming). Computer and math fear are not a factor in the process since difference equations are created automatically for the user based upon the diagramming process.
3. Simulation models can be created fairly rapidly and modifications of a model can be made almost instantly.
4. Graphical representations of the output are easily and quickly generated.

The Planning Conflict.

The major conflict that emerged from the planning process was between representatives of mosquito control and those representing the endangered species. Ground cracks that develop seasonal wetlands create ideal habitat for the California salt marsh mosquito, *Aedes squamiger* (Coquillett). The representatives of mosquito control felt that disking the cracked ground every 7-10 years was necessary if mosquito control was to be effective over the long term. They argued that deepening of the cracks and increased growth of vegetation would increasingly impair the effectiveness of a biorational pesticide program, resulting in increased applications, rising costs and ultimately intolerable numbers of mosquitoes. They felt, because the vegetation regenerated rapidly, that disking relatively small portions of the marsh (phase disking) over a period of years would allow the population of the endangered salt marsh harvest mouse (*Rethrodontomys megalotis*) to recover from any effects of the disking.

Wildlife representatives argued that the mouse population was just now recovering in the salt marshes from a variety of man-induced impacts, and that disking would place the population at risk. They felt that continued applications of biorational pesticides would suffice. The committee as a whole felt that if this conflict could not be resolved, the committee would have to look to novel water management strategies to prevent soil cracking.

Seasonal Wetland Management Model.

The authors (Page and Roberts 1990) felt the model should focus on the disking conflict and, therefore, developed the Seasonal Wetlands Management Model to test alternatives of mosquito control on a seasonal wetland with respect to costs, effectiveness of mosquito control, and impact on the salt marsh harvest mouse. The authors developed the model by interviewing various members of the planning committee representing the fields of wildlife management, mosquito control, and wetlands research. Literature was reviewed as necessary to fill in gaps in the knowledge. Where assumptions or guesses had to be made, the best approximation of an expert was used. The completed model consisted of sixty-one variables. Management options (decision variables) included:

1. Selection of a level of mosquitoes (threshold level) that would trigger an application of biorational pesticides.
2. A depth of soil cracks that would trigger disking.
3. A stocking rate for the planned introduction of salt marsh harvest mice as well as an immigration rate from the surrounding marshes.

The major stocks (state variables) were depth of cracked soil, biomass of pickleweed, number of mosquito larvae, mosquito control costs, number of mosquito complaints by citizens, number of saltmarsh harvest mice, and number of marsh hawks. A time horizon of thirty years was established for the model.

Model Operation and its Impact on the Experts.

The completed model functioned remarkably similar to predictions by the experts, tending to verify the conclusions of the committee (Page and Roberts 1990). Three alternative mosquito control options or scenarios were tested:

1. No mosquito control.
2. The traditional mosquito control program consisting of an established spray threshold of one larval mosquito per dip and disking every seven years (A pint dipper is used in a standard sampling technique to provide a relative measure of mosquito density).
3. No disking with a spray threshold at <0.5 larval mosquito per dip.

Scenario one created a simulated nightmare of mosquito problems as expected. It also showed, as suggested by the wildlife experts, inherent instability of the salt marsh harvest mouse population associated with random flood events on the wetlands. Scenario two solved the mosquito problem, but had severe impact on the salt marsh harvest mouse population because of the impact of disking. Scenario three, the compromise, did not negatively affect the mice but created a mosquito control program which was judged too costly and of limited effectiveness. The model had verified the nightmares of the mosquito control experts; no disking meant increasing costs and decreasing effectiveness of mosquito control efforts. It had also verified the concerns of the wildlife specialists that disking would have devastating and lasting effects on mouse populations that were already unstable. The model, therefore, supported the committees decision to search for other approaches to preventing soil cracking, such as water management.

For the most part, the various experts were interested and positive about the results of the model. A mosquito control expert, while disappointed that his control recommendations (scenario two) did not appear feasible because of negative impact on endangered species, was, however, gratified to see that the simulation did show cost-effective mosquito control. The views of the wildlife experts tended to be supported by the simulations and as would be expected, they did not appear negative to the modelling approach. At the same time, it must be said that they did not appear to have a great amount of enthusiasm for the approach either.

Conclusions.

The simulation model focused on the problems created by disking cracked ground and relying upon pesticides (biorationals) for the purpose of mosquito control. The committee concluded that disking was inconsistent with proper management of the marsh - a conclusion also supported by the model. The committee is currently looking into the possibility of water management as a means to prevent cracking. The model, with some modifications, may also serve to test proposed water management alternatives.

It is the opinion of the authors that computer simulation is a useful tool in planning wetlands. Such an approach could be of value by testing alternative design and management strategies. More importantly, the authors feel computer simulation in an multi-disciplinary setting may be most valuable in helping individuals see and address the negative consequences of their recommendations.

Epilogue.

It must be evident by now that the major problem addressed by this paper is the problem posed when individuals from different disciplines, with their differing paradigms, come together to plan a complex ecosystem. Kuhn (1962) explained how powerful a paradigm can be to a scientific community by providing a fruitful view of reality. He also warned us that there is no one correct paradigm and that all paradigms have their blind spots. Finally, he explained that communication breaks down between adherents of different paradigms (Horgan 1991), and defined this as incommensurability.

When individuals of differing disciplines are brought together to plan wetlands, they spotlight only that part of reality that is visible from the perspective of their paradigm. Much that is important may be left in darkness. The problem of incommensurability creates additional problems because communications between the disciplines is distorted. The resulting frustration may further impair communication. The group view of reality that ultimately emerges is likely to be incomplete and distorted, with many shadowy areas. The problem cries out for a paradigm broad enough to shine a floodlight on the problem while providing a basis for effective communication. Our use of simulation modeling is an attempt at solving the problems.

We realize that planning wetlands is just one part of total environmental planning. We expect that the problems posed by numerous disciplines coming together is currently occurring throughout the country in many planning settings. We feel that an important reason for presenting this paper to the Conference of the California Mosquito and Vector Control Association is to assist members in developing the needed tools and the perspective to be effective partners in wetland planning.

References.

Horgan, J. 1991. Profile: reluctant revolutionary. Sci. Amer. 264(5):40-49.

Kuhn, T.S. 1962. The Structure of Scientific Revolutions. University of Chicago Press, Chicago.

Page, B. and F.C. Roberts. 1990. Seasonal wetland management model. A report presented to Department of Anthropology and Cybernetic Systems, San Jose State University, San Jose, California.

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THE FISCAL IMPACTS OF NEW GROWTH AND DEVELOPMENT ON BUTTE COUNTY MOSQUITO ABATEMENT DISTRICT'S BUDGET

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Introduction.

As a special district, the Butte County Mosquito Abatement District (BCMAD) poses a structural form with public accountability. A special district as defined by the Controller of the State of California is a "legally constituted government entity which is neither a city nor county, established for the purpose of carrying on specific activities within ...defined boundaries". These districts have considerable fiscal and administrative independence from local government. However, the passage of Proposition 13 and the codification of Community Redevelopment Law have reduced these characteristics. Unlike most other governmental agencies, Butte County Mosquito Abatement District provides only one function - the suppression of nuisance and vector mosquitoes.

In 1948 a group of citizens petitioned the Butte County Board of Supervisors to form a special district that could provide mosquito control throughout all of Butte County. Although the Oroville and Durham Mosquito Abatement Districts were formed in 1915 and 1917, respectively, these two districts did not meet the demands for mosquito control in the remaining communities and rural areas of Butte County. Since Butte County government did not have the expertise in the areas of function, finance, and administration necessary for mosquito control, the Butte County Mosquito Abatement District was formed in 1948 to meet the demand of providing this public service to the citizens of Butte County. Presently, the Butte County Mosquito Abatement District includes all of Butte County except the areas of Oroville and Durham which remain separate with their own mosquito abatement districts.

Prior to the passage of Proposition 13, the Butte County Mosquito Abatement District was able to levy fifteen cents ($0.15) on each one hundred dollars of taxable real property value in Butte County. Real property is land, structures, and improvements as opposed to personal property (i.e., vehicles and boats). If the rate exceeded fifteen cents ($0.15), the Butte County Board of Supervisors would require the District to provide information to determine the necessity of their expenditures. Implementation of Proposition 13 not only changed this taxing mechanism but involved two issues: property tax base and property tax rates. It limited annual inflationary increases to 2% and limited property tax rates to 1% of the assessed property value.

Following on the heels of Proposition 13 was Paul Gann's Proposition 4. The legislative interpretation of the Gann Initiative, Assembly Bill 8 (AB8) established a percentage of the tax rate based on the prior three fiscal years starting from 1977. This established BCMAD's present apportionment factor (rate) of 0.01445. This apportionment factor is the amount of property tax that the District receives on assessed property values in Butte County. This is in dramatic contrast to the fifteen cents ($0.15) per one hundred dollars that the District received prior to Proposition 13.

Literature Review.

Empirically-specific studies have not been made to analyze a mosquito abatement district's revenue and its ability to serve its local clientele. Literature review in the Education Index (ERIC) files from 1970 through 1990 has resulted in no studies. The Social Science Index from 1980 through 1990 makes reference to growth rate and tax revenue, although there is no analyzes of a mosquito abatement district's revenue in relation to its ability to provide service. Doctor Harold Chapman, the Executive Director of the American Mosquito Control Association (AMCA), was contacted to determine if any papers have been presented at national or regional conferences or published in applicable trade journals regarding an analysis of a district's budget in relation to its ability to provide service. He indicated that he was not aware of any past studies. The results were the same when the California Mosquito and Vector Control Association (CMVCA) was contacted.

Analysis.

The methodology utilized in this study is a cost/revenue analysis to determine the fiscal impact of growth on the BCMAD's budget. Cost/revenue analysis as referred to in this study is to review the assessed property value of a specific year by calculating the difference in property value, then subtracting the prior year property value for a given year. The 2% property tax increase cap, the inflation factor for the given year, and the mosquito abatement district's apportionment factor will be discounted to produce a per person dollar estimate for funds received by the District in Butte County. This per person dollar estimate will be compared to the BCMAD per capita appropriation figure to determine if Butte County Mosquito Abatement District's service to the public is keeping pace with growth.

The aim of this study is to provide a definitive analysis as to whether new growth and development in Butte County pays for itself in terms of the revenues generated with respect to BCMAD's costs. Since the cost/revenue issue is inextricably tied to the philosophy of taxation, one needs to determine whether the apportionment factor is sufficient to allow the District to provide adequate mosquito services to the people of Butte County.

To determine if Butte County Mosquito Abatement District is providing an effective level of service to the existing and new residents of Butte County, one has to define an effective service level. The following assumptions were made regarding the District's ability to provide a public service, the District is providing an adequate level of service if: 1) no human cases of encephalitis or malaria were reported by physicians to the Butte County Health Department or to the District within the given year, 2) the number of service requests were approximately equal to or less than the previous year (a service request is a call by an individual to the District requesting more service to reduce the annoyance of nuisance mosquitoes), and 3) no reportable cases by a veterinarian to the District of domestic animals having symptoms of mosquito-borne encephalitis or canine heartworm.

Over the four years of the study there has been a steady increase in annual growth of Butte County including increases in assessed property values and population (Table 1). At the same time, Butte County Mosquito Abatement District's budget authorizations and appropriations have similarly increased with the increase in property values.

One also observes that the proportion of BCMAD's revenue appropriated for contingency measures has also subsequently increased each year. It is the policy of the governing board of the Butte County Mosquito Abatement District that 25% of appropriations be set aside for contingencies. The California State Health and Safety Code (Article 5, §2300) authorizes that money necessary for District purposes may also include an unappropriated reserve (emergency fund) for the purpose of defraying unanticipated expenses. The emergency

Table 1. Impact of population and property value growth on BCMAD's budget over a four year period.

Value	Symbol	1990	1989	1988	1987	1986
Population	POP	182,085	176,738	171,870	167,370	164,002
Assessed Property Value	PV	$58,841,960	$54,734,653	$50,120,237	$47,381,930	$44,930,627
BCMAD Authorization	MAD AUTH	$1,494,016	$1,295,034	$1,133,825	$1,077,047*	
BCMAD Appropriation	MAD APP	$1,253,503	$1,062,258	$912,797	$859,116*	
BCMAD Contingency	MAD CONT	$240,513	$232,776	$221,028	$217,931	
Population Change	%POP	3.03%	2.83%	2.69%	2.05%	
Apportionment Factor	AF	0.01445	0.01445	0.01445	0.01445	
Annual Inflation	INFLTN	4.3%	4.3%	4.5%	3.4%	

* $85,000 in Augmentation Funds removed from the 1987 budget since there is no augmentation in subsequent years.

fund shall not exceed 25% of the estimated expenditures for a fiscal year. Although it is the policy of the Butte County Mosquito Abatement District's Board of Trustees that 25% of the District's appropriation be set aside for contingency reserves, the actual amount can vary slightly from year to year as it did in 1987 when only 24% was set aside for this purpose.

Three mosquito abatement district managers in the Sacramento Valley region of the CMVCA were interviewed by telephone to determine what percentage of their yearly budget appropriation is set aside for contingency measures and if this percentage had been in effect for a long period of time. The percentage of revenue set aside for contingency varied from 1% to 8% within these districts and had been more or less at these levels for over five years.

To ascertain if the Butte County Mosquito Abatement District's budget is capable of providing service to the expanding growth in Butte County, a conceptual framework was utilized as a 15-step equation recursive model using the period from 1987-1990 (Table 2).

The BCMAD per capita appropriation was at $5.13 in 1987 and has increased in each of the succeeding years to $6.88 in 1990. The annual increase in assessed property value has also generally risen, although in 1990 a decrease was observed. One possible reason for the decrease was due to only a 7.5% increase in assessed property value from 1989 to 1990 as compared to a 9.2% increase from 1988 to 1989.

This difference is also reflected in the property value increase due to growth only (overall increase less the 2% property tax cap values) and the budget increase due to growth in the period from 1989 to 1990. In addition, the increased revenues to BCMAD on a dollar per new person basis and the BCMAD per capita appropriation levels were nearly comparable in 1988, suggesting that ability to service was barely keeping pace with growth. The differential between these two figures was comparable in 1987 and 1990 although in 1989 a significant difference between the BCMAD per capita appropriation and increased revenues per new person revenues was observed due to a larger increase in assessed property value that year.

After adjustments for inflationary costs, the adjusted property value accounting for the 2% property tax cap and inflation is higher in 1989 than 1990. This was again due to the 9.2% increase in assessed property values from 1988-89 as compared to only a 7.5% increase in 1989-90.

In comparing the BCMAD per capita appropriations with increased revenues after adjustments for inflation, the differentials between these two figures in 1987 and 1990 were nearly identical with the large differential observed in 1989 once again resulting from the higher assessed property values, while the differentials observed for 1988 were much smaller, suggesting that the District could minimally provide service to increased growth in Butte County during that year.

While it appears the District's operating budget was sufficiently capable of keeping up with the increased demands of growth in three of the four years examined, the budgetary policy and alternatives to the Butte County Mosquito Abatement District should be more closely examined in case decreases in assessed property value should occur again. The District's policy to set aside 25% of the budget appropriation for contingency measures is not common in other districts. In the surveyed districts of the Sacramento Valley region, contingency levels were less than 10%. If the Butte County Mosquito Abatement District had (in 1988) set 10% of its budget appropriation aside in contingency instead of 25%, approximately $200,000 could be have been added to the operating budget. The additional revenue would provide a differential between the BCMAD per capita appropriation and the revenue increases adjusted for inflation similar to that observed in 1987 and 1990 (Table 3). This revenue would have recovered some of the revenue short fall created by decreased property values in 1988.

Since property tax is the single most important source of revenue to California mosquito abatement districts and with the decrease of this revenue imposed by the implementation of Proposition 13, there is generally an increasing interest in finding substitutes to this revenue source. One alternative available to all mosquito abatement districts within the state is the formation of benefit assessment districts. This benefit assessment can cover the District as a whole or a single defined area (zone). The District Board may institute projects for one or more zones for the purpose of financing and execution of vector surveillance and control projects of common benefit to the zone or zones (California Health and Safety Code, §2291.2). Another alternative is the use of a service charge against all or some parcels of land within the District to pay

Table 2. Estimates of BCMAD's ability to fund growth over a four year period using a 15-step equation recursive model. Sample formulas are based on 1990 figures.

Step	Factor	Symbol	Formula	1990	1989	1988	1987
1	BCMAD Per Capita Appropriation	APP/PERS	MAD APP90 / POP90	$6.88	$6.01	$5.31	$5.13
2	Property Value Increase	ΔPV	PV90 - PV89	$4,107,307	$4,614,416	$2,738,307	$2,451,303
3	Property Value Change	%PV	ΔPV90 / PV89	7.5%	9.2%	5.7%	5.4%
4	Property Tax Cap	CAP	2.0%	2.0%	2.0%	2.0%	2.0%
5	Property Tax Cap Value	CAP VAL	CAP90 x PV89	$1,094,693	$1,002,405	$947,639	$898,613
6	PV Increase Due to Growth	ΔPV(GRWTH)	ΔPV90 - CAP VAL90	$3,012,614	$3,612,011	$1,790,668	$1,552,690
7	Apportionment Factor	AF	0.01445	0.01445	0.01445	0.01445	0.01445
8	Budget Increase Due to Growth	ΔBDGT(GRWTH)	ΔPV(GRWTH)90 x AF90	$43,532	$52,194	$25,875	$22,436
9	Population Increase	ΔPOP	POP90 - POP89	5,347	4,868	4,500	3,368
10	Revenue Increase Per New Capita	ΔREV/PERS	ΔBDGT(GRWTH)90 / ΔPOP90	$8.14	$10.72	$5.75	$6.66
11	Cost	COST	ΔPOP90 x APP/PERS89	$32,135	$25,849	$23,085	$16,402
12	ΔPV Due to Inflation	ΔPV(INFLTN)	ΔPV(GRWTH)90 x INFLTN90	$129,542	$155,316	$76,999	$66,766
13	ΔPV Adjusted for Cap and Inflation	ADJ ΔPV	ΔPV(GRWTH)90 - ΔPV(INFLTN)90	$2,883,072	$3,456,695	$1,713,669	$1,485,924
14	ΔBDGT Adjusted for Cap and Inflation	ADJ ΔBDGT	ADJ ΔPV90 x AF90	$41,660	$49,949	$24,762	$21,472
15	Adjusted ΔBDGT Per New Capita	ADJ ΔBDGT/PERS	ADJ ΔBDGT90 / ΔPOP90	$7.79	$10.26	$5.50	$6.38

Table 3. Projected effects on BCMAD's budget over a four year period if $200,000 in contingency reserves is annually transferred to appropriations.

Value	1990	1989	1988	1987
Projected Budget Appropriation	$1,453,503	$1,262,258	$1,112,797	$1,059,116
Projected Per Capita Approprtiation	$7.98	$7.14	$6.47	$6.33
Projected Inflation-Adjusted Appropriation	$7.79	$10.26	$5.50	$6.38

for the cost of vector surveillance and control (California Health and Safety Code, §2270). Recently, the Butte County Mosquito Abatement District implemented two benefit assessments, and to date, there has been one service charge on all parcels of land.

The fiscally conservative District Manager currently heading the District has been able to provide service to the growth demands of Butte County despite having 25% of budgetary appropriation set aside for contingency measures. This seemed to be effective in three of the four years examined. If a more liberal budgetary process were allowed in which only 10% of the budget appropriations are placed in contingency, the results could be different and of greater benefit to the District.

Using the pre-defined assumptions concerning the relationship between the presence of mosquito-borne diseases and number of received service requests to the District's level of service, it must be assumed that throughout this period, despite the ups and downs of budgetary positions, BCMAD was able to provide adequate or at least historically-equal levels of service. The number of service requests received by the District did not significantly differ during 1987 (402), 1988 (509), and 1989 (541) with a comparable number (347) being received through October of 1990. In addition, there were no reported cases of mosquito-borne encephalitis and only a single case of human malaria reported from the county during this same period.

In conclusion, it appears that in 1987, 1989, and 1990 the increase in local tax revenues to the District attributable to the increases in assessed property values in Butte County provided sufficient funds to maintain an effective level of service. However, in 1988 revenues received through new growth barely kept pace with the District's expenditures to provide service.

It is the opinion of the writer that the demands of service related growth, the budget revenues, and the District's policy on contingency reserves need to be re-examined. It is reasonable to assume that if the adjusted for inflation revenues brought on through new growth is less than the BCMAD per capita appropriation, one needs to examine whether assessed property values are growing too slowly, growth expanding too fast, or the apportionment factor too small to avert a budgetary dilemma similar to that which occurred to the District in 1988.

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ESTABLISHING AN ARTIFICIAL AQUATIC WEATHER STATION AND ITS RELATION TO ALAMEDA COUNTY MOSQUITO ABATEMENT DISTRICT'S COMPUTER SIMULATION (ECOSIM)

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ABSTRACT

Alameda County Mosquito Abatement District uses a temperature-dependent larval growth computer model (ECOSIM) for the simulation of larval mosquito growth. This paper discusses previous techniques used by the district to obtain temperature data for the model and present techniques and materials used in the artificial aquatic weather stations. Conclusions about the temperature data which is now available and the possible direction of future effort's by the district are also discussed.

Introduction.

A computer model (ECOSIM - Evolving COmputer SIMulation) has been developed in the Alameda County Mosquito Abatement District (ACMAD) to assist technicians in creating daily inspection/treatment schedules of larval mosquito sources (Roberts et al. 1990). The validity of the model is heavily dependent upon accurate predictions of larval source temperatures. Recent evaluations of the temperature subroutine used to predict source temperatures in ECOSIM suggested that improvements were necessary to bring the model to acceptable levels of reliability (Mead et al. 1990). This paper will discuss the design, operation, and evaluation of artificial aquatic weather stations aimed at accomplishing the desired improvements. The use of artificial stations was selected from a number of options because of their high potential to provide highly accurate, yet very economical, real time temperature data to simulate larval growth in ECOSIM.

Techniques.

Ideally, temperatures would be taken from each known source within the ACMAD and utilized in a model to simulate larval growth at each site. However, this technique is prohibitively costly, as well as being unwieldy in implementation. Therefore, techniques were devised which limited the number of sources necessary for monitoring. General source types, consisting of nine groupings, were used to characterize all sources within the district (Table 1). This technique allowed any technician to evaluate a source in terms of its potential for heating, and therefore its potential for larval growth.

An On-site Weather Logger (OWL) was used to obtain 24-hour water and air temperature profiles for a variety of larval sources. When these temperature profiles were compared, most sources exhibited one of three basic profiles (plus or minus a correction factor). Analysis of the physical attributes of these sources (Mead et al. 1990) indicated a distinct separation of the sources into three resultant source types: Shallow, Deep, and Subterranean. The first group, Shallow sources, are less than one foot deep and have relatively clear, still water. The second group, Deep sources, are deeper than one foot and have relatively clear water. The final group, Subterranean sources, are below ground level with a very stable 24-hour temperature profile, implying that underground larval production sources are buffered from extreme temperature fluctuations by the mass of concrete

Table 1. Categorization of larval sources found within ACMAD based upon temperature profiles and key indicator(s) used to characterize them.

	Source Type	Key Indicator(s)
1	subterranean (cold)	underground, open to air
2	subterranean (warm)	underground, closed to air
3	shallow (cold)	<12" deep, 50% shaded or flowing
4	shallow (warm)	<12" deep, little shade, not flowing
5	deep (no vegetation)	>12" deep, no vegetation
6	deep (vegetation, hot)	>12" deep, vegetation, no shade
7	deep (vegetation, cool)	>12" deep, vegetation, 50% shade
8	deep (turbid)	>12" deep, water turbid
9	very deep	>4' deep, deep source

and/or earth around them.

Further analysis suggested that ACMAD larval sources were divided into three distinct climate/temperature regions (Fig. 1). A statistical analysis of National Weather Service Data for the daily high temperatures in Alameda County further reinforced this conclusion. The three climate regions are designated: 1) South area, including the cities of Fremont and Union City; 2) North area, including Hayward, San Leandro, Oakland, Alameda, and Berkeley; and 3) East area including those areas east of the coastal hills including Pleasanton, Dublin, and Livermore.

History.

Having determined the type of sources needing to be monitored, it became apparent that specific data from each of the three source types (Shallow, Deep, Subterranean) as well as nearby ambient temperatures were necessary from within each of the previously defined climate regions (North, South, East).

Historically, it was a technician's duty to record temperatures in representative source types within their assigned area (zone) of responsibility. The technician would attempt to take larval source temperatures at the hottest point of the day, thereby obtaining a theoretical high temperature for that source for that day. This process introduced two possible sources of error: 1) selecting a representative source type and 2) measuring the high temperature at that source. Standardization of technique was difficult as no two sources or technicians were the same. Also, since temperatures were collected only three days a week, there was a time lag between temperature data collection and utilization of the data within the ECOSIM model. The ECOSIM model simulates larval mosquito growth by predicting that a generalized source type will produce adult mosquitoes in a certain number of days or weeks given the current temperature regime.

To limit the effects of technique error, a technician was hired to measure larval source temperatures three days a week at all of the previously selected representative source types within each of the three climate regions. This technician further attempted to measure the sources at the coolest time of day (5 AM to 8 AM). This decision was based on the 24-hour temperature profiles which showed that a source's high temperature is reached for only a short while, but the low temperature generally occurs during an early morning window of time. This change in monitoring resulted in a reduction of error since the high temperature was often missed in monitoring.

Once the source low temperature had been obtained, a computer model utilizing National Weather Service Data for the corresponding high and low temperatures was used to mathematically derive an average temperature for that source type in that climate region, which could then be utilized by ACMAD's larval growth simulation ECOSIM model. ECOSIM applied this average temperature

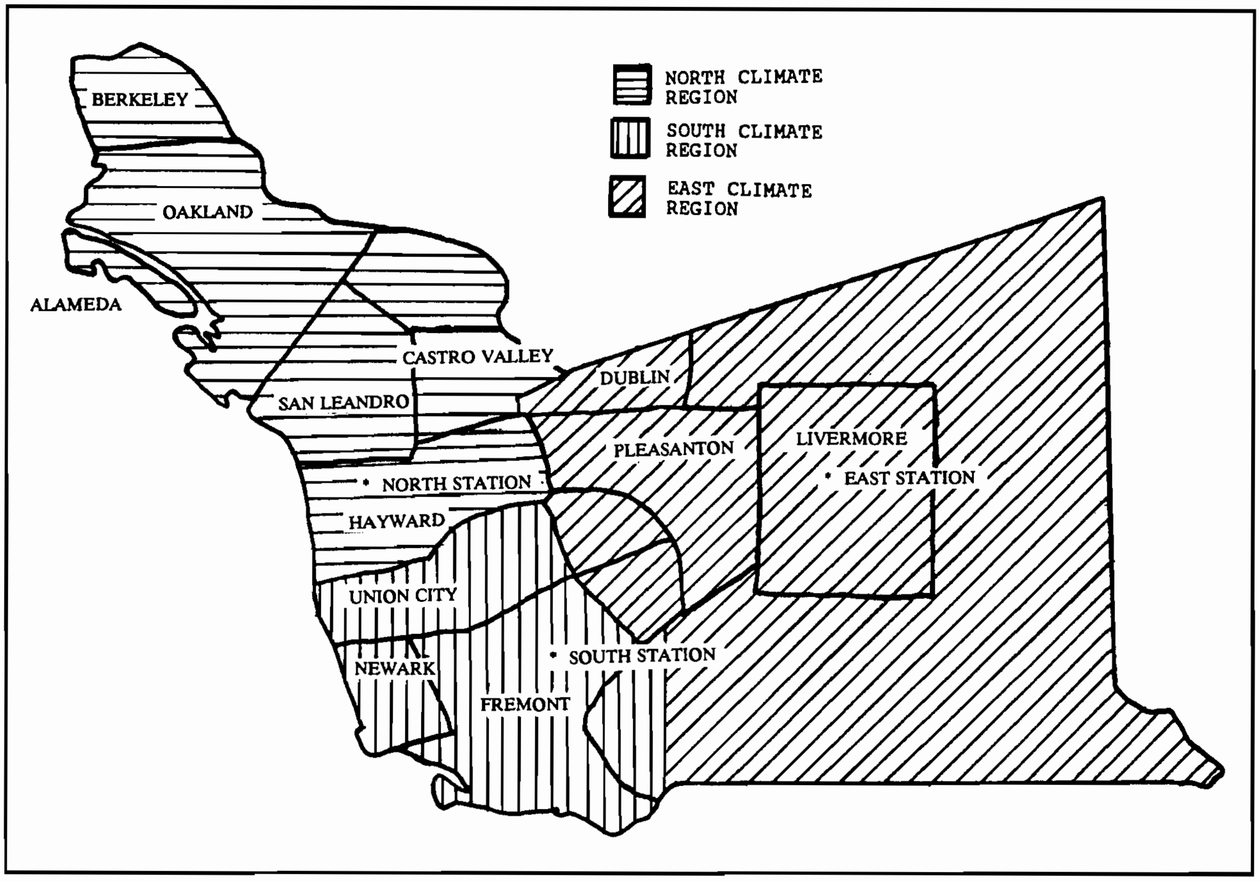

Figure 1. Map of ACMAD indicating the major cities, three climate regions, and three artificial aquatic weather stations established by the district to monitor weather parameters within each region.

to all similar larval source types (Shallow, Deep, Subterranean) for that climate region (North, South, East) to predict the rate of larval growth in that area. Although this methodology was able to further reduce the temperature collection error problems encountered before, the district model still relied on a mathematically derived average temperature. Additionally, this technique still collected data only three days a week, introducing the possibility that the data time lag was leading to a certain amount of inaccuracy within the model for temperature data derivation. This technique also required one technician to devote three days a week to temperature collection, thereby increasing the expense and liability incurred by the district.

A more timely system which would offer more precise data was of primary concern to the district. Rather then having technicians or other district personnel collect temperatures, it was decided that some form of electronic temperature measuring and storage device should be used. This system would eliminate not only the standardization problem but also the time lag problem by using a telephone line and modem to transmit data daily. In theory, a temperature logging device would be placed in each of the three climate regions on a site that contained all three naturally occurring source types in close proximity. However, no such pre-existing natural sites occurred within the county. Therefore, artificial sources, sources that closely mimic actual sources, would have to be established in each climate region.

A study was conducted in which 24-hour temperature profiles for various commercially available containers were compared with profiles of nearby natural sources. Only containers that fit the source type definition were compared against the corresponding natural source type, e.g., a tray with depth less then 12 inches was compared with a Shallow source, a container of depth greater then 12 inches was compared with a Deep source, etc. The container with the most favorable comparison between its profile and the natural source profile was chosen as the artificial source and was included into the artificial aquatic weather station (Fig. 2).

Paralleling this study, a search was conducted for the best electronic measuring and storage device. Four major factors were considered in the selection process: 1) Ease of use - the device should be simple to use for both trained and untrained personnel; 2) Versatility - more than one weather parameter should be able to be measured at the same time thereby allowing the district the ability to incorporate more factors into the model as needed; 3) Cost - the cost should be low enough so that multiple units could be purchased without taxing the district's budget; and 4) Accuracy - the unit should give an accurate reading for any parameter chosen.

Initially, public and private agencies were contacted for available for weather data collection devices. Literature studies were then conducted on those devices mentioned most frequently by the agencies contacted. After an extended study, the best device for the job was determined to be the On-site Weather Logger (OWL) already in the district's possession. Because the OWL features a Tandy laptop computer programmable in BASIC, it is easy to use and cost efficient. Since the laptop computer includes a built-in modem, it has the capability to transmit data over the phone line. Also, the OWL has the ability to measure 15 different weather parameters (eight at any one time), thereby making it the most versatile of all devices studied.

Materials.

Having completed the necessary studies, the district was ready to implement the concept. Implementation required that suitable sites be found for locating the weather stations, so a survey was conducted for the best site available in each of the three climate regions. Each possible site was evaluated with respect to its security, exposure to weather, proximity to a phone line, ease of access, and its probable length of service. In general, property publicly owned, by either a city or the

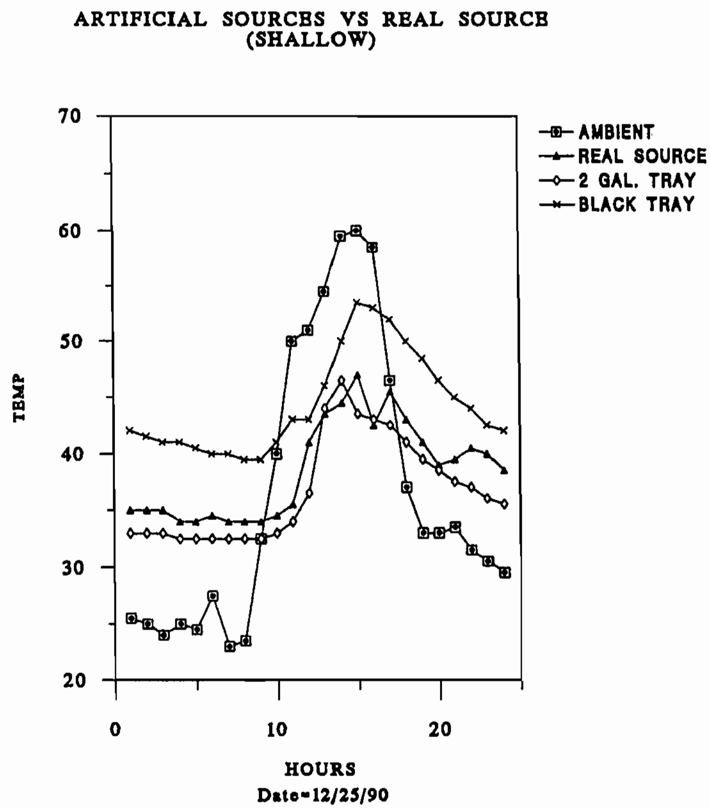

Figure 2. Example data generated from one of 14 separate tests to determine the best artificial source for a source type. Generally 2-6 commercially available containers were compared per test.

county, best fulfilled the needed prerequisites. Again, county agencies and municipalities were contacted and told of our needs. Through this process, suitable sites were obtained from the cities of Fremont and Livermore and construction of the artificial weather stations began.

Each artificial aquatic weather station consists of a 5' X 5' plot of land on which three artificial sources are constructed, representing the three main source types in the district. The artificial shallow source consists of a 12" X 18" X 4" tray of water and the artificial deep source is a 10 gallon circular bucket with a diameter of 18" and a depth of 16 inches. Both of these sources are buried in the soil to more accurately simulate real sources. The artificial subterranean source is a 6" diameter ABS plastic pipe buried to a depth of 6 feet. Located at the bottom of this pipe is a small ABS plastic "cup" that holds the water from which the temperature is obtained. The water levels in the artificial deep and shallow sources are maintained for the short term by float valves connected to a five gallon reservoir. Temperatrre probes from the OWL are placed in each source to obtain the necessary data and ambient temperature is measured by a probe located at a height of six feet above ground level.

To decrease the likelihood of small animals and people falling into the sources, a cage was constructed to shield the station but not to interfere with the sources' interaction with the environment. The OWL strobes the temperature probes every two minutes and logs the data to memory every hour. Just before midnight, at a pre-programmed time, the OWL dials up the district's computers and downloads the day's data over the phone line. The data is then made available to the district's ECOSIM model. ECOSIM derives a 24-hour average from this data for each source type and applies this temperature to the model. Each station is serviced on a biweekly basis by a technician, who replaces the used battery with a recharged one, and tops off the reservoir with water.

Future Plans.

With the installation of the monitoring device, the system as described above is expected to increase the reliability of ECOSIM. Figure 3 shows an example comparison of the artificial weather station's shallow sources with the temperature profile from a nearby real shallow source. The accuracy of the artificial source in mimicking the ambient temperature and heating and cooling of the real source is demonstrated by the relatively high correlation coefficients (r^2) of 0.88 and 0.93, respectively. Future validation studies will be conducted to determine the increase in general reliability. In the meantime, however, the most important future tests of the stations will be definitive statistical studies comparing concurrent temperature data from existing sources with that data obtained from the artificial sources. Towards this end, the district is obtaining a portable device that will provide 24-hour temperature profiles for any source. This device will be used to validate and/or refine the present sources contained in the stations.

Another envisioned refinement is the establishment of other artificial aquatic weather stations within the county. This development will help define the climate regions within the district and may actually lead to the establishment of a fourth climate region. This change is dependant, however, on the validation process mentioned above.

Another envisioned modification involves the ECOSIM model itself. Because the data received from each station is in the form of an hourly reading, the data could be used by the model to "grow" the mosquitos on an hourly basis, adding another significant advance in reliability since, at present, ECOSIM uses the data on a daily basis by obtaining a 24-hour average and then applies this figure to a mosquito growth algorithm. Incorporation of this iterative modification would be dependant on two factors: 1) Would this added complexity actually amount to any more efficiency in the real world? and 2) Is there a computer processor that could perform the calculations in a timely fashion and still be cost efficient?

Conclusions.

In conclusion, the artificial aquatic weather stations are viewed by the district as the most efficient and economical way to provide temperature data to support district computer simulations. The inception of this system eliminated previous data collection errors inherent in the older methods. Moreover, the new system provides a 24-hour temperature profile as opposed to the singular temperature provided by the previous methods. Also, the data is much closer to real time data, making it more useful to the district (Table 2). With future refinements, it is expected that the artificial aquatic weather stations will provide the district with even more accurate, usable data.

Table 2. Summary of improvements in larval source temperature data gained by utilizing artificial weather stations over historical measures.

	Artificial Station	Historically
1	Real time data	48-Hour time lag in data usage
2	Building a large data base for future analysis	Singular event data (one temperature reading)
3	24-Hour temperature average used	Hi/Lo average used
4	Actual high temperature used	Derived high temperature used
5	Eliminates manual data collection costs	High costs and maintenance requirements
6	Standardization of measurement techniques	No standardization of techniques
7	Sources remain constant throughout the year	Sources change seasonally
8	Flexibility in site modification (as needed)	No or little site modification possible
9	Ease in comparision of data (24-hour profile)	No comparisions available (see #2 above)

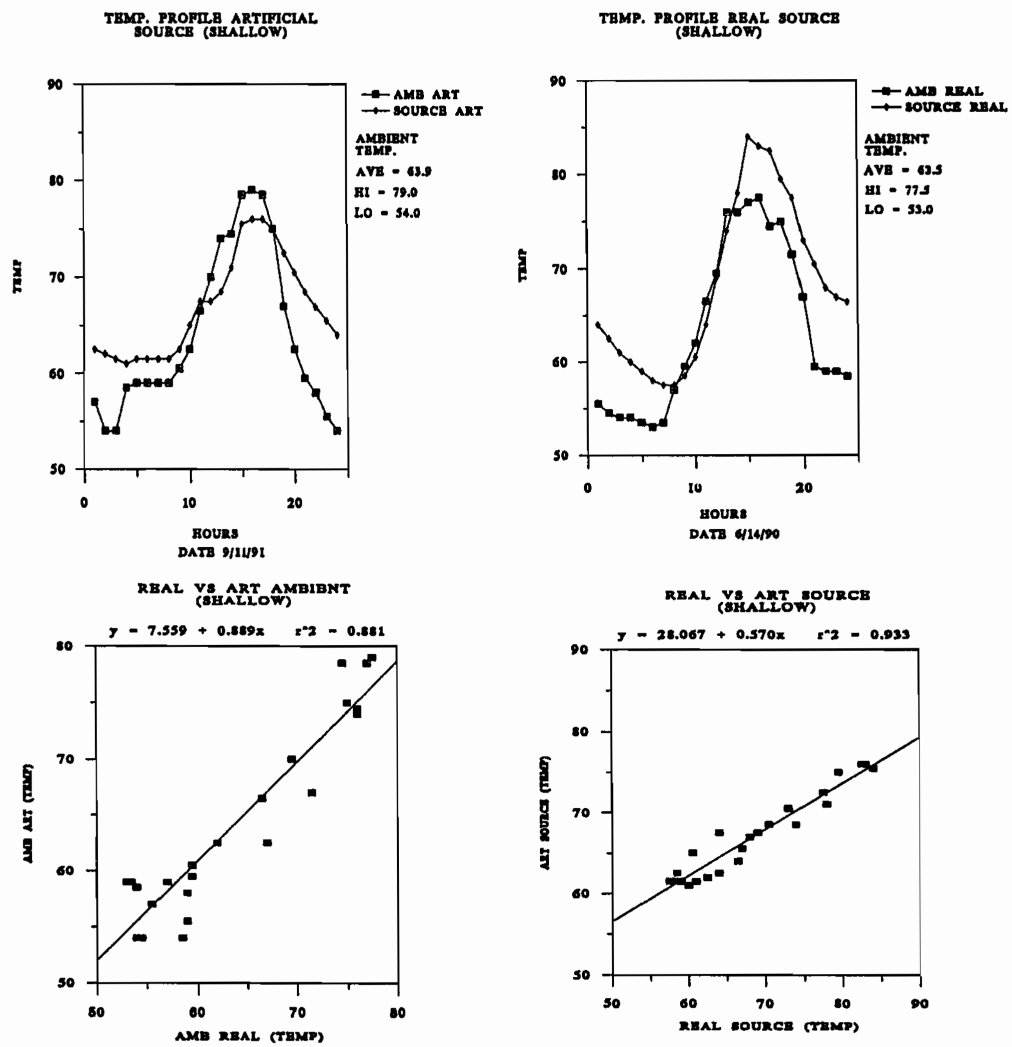

Figure 3. Comparison between real and artificial source (shallow) temperature data. Artificial and actual temperature data were compared if ambient temperature parameters were roughly the same (high, low, mean).

Acknowledgments.

The authors gratefully thank Fred Roberts, Wes Maffei and the other employees of the Alameda County Mosquito Abatement District for their assistance in the design and construction of the artificial weather stations. Their understanding and willingness to accept this new technology will create a more effective and efficient program for mosquito control.

References.

Mead, S.S.,T.J. McMahon and W.A. Maffei. 1990. Prediction of larval source temperatures by an Evolving Computer Simulation (ECOSIM) of mosquitoes. Proc. Calif. Mosq. Vector Control Assoc. 58:81-85.

Roberts, F.C., G.E. Conner and P.S. Turney. 1990. An Evolving Computer Simulation (ECOSIM) of mosquitoes to support a larval control program in Alameda County, California. Proc. Calif. Mosq. Vector Control Assoc. 58:70-78.

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ROOF RAT HARBORAGE ASSESSMENT IN THE KERN MOSQUITO AND VECTOR CONTROL DISTRICT

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Introduction.

Beginning in July, 1991, the Kern Mosquito and Vector Control District (KMVCD) initiated a roof rat (*Rattus rattus*) control program in response to an increase in the number of rat complaints that were directed towards the City of Bakersfield, the Kern County Health Department, and the KMVCD Board of Trustees. Funding for the program was obtained through a legal tax assessment on all improved parcels within the KMVCD. Before the KMVCD Board of Trustees approved the program, a cursory survey of infested sections of Bakersfield in 1989 by E.W. Mortensen (consultant) revealed that much of the roof rat infestation in the city was attributed to the presence of optimal harborage conditions coupled with the prevailing mild climate of the southern San Joaquin Valley.

High numbers of roof rats were associated with landscape vegetation, refuse in backyards, abundance of fruit trees and uncovered garbage. Since these conditions greatly influence the maintenance of roof rat populations, our first major challenge was to establish a harborage rating system that could be used to quantify harborage conditions at private and business residences. An overall understanding of harborage types and their distribution patterns within the KMVCD would be essential in developing roof rat management strategies. This paper presents the results of our initial roof rat harborage assessment of improved parcels within the Kern Mosquito and Vector Control District.

Assessment and Harborage Criteria.

The location of individual roof rat service requests are recorded and mapped by grid using an alpha-numeric system of codes for urban (1 sq. mi.) and rural (4 sq. mi.) sections. Letter codes for section columns (alpha component) are from west to east and number codes for section rows (numeric component) are from north to south. For example, the section code for the KMVCD headquarters is BF3 where "B" is the designation for the greater Bakersfield area, and the District is located in a section (1 sq. mi.) designated by column "F" row "3".

The grid for the greater Bakersfield area, including Oildale, Green Acres, and Greenfield, consists of 186 coded sections of which 121 sections represent predominately peridomestic or mixed agricultural environs where there is a potential for future urban expansion. The remaining 65 sections represent heavily urbanized commercial and residential developments. Our harborage assessments were limited to parcels contained within 24 urbanized sections that were selected at random from the 65 sections designated as heavily urbanized. Harborage at parcels located within the satellite communities of Wasco, Shafter, Lamont, Arvin, and Buttonwillow also was assessed. However, harborage assessments were limited to only one section selected at random from each of those communities.

Within each of 24 urbanized sections in the greater Bakersfield area, 100 (2,400 total) individual improved parcels (private residences) were assessed for harborage conditions. An additional 200 (850 total) parcels were assessed per satellite community; only 50 parcels were assessed in the community of Buttonwillow. Improved parcels were selected at random as follows: ten streets within each section were selected at random and every third parcel on the same side of the street was assessed. In the case of short streets with few parcels, the remaining parcels were selected from the opposite side of the street using the same every third parcel selection process.

Harborage conditions and roof rat food resources associated with each improved parcel were assessed by a set of criteria that was used to develop a simplistic system of harborage categories. Prior to beginning the assessment process, our roof rat technicians were instructed on how to evaluate parcels and designate category status. Table 1 outlines the criteria used to characterize conditions or collective conditions that delineated our designation of a Category 1, Category 2, Category 3, and Special Category parcel. Parcels without substantial harborage or food resources were not rated and were considered free of any conditions that would obviously promote the utilization by roof rats.

The Special Category designation was given to the presence of one or more unpruned fan palms on the parcel being rated. Unpruned fan palms are used extensively by roof rats in urban situations and we consider them as "prime" harborage in the KMVCD. Category 1 parcels were characterized by either 1) extensive growths of ivy, cypress, tam juniper, or other types of landscaping that formed thickets of cover and/or 2) extensive refuse and wood piles located somewhere on the premises. Category 2 parcels were rated according to a number of conditions that together (e.g., 3 of 4 conditions) would provide potential roof rat harborage. Category 3 was created to account for rating parcels on the basis of roof rat food resources. The principal criteria for that category were 1) the presence of fruit trees with either ripe fruit still hanging on the tree or fruit that has fallen to the ground and 2) uncovered garbage or damaged garbage container that would give access to foraging rats.

Results of Harborage Assessments.

Results of harborage assessments corroborated the earlier cursory findings of E.W. Mortensen and also indicated that harborage conditions were much more widespread than we had anticipated. Overall, gross harborage conditions were related to socioeconomic status where harborage in low income housing tracts was predominately the result of poor sanitation (e.g., backyard refuse and abandoned vehicles) while harborage in upper to middle class neighborhoods was created by the presence of extensive and variably maintained landscaping (e.g., unpruned fan palms and Italian Cypress).

Summaries of our harborage assessments conducted in the KMVCD during August and September, 1991, are presented in Table 2 and Figure 1. The city of Bakersfield was subdivided into four geographic areas or sections to facilitate different regional assessments. Included in the greater Bakersfield area and surveyed separately were the communities of Oildale, Green Acres, and Greenfield. Both central and northeast Bakersfield are heavily infested with roof rats. High levels of infestation in those sections of the city reflect harborage conditions that are typical of older neighborhoods, such as 1) extensive vegetation, including numerous unpruned fan palms, and fruit trees, and 2) backyard refuse. South and southwest Bakersfield represent generally newer neighborhoods with more expensive housing. Even though most properties in the newer neighborhoods are well maintained, roof rat infestations are still relatively high as a consequence of 1) extensive, but

Table 1. Assessment criteria for determining the category of roof rat harborage associated with selected residential and commercial parcels within the KMVCD.

Assessment criteria	Category			
	Special	1	2	3
Unpruned fan palm	X			
Extensive dense vegetation		X		
Extensive refuse/wood pile		X		
Localized dense vegetation			X	
Localized refuse/wood pile			X	
Abandoned automobile(s)			X	
Premise or utility shed with access			X	
Damaged dumpster or uncovered garbage				X
Unharvested fruit or fruit on ground				X

well maintained landscaping and 2) fruit trees. With the exception of Oildale, only a few parcels in Green Acres and Greenfield rated a Category 1 or 2 assessment. Most roof rat infestations in those communities are related to readily available food resources.

The economic status among residents of Bakersfields' satellite communities is mostly lower to middle income. Overall harborage conditions in those neighborhoods are unfortunately related to a general lack of understanding of proper sanitation practices. The existence of poor sanitation is clearly indicated by the prevalence of Category 2 parcels. For example, in a rural agricultural community like Arvin with a significant roof rat infestation, a noticeable portion of the parcels surveyed had backyard fruit trees, refuse piles, poorly constructed utility sheds, abandoned automobiles and neglected landscaping. Under these conditions, roof rats would be expected to have "free access" to a variety of harborage types and food resources.

One of our major concerns after conducting this survey was the overall lack of sanitation in neighborhoods regardless of neighborhood or family income (Table 2, Fig. 1). At least one in every three surveyed parcels had either uncovered garbage or the garbage container was damaged in such a

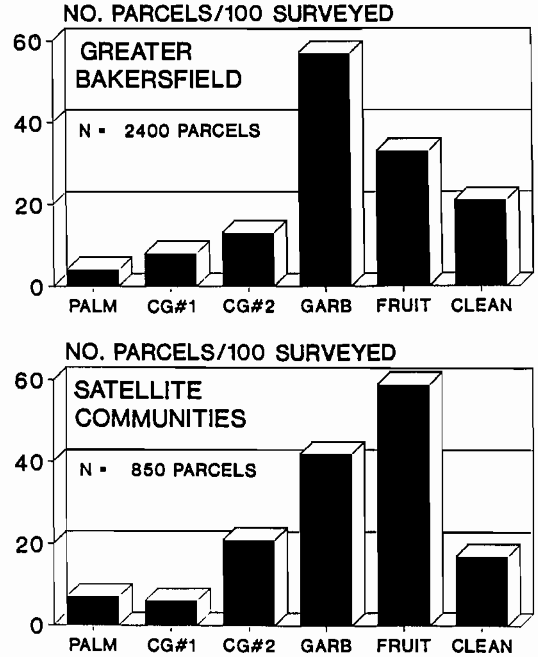

Figure 1. Roof rat harborage conditions per 100 surveyed parcels in greater Bakersfield and its satellite communities during August and September of 1991.

Table 2. Results of roof rat harborage assessments of greater Bakersfield and its satellite communities within the KMVCD during 1991.

Area Section or City	Parcels surveyed	Unpruned fan palm	Category 1	Category 2	Garbage	Fruit	Clean
Greater Bakersfield							
Northeast	500	26	44	89	178	269	100
Central	600	30	48	120	234	386	65
South	400	12	27	311	97	177	111
Southwest	300	11	42	25	145	174	58
Oildale	400	6	24	30	101	230	110
Green Acres	100	1	4	4	13	49	37
Greenfield	100	5	3	13	22	65	24
Satellite Communities							
Buttonwillow	50	15	5	21	13	26	13
Wasco	200	6	13	40	92	126	34
Shafter	200	4	1	29	47	122	32
Lamont	200	17	16	52	76	104	36
Arvin	200	17	11	36	134	119	27
Totals	3250	150	238	490	1152	1847	647

way that rats could gain access to forage. A successful program limiting roof rat access to garbage will require considerable collateral effort from local city and county agencies.

Our roof rat harborage assessments of improved parcels was an attempt to characterize and quantify the extent of roof rat harborage and food resources present within the KMVCD service area. A more thorough understanding of the distribution patterns of harborage conditions and types of food resources available to roof rats should be obtained prior to initiating management operations. The harborage assessment process has clearly benefitted our roof rat management activities by allowing the KMVCD to develop different management strategies based upon local conditions and available resources.

Acknowledgements.

We gratefully thank Veachel Geer, Mona Fuller, Steve Freeman, and Joe Neri, Jr. of the Kern Mosquito and Vector Control District for their efforts in conducting the harborage assessments of selected parcels in the cities of Bakersfield, Arvin, Buttonwillow, Lamont, Shafter, and Wasco.

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THE DESIGN AND USE OF A MODIFIED REITER GRAVID MOSQUITO TRAP FOR MOSQUITO-BORNE ENCEPHALITIS SURVEILLANCE IN LOS ANGELES COUNTY, CALIFORNIA

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Introduction.

Following the 1984 outbreak of 21 cases of St. Louis encephalitis (SLE) in the Los Angeles metropolitan area, researchers have tried to determine the relative importance for virus transmission of several mosquito species in the Los Angeles Basin. Studies have focused primarily on three *Culex* species: *Culex tarsalis* Coquillett, *Culex quinquefasciatus* Say, and *Culex stigmatosoma* Dyar.

Historically, *Cx. tarsalis* has been recognized as the primary rural encephalitis vector in California (Reeves and Milby 1990). However, its role in virus transmission in suburban, peridomestic environments of southern California is not well defined. *Culex tarsalis* breeding is not widely abundant and occurs mostly in isolated marsh/riparian habitats; consequently, adult densities are low in most suburban areas of the Los Angeles Basin (Reisen et al. 1990). *Culex stigmatosoma* is also sampled infrequently in residential neighborhoods (Reisen et al. 1990). It rarely bites humans (Reisen and Reeves 1990) and is considered only a secondary vector of SLE virus (Reeves and Milby 1990). *Culex quinquefasciatus*, on the other hand, is abundant in suburban, peridomestic habitats of southern California (Schreiber et al. 1989, Reisen et al. 1990). Females of this species have the lowest experimental vectorial capacity of the three (Hardy and Reeves 1990) and are rarely found infected in nature; consequently, this species is also considered only a secondary vector of SLE virus in California (Reeves and Milby 1990).

In spite of its lesser vectorial status, some researchers have concluded that a few cases during the 1984 epidemic may have resulted from contact with infected *Cx. quinquefasciatus* females in suburban, peridomestic environments (Tsai and Mitchell 1989). Furthermore, in Texas and other midwestern states, *Cx. quinquefasciatus* has been implicated as the vector responsible for urban SLE epidemics (Sudia et al. 1967).

Prior to 1986, no collection methods were very successful at catching representative samples of adult *Cx. quinquefasciatus* in suburban neighborhoods. Standard CO_2-baited traps (Sudia and Chamberlain 1962) have proven highly effective at collecting *Cx. tarsalis* females in rural habitats, but only marginally efficient at catching *Cx. quinquefasciatus* in urban areas (Sudia et al. 1967, Reisen and Pfuntner 1987). Other collection techniques, such as bird-baited lard can traps (Bellamy and Reeves 1952) and walk-in red boxes (Meyer 1985), have proven equally ineffective at capturing *Cx. quinquefasciatus* females in suburban localities (Reisen and Pfuntner 1987). Considering the abundance of *Cx. quinquefasciatus*-positive breeding sources in the Los Angeles Basin, dry ice-baited traps and other collection methods have often drastically undersampled the adult population.

In the past few years, the CDC gravid or Reiter trap (Reiter 1983) has been recognized as an excellent device for collecting a variety of *Culex* species associated with urban/suburban habitats. This trap collected large numbers of *Culex* mosquitoes when used in Memphis, Tennessee for disease surveillance, averaging 140.6 females (over 95% gravid) per trap-night (Reiter et al. 1986).

Unlike CO_2-baited traps which collect mostly unfed nullipars (Reisen and Pfuntner 1987), gravid traps catch mostly ovipositing females that have imbibed and digested at least one blood meal. Collections of large quantities of gravid females increase the probability of recovering virus-infected mosquitoes, thereby enhancing the sensitivity of an encephalitis virus surveillance (EVS) program.

Based on the specificity of this collection method, CDC-style gravid traps were incorporated into the Los Angeles County West Mosquito Abatement District's (District) EVS program in 1986. An improved version was designed by this author in 1987 and a number of these traps have been used extensively by several agencies. This paper will discuss the design and use of a modified Reiter gravid mosquito trap for monitoring encephalitis virus activity in *Cx. quinquefasciatus* populations of urban/suburban Los Angeles County, California.

Mosquito Abundance in the District.

The Los Angeles County West Mosquito Abatement District encompasses a large (400 square mile) urban area along the coastal portion of Los Angeles County. Peridomestic larval habitats account for approximately two-thirds of the mosquito breeding sources. *Culex quinquefasciatus* is well-represented in larval collections and exploits nearly 70% of the larva-positive peridomestic sources and 47% of the positive peripheral sites. *Culex stigmatosoma* and *Cx. tarsalis* larvae are found in approximately 15% and 1% of the positive peridomestic habitats, respectively. *Culex stigmatosoma* is found equally in either peridomestic or peripheral sources, while *Cx. tarsalis* breeding is confined largely to focal marsh/riparian habitats. Overall, only 6% of the District's sources, peridomestic and peripheral combined, support *Cx. tarsalis* breeding.

Adult densities of *Cx. tarsalis* and *Cx. stigmatosoma* in suburban neighborhoods of the District are also low, as measured by New Jersey light traps (Mulhern 1942) and standard CO_2-baited traps. Females of these species are rarely collected in residential areas and average less than one per trap-night in either type of sampling method. Adult densities for both species correspond roughly with their low numbers in suburban, peridomestic breeding habitats.

Most of the District's service requests have been in response to annoyance by endophilic, host-seeking *Cx. quinquefasciatus* females. Past attempts to collect representative samples of this species were never very successful. Counts in dry ice-baited traps rarely exceeded 20 *Cx. quinquefasciatus* females per trap-night in residential neighborhoods of the District. Following the introduction of gravid traps in 1986, collections of this species have increased to levels more accurately reflecting its larval abundance in suburban habitats of southern California. Cummings (Table 1, 1986 data), Medina (unpublished data, 1987) and Webb et al. (1988) have established the effectiveness of this method in Los Angeles and Orange Counties for capturing large quantities of gravid *Cx. quinquefasciatus.* Medina directly compared the efficiency of gravid traps and CO_2-baited traps for sampling adult *Cx. quinquefasciatus* in neighboring suburban Orange County. Gravid traps caught approximately 6.3 times as many female *Cx. quinquefasciatus* per trap-night as CO_2-baited traps (80.3 vs. 12.7).

Trap Design.

One problem with Reiter's first version is that the collection net is placed on the exhaust side of the motor/fan combination. As a result of this configuration, mosquitoes must first pass through the rapidly-spinning fan blades before being blown into the net. Hence, a significant portion of the catch can be killed. When this model was used by the District in 1986, mosquito mortality was approximately 21.3% (Table 1).

In the District's modified version (Fig. 1) as well as in Reiter's revised model (Reiter 1987), the motor/fan combination is mounted in a separate exhaust tube with the collection net placed on the inlet side of the motor. As air is blown out by the fan, a vacuum forms in the trap chamber causing air to flow inside the inlet tube. Mosquitoes are drawn into the trap with the incoming air stream and caught in the net before reaching the fan blades.

The District's modified version uses a plastic tool box as the trap body or housing. Photoelectronic controls are included to extend battery life and other inexpensive materials are incorporated for easy assembly. The total cost of materials (Table 2) is about $60.00.

Trap Construction.

Trap Housing: The trap housing is constructed from a Flambeau Model 17800 Plastic Tool Box which measures 17" long x 8.5" wide x 7.0" high. Two 3" diameter (dia.) holes are cut, one in the bottom for an air inlet tube and another in one end of the box through which an air exit (exhaust) tube is mounted. A four "D"-cell battery holder is fastened on the end opposite the exit hole. Two 5.125" long pieces of 1" x 2" wood are secured across the exterior bottom of the tool box, one at each end.

Air Flow Tubes: The air inlet tube is made

Table 1. Comparison of collection results between 1986 (using CDC gravid traps) and 1991 (using District-modified Reiter gravid traps).

	1986 CDC gravid traps	1991 Modified Reiter traps
Total female mosquitoes collected	2,451	19,205
Total surviving females	1,927	19,111
Percent mortality	21.3%	<0.5%
Total *Cx. quinquefasciatus* collected	1,861	18,496
Percent of total collected	96.6%	96.3%
Trap-nights	22	165
Average *Cx. quinquefasciatus* per trap-night	84.6	112.2
Range	22-370	1-1,225
Gravid *Cx. quinquefasciatus* collected	1,682	17,774
Percent gravid	90.4%	96.1%

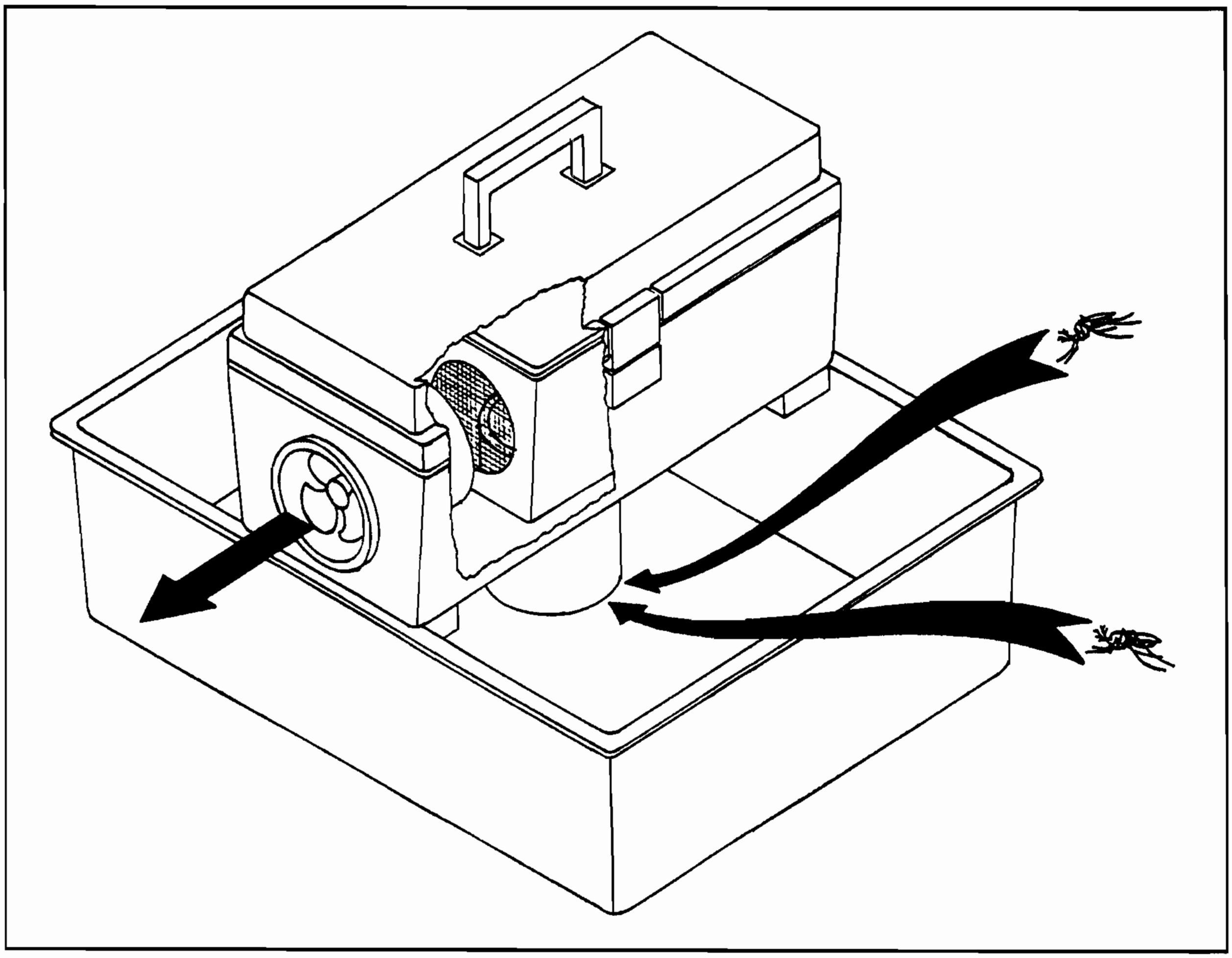

Figure 1. Modified Reiter gravid mosquito trap.

Table 2. Parts list for the modified Reiter gravid mosquito trap.

	Part	Source and/or specifications
1	Trap Housing	Flambeau Model 17800 plastic tool box, 17" long
2	Air Inlet Tube	Black ABS plastic drain pipe, 4.5" long x 3" diameter
3	Air Exit (Exhaust) Tube	White ABS plastic drain pipe, 3.5" long x 3" diameter (or spray paint a black pipe white)
4	O-Ring	Hoover or Eureka vacuum cleaner drive belt, 3" diameter (any similar item will work, too)
5	Wooden Legs	Two, 5.125" long pieces of 1" x 2" wood
6	Battery Holder	Radio Shack #270-396, 4 place "D"-cell battery holder
7	Toggle Switch	Radio Shack #275-634, SPST 12-volt switch
8	Circuit Box	Radio Shack #270-283, box with PC board
9	Wire	Radio Shack #278-1221, 22 gauge (solid)
10	Circuit Parts:	
	a) SPST-NO Reed Relay	Marvac Dow Electronics ECG #RLY 5310C, 5/6 volts,
	b) Silicon-Controlled Rectifier	Marvac Dow Electronics ECG #5404, 200 volt
	c) 100K-ohm Resistor	Radio Shack #271-1347
	d) 1N914/4148 Diode	Radio Shack #276-1122
	e) Photoresistor	Radio Shack #276-1657, large one only
11	Collection Chamber (Net):	
	a) Plastic Container and Lid	Industrial Plastics #85120 and #85171 (lid), 2 quart capacity
	b) Holder	Black ABS plastic connector (coupler) for 3" diameter pipe
	c) Net Plug	Black ABS plastic pipe "knockout" plug for 3" diameter pipe
	d) Plug Strap	5" long nylon strap
	e) Corner Braces	2 needed
	f) Screen	Window screen material
12	Motor Assembly:	
	a) Motor	BioQuip Products, Mabuchi RF-500T-12580, 9-volt
	b) Fan	BioQuip Products, four-bladed plastic fan, 2.875" diameter
	c) Motor Bracket	John W. Hock Co., 3.5" metal holder for CDC light trap motor
13	Attractant Basin	7" deep plastic busboy dish basin
14	Miscellaneous Hardware	Nuts, bolts, wood screws, glue, etc.

from a 4.5" section of 3" dia. black ABS plastic pipe which has been grooved around its exterior circumference 1.0" from an end. An O-ring is placed around the groove to hold the tube in place when inserted into the trap's inlet hole.

The exhaust tube is made from a 3.5" section of 3" dia. white PVC plastic pipe into which two 1.5" long slots have been cut into opposite sides. A 9-volt Mabuchi motor and 2.875" dia. four-bladed fan are positioned in a motor bracket and inserted into the slots. A 0.375" dia. hole is drilled into the top of the white tube, 1.25" from the end opposite the slots, through which the photoelectronic eye detects light. This assembly is mounted in the tool box with 0.125" of the tube protruding through the exit hole to the outside.

Photoelectronic Circuit: A 6-volt single pole, single throw - normally open (SPST-NO) relay, photoresistor, silicon-controlled rectifier (SCR), 100,000 ohm (100K) resistor, and diode are configured in a manner (Fig. 2) which turns the motor on at sunset and keeps it running when daylight returns. Otherwise, much of the previous night's catch would escape.

The electronic parts are mounted in a sealed 3.25" long x 2.125" wide x 1.375" high box with a 0.375" dia. hole drilled in the bottom, 1" from an end. The photoresistor is aligned with the holes in the electronic box and the white exhaust tube. The electronic box is mounted on top of the air exit tube

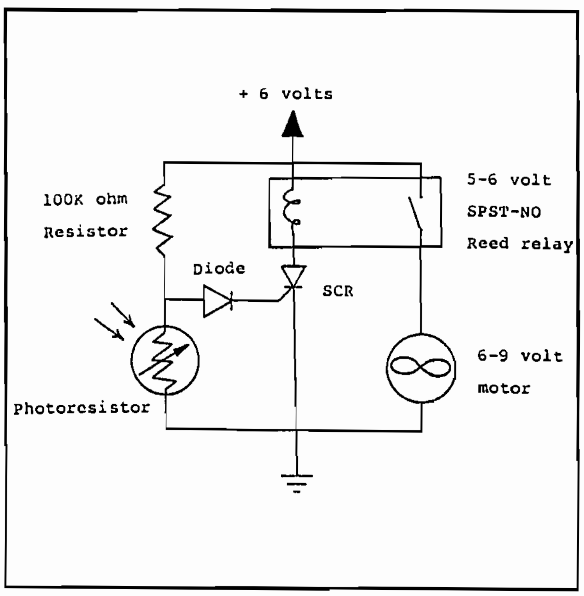

Figure 2. Photoelectronic circuit diagram for modified Reiter gravid mosquito trap.

and wired to a toggle switch fastened to the circuit box. Wires connect the circuit with the motor, switch, and battery holder.

This arrangement enables the photoresistor to detect light reflected off the inside of the white exhaust tube. Hence, the circuit is never exposed to the outside elements.

Collection Chamber (Net): A 6.5" long x 6.5" wide x 4.0" high plastic container is used as the collection chamber, or net. A 3" dia. hole is cut in the bottom and a 2.75" dia. hole is cut into one of the sides. A 3.5" dia. ABS plastic connector for 3" dia. pipe is mounted with corner braces over the bottom hole inside the net. A screen is placed over the net's smaller, air exit hole. A 3" dia. ABS plastic plug is attached to the bottom of the chamber by a 5" long nylon strap. (The inlet tube is coupled with the collection chamber when the trap is set up).

Basin and Attractant: A black, 20" long x 15" wide x 7" deep plastic container is used as the attractant holder. A hay-infusion media is used as the attractant (Reiter 1983).

For more detailed information about trap and circuit design or construction, please contact the author.

Trap Operation.

The basin is placed on the ground and five quarts of hay-infusion media are poured into it. The trap is then mounted across the basin's width. The wooden legs of the trap keep it snug in the basin. The trap is opened and the collection chamber is removed and coupled with the inlet tube. This assembly is then placed back into the trap so that the inlet tube protrudes through the trap bottom about 2" above the attractive media's surface. Finally, the toggle switch is turned on (four "D"-cell batteries inserted previously) and the trap is closed.

The motor turns on at sunset, creating a vacuum within the trap. As gravid mosquitoes fly over the pungent media, they are drawn into the net through the inlet tube. The air stream exits the net through the screened exit hole, trapping the catch inside. No mosquitoes ever pass through the fan blades. The motor continues to run past sunrise, since the circuit must be turned off manually.

At collection time, the trap is opened and the collection chamber/inlet tube combination is removed. The inlet tube is quickly detached, and the plug is inserted into the chamber's inlet hole to prevent the catch from escaping. The trap is turned off and all components are placed back inside for easy carrying. The basin is emptied and taken.

This design has proven to be reliable and easy to use. Four "D"-cell batteries usually last for 3-4 nights of operation. In addition to saving batteries, the photoelectronic circuit makes it possible to set up the trap at any time, since the motor does not run needlessly during the day.

Mosquito Collection Program.

Ten gravid traps were placed throughout the District in 1991, mostly in suburban areas. If a particular location yielded high counts, trapping continued at the same site until District operations found and abated a source responsible for the large numbers. Collections were also made near sentinel chicken flocks and feral bird traps.

Trapped mosquitoes were anesthetized with triethylamine (TEA), sorted to species and sex, and pooled into freezer vials. The vials were stored on dry ice and sent to the California Department of Health Services, Viral and Rickettsial Diseases Laboratory (VRDL) for testing.

Results.

During 1991, District-modified gravid traps collected a total of 19,205 female mosquitoes in 165 trap-nights (Table 1). *Culex quinquefasciatus* comprised 96.3% (18,496 females) of this total. The average collection was 112.2 *Cx. quinquefasciatus* females per trap-night, of which 96.1% (17,774) were gravid. The remainder of the catch consisted of 474 *Culiseta incidens* (Thomson) (2.5%), 160 *Cx. stigmatosoma* (0.8%), and 75 *Cx. tarsalis* (0.4%). Mortality was less than 0.5% for the entire season.

Of 20,952 mosquitoes submitted in 491 EVS pools by the District in 1991, gravid traps contributed 15,718 *Cx. quinquefasciatus* (354 pools). Thirteen additional pools of *Cx. quinquefasciatus* (428 females) were collected in dry ice-baited traps. The remaining submissions consisted of 4,674 *Cx. tarsalis* (117 pools) and 132 *Cx. stigmatosoma* (7 pools). Almost all of these were collected in CO_2-baited traps. Gravid traps caught approximately 75% of the mosquitoes and 97.3% of the *Cx. quinquefasciatus* submitted by the District for arbovirus testing in 1991.

Three pools of *Cx. quinquefasciatus* collected by gravid traps near an oil refinery in Torrance, California tested positive for western equine encephalomyelitis (WEE) virus in September, 1991. Western equine encephalomyelitis virus was also found in four pools of *Cx. tarsalis* collected by dry ice-baited traps in the same month. One of these pools contained mosquitoes collected from Torrance. Females in the other three pools came from rural areas of Malibu, California.

Conclusions.

The 1991 data demonstrated the effectiveness of the District's modified traps for capturing large quantities of nearly homogenous collections of gravid *Cx. quinquefasciatus*. This agency has used gravid traps extensively since 1987 for encephalitis virus surveillance and to assess the effectiveness of the mosquito control program. In spite of the success of this sampling method, only three out of approximately 1,100 pools of gravid *Cx. quinquefasciatus* females submitted by the District since 1987 have tested positive for arboviruses. While the three positive pools indicated the presence of WEE virus in the Torrance area, *Cx. quinquefasciatus* is not a competent vector of WEE virus. The single, WEE virus-positive pool of *Cx. tarsalis* collected from the same area was of greater public health significance.

In an effort to further improve EVS monitoring, a year-round wild bird bleeding program similar to the one employed by the Orange County Vector Control District (Gruwell et al. 1988) was implemented in the summer of 1991. Sera from feral birds maintained a combined average positive rate of 1-3% for SLE and WEE antibodies in 1991; comparable to the levels reported previously in Orange County (Bennett et al. 1991). The information from the feral bird programs supports the theory that SLE and WEE virus transmission has been endemic and continuous in Los Angeles and Orange Counties for some time.

Even as effective as gravid traps are in sampling the potentially disease-carrying portion of the female *Cx. quinquefasciatus* population, other sentinel systems (e.g., sentinel chickens or wild bird sera sampling) are currently proving to be more sensitive at detecting low-level arbovirus activity in suburban areas. Virus activity may have to reach a higher threshold in the suburban environment before gravid traps become effective monitoring devices. The role of *Cx. quinquefasciatus* as a significant urban vector of SLE virus in the Los Angeles Basin has still not been demonstrated, based on the persistently small number of infected female mosquitoes.

Acknowledgments.

The author thanks Jean Kovaltchouk, Greg Pierson and the staff of the Los Angeles County West Mosquito Abatement District for assisting in the collection of mosquitoes used in this study. Special thanks goes to Dr. Jim Webb, Orange County Vector Control District, for encouragement and to Stephen Durso, Antelope Valley Mosquito Abatement District, for prodding me to publish my findings.

References.

Bellamy, R.E. and W.C. Reeves. 1952. A portable mosquito bait-trap. Mosq. News 12:256-258.

Bennett, S.G., J.P. Webb, Jr., Z.T. Siruno and T.J. Smith. 1991. Evaluation of mosquito and arbovirus activity in Orange County, California, 1990. Proc. Calif. Mosq. Vector Control. Assoc. 59:35-41.

Gruwell, J.A., B.L. Brown and J.P. Webb, Jr. 1988. Passeriform birds as a surveillance method for arbovirus activity in rural and suburban sites in Orange County, California, 1987. Proc. Calif. Mosq. Vector Control Assoc. 56:58-65.

Hardy, J.L., R.P. Meyer, W.K. Reisen and S.B. Presser. 1986. A further evaluation of *Culex* mosquitoes in the greater Los Angeles area for their ability to vector St. Louis encephalitis virus. Proc. Calif. Mosq. Vector Control Assoc. 54:9-10.

Meyer, R.P. 1985. The "walk-in" type red box for sampling adult mosquitoes. Proc. N.J. Mosq. Extermin. Soc. 72:104-105.

Mulhern, T.D. 1942. The New Jersey mechanical trap for mosquito surveys. N.J. Agric. Exp. Sta. Circ. 421:1-8.

Reeves, W.C. and M.M. Milby. 1990. Natural infections in arthropod vectors. *In:* W.C. Reeves (ed.), Epidemiology and Control of Mosquito-Borne Arboviruses in California, 1943-1987. California Mosquito and Vector Control Association, Sacramento, CA. pp. 128-144.

Reisen, W.K., R.P. Meyer, C.H. Templis, and J.J. Spoehel. 1990. Mosquito abundance and bionomics in residential communities in Orange and Los Angeles Counties, California. J. Med. Entomol. 27:356-367.

Reisen, W.K. and A.R. Pfuntner. 1987. Effectiveness of five methods for sampling *Culex* mosquitoes in rural and urban habitats in San Bernardino County, California. J. Amer. Mosq. Control Assoc. 3:601-606.

Reisen, W.K. and W.C. Reeves. 1990. Bionomics and ecology of *Cx. tarsalis* and other potential mosquito vector species. *In:* W.C. Reeves (ed.), Epidemiology and Control of Mosquito-Borne Arboviruses in California, 1943-1987. California Mosquito and Vector Control Association, Sacramento,CA. pp. 254-329.

Reiter, P. 1983. A portable, battery-powered trap for collecting gravid *Culex* mosquitoes. Mosq. News 43:496-498.

Reiter, P. 1987. A revised version of the CDC gravid mosquito trap. J. Amer. Mosq. Control Assoc. 3:325-327.

Reiter, P., W.L. Jakob, D.B. Francy and J.B. Mullennix. 1986. Evaluation of the CDC Gravid Trap for the surveillance of St. Louis encephalitis vectors in Memphis, Tennessee. J. Amer. Mosq. Control Assoc. 2:209-211.

Schreiber, E.T., J.P. Webb, Jr., J.E. Hazelrigg and M.S. Mulla. 1989. Bionomics of adult mosquitoes associated with urban residential areas in the Los Angeles Basin, California. Bull. Soc. Vector Ecol. 14:301-318.

Sudia, W.D. and R.W. Chamberlain. 1962. Battery-powered light trap, an improved model. Mosq. News 22:126-129.

Sudia, W.D., P.H. Coleman, R.W. Chamberlain, J.S. Wiseman and T.H. Work. 1967. St. Louis encephalitis vector studies in Houston, Texas, 1964. J. Med. Entomol. 4:32-36.

Tsai, T.F. and C.J. Mitchell. 1989. St. Louis encephalitis. *In:* T.P. Monath (ed.), The Arboviruses: Epidemiology and Ecology, Vol. IV. CRC Press, Boca Raton, FL. pp. 113-143.

Webb, J.P., M.J. Medina and S.G. Bennett. 1988. Mosquito abundance and arbovirus activity in Orange County, 1987. Proc. Calif. Mosq. Vector Control Assoc. 56:32-36.

1992 Proc. Calif. Mosq. Vector Control Assoc. 60: 177-179

A COMPARISON STUDY OF TWO YELLOWJACKET TRAPS FOR SURVEILLANCE OF YELLOWJACKET POPULATIONS IN THE LAKE TAHOE BASIN, CALIFORNIA

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Introduction.

Seven species of yellowjackets have been identified in the Lake Tahoe Basin of California. Two of the seven, *Vespula pensylvanica* (Saussure) and *Vespula vulgaris* (L.) account for approximately 70% of our service requests for yellowjackets, and are responsible for most of the problems around campgrounds, picnic areas, barbecues, and other outdoor activities. These two species can be successfully controlled using a bait station control program which combines a protein bait (e.g., meats, fish, etc.) with microencapsulated diazinon, Knox-Out® 2FM, insecticide (Ennik 1973). The success of this type of control program primarily depends on the timing, i.e., beginning the baiting program early in the yellowjacket season when the first brood of workers are emerging from the nests.

Some yellowjacket species can easily be attracted with heptyl butyrate synthetic attractant (Davis et al. 1973, MacDonald et al. 1973). Others readily come to protein baits such as hamburger, fish, etc. In 1989, many different kinds of commercially made yellowjacket traps came on the market. Some were baited with the synthetic attractant heptyl butyrate, others with various types of protein baits, and others with carbohydrate (sugar) baits.

The purpose of this study was to determine if commercially made traps could be used to monitor the populations of *V. pensylvanica* and *V. vulgaris* to determine when the first brood of workers emerge in order to begin baiting control programs as early as possible. We initially tested various models and designs before finally settling on two types: the heptyl butyrate-baited Jacket Trap® and the protein-baited Yellow Jacket Trap® (Fig. 1). The main advantage of the Jacket Trap over the Yellow Jacket Trap is that the attractant lasts a longer time and therefore doesn't need to be serviced as frequently. The Yellow Jacket Trap requires frequent rebaiting because the bait either drys out or spoils in a few days, thus becoming unattractive to yellowjackets. Because of their designs, both of these traps capture most of the individuals that enter them.

Materials and Methods.

The Jacket Traps and Yellow Jacket Traps were hung in trees approximately five feet above the ground at 13 different locations on July 1, 1991, and monitored throughout the summer and fall until November 19, 1991. The traps were separated by approximately 50 feet at each site. The Jacket Traps were rebaited with heptyl butyrate and emptied on a weekly basis. Rebaiting them consisted of adding two drops of heptyl butyrate. The Yellow Jacket Traps were emptied and rebaited with approximately two ounces of canned mackerel on a weekly basis for the first six weeks of the study. However, we switched to twice weekly collections and rebaitings on the seventh week because of bait spoilage. The rebaiting of these traps consisted of removing the old bait and replacing it with fresh bait. All the yellowjackets caught in both types of traps were removed and brought to the laboratory for identification.

Results and Discussion.

[1] Present Address: 21111 Country Squire Drive, Bend, Oregon 97701.

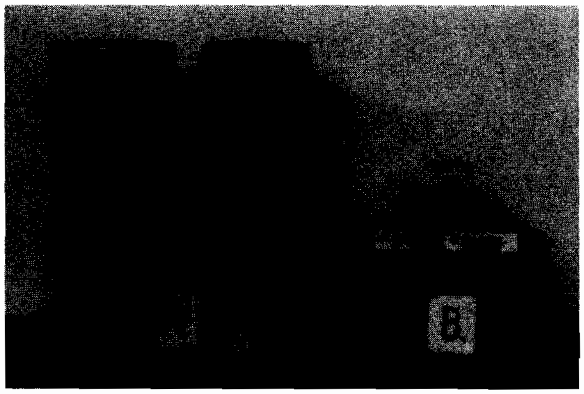

Figure 1. Two trap types used in the study: A. Jacket Trap® B. Yellow Jacket Trap®

The Jacket Traps (baited with heptyl butyrate) began catching a few *Vespula atropilosa* (Sladen) workers as early as the week of July 17. Two *V. pensylvanica* workers were captured during the week of July 23, three during the week of July 31, and nine during the week of August 8. The Yellow Jacket Traps didn't capture any yellowjackets until the week of August 15, when nine *V. pensylvanica* workers were caught. After August 15, both trap types consistently captured workers throughout the season.

The Jacket Traps were effective for monitoring populations of *V. atropilosa* and *V. pensylvanica* (Fig. 2). In addition, only a few *Vespula acadica* (Sladen) and *V. vulgaris* individuals were captured in these traps. The Yellow Jacket Traps were effective for both *V. pensylvanica* and *V. vulgaris* (Fig. 3) with no other species captured in these traps.

The protein-baited traps caught far more *V. vulgaris* than *V. pensylvanica*. The main reason for this difference was that the two trap types were located within 50 feet of each other at each trapping location. Since *V. pensylvanica* is attracted to both the protein bait and the synthetic attractant, the numbers captured at each trap site were divided between the two trap types. When combining the numbers of *V. pensylvanica* trapped for both trap types at each trap site, the number captured was comparable to the number of *V. vulgaris* captured.

Although the heptyl butyrate-baited traps did give a good indication of the *V. pensylvanica* populations, they gave no indication of the *V. vulgaris* populations. These traps also captured

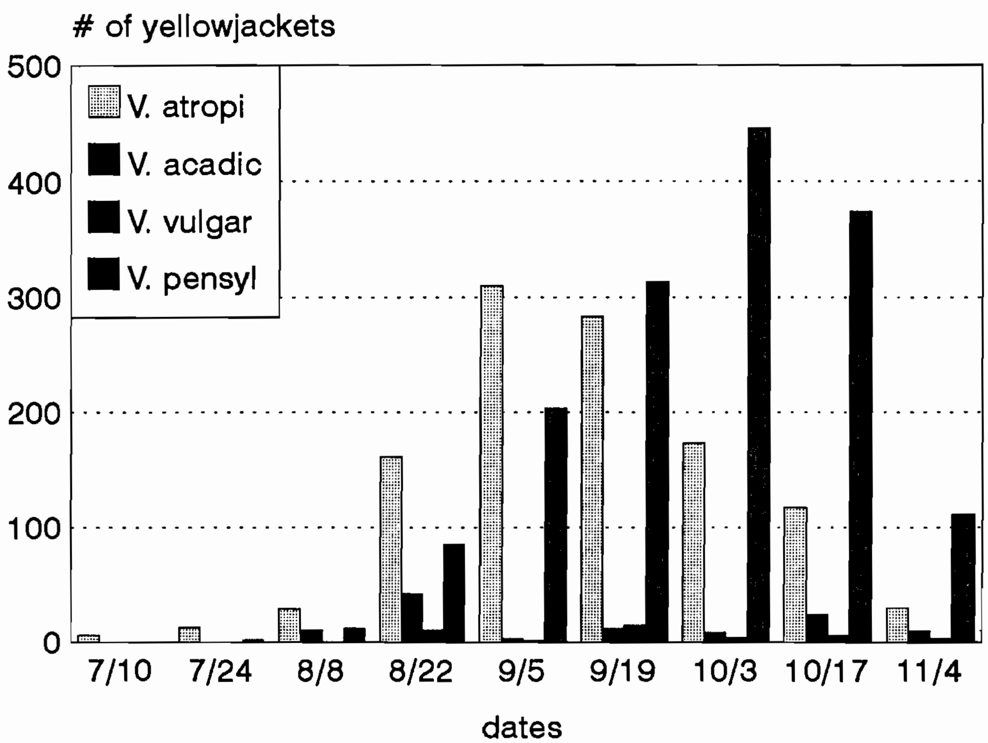

Figure 2. Yellowjacket collection results using Jacket Traps® during July 3 - November 4, 1991.

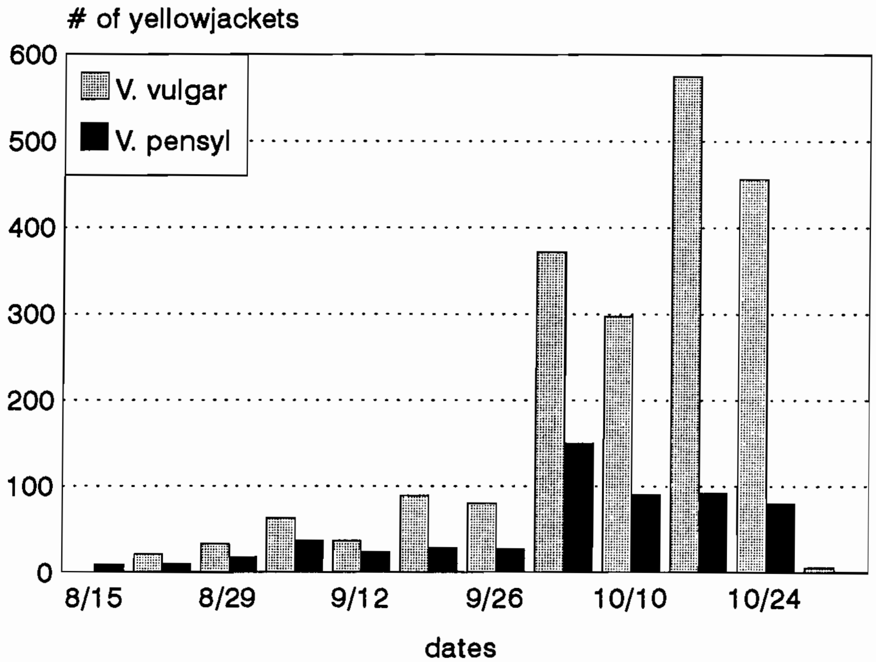

Figure 3. Yellowjacket collection results using Yellow Jacket Traps® during August 15 - November 7, 1991.

large numbers of *V. atropilosa*, a beneficial species which is strictly predacious (MacDonald et al. 1973) and doesn't cause problems for humans.

While the protein-baited traps are more labor intensive for use in a monitoring program, they are specific for the species that feed on protein baits. This is advantageous because it doesn't effect the beneficial non-target species while still giving a good indication of when to begin a baiting control program.

Acknowledgements.

I thank Mark Bonfield and Kim Sallmen of El Dorado County Vector Control for their assistance in collecting and identifying the yellowjackets, and compiling the data presented in this paper.

References.

Davis, H.G., R.W. Zwick and W.M. Rogoff. 1973. Perimeter traps baited with synthetic lures for suppression of yellowjackets in fruit orchards. Environ. Entomol. 2:569-571.

Ennik, F. 1973. Abatement of yellowjackets using encapsulated formulations of diazinon and rabon. J. Econ. Entomol. 66:1097-1098.

MacDonald, J.F., R.D. Akre and W.B. Hill. 1973. Attraction of yellowjackets (*Vespula* spp.) to heptyl butyrate in Washington state (Hymenoptera: Vespidae). Environ. Entomol. 2:375-379.

MOSQUITO CONTROL WITH FLOATING SUSTAINED-RELEASE *BTI* BRIQUETS IN CITY STORM DRAIN CATCH BASINS

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ABSTRACT

Simulated and operational tests were undertaken to determine the ability of floating sustained-release Bactimos® *Bti* (*Bacillus thringiensis* var. *israelensis*) briquets to control *Culex quinquefasciatus* Say mosquitoes breeding in street-side storm water catch basins.

Laboratory-simulated catch basins indicated that a 1/4 briquet applied at 1-month intervals per basin (0.26 square meter mean surface area with a mean of 25 gallons of water) controlled approximately 95.1% of emergence. The most susceptible stages were the younger larval instars; 81.4% of mortality occurred during the 1st and 2nd instar stages. Older larvae and pupae were very tolerant to the treatment; only 3.7% of 4th instars and 0.4% of the pupae were killed by the treatment. Total mortality of the test controls was 5.3% with 3.0% killed during the 1st and 2nd instar stages and 0.5% killed at the pupal stage.

The operational field tests were conducted during the 1990 and 1991 seasons in street-side catch basins like those typically found throughout the Fresno area. One briquet applied per basin per month controlled 88.2% of the adult *Cx. quinquefasciatus* emergence in 1990 and 91.0% during 1991.

RESIDUAL EFFECTS OF PUNT® APPLIED AS A BARRIER TREATMENT AGAINST *AEDES VEXANS* IN WOODED AREAS OF MINNESOTA

Merry L. Holliday-Hanson[1], Chris E. Boxmeyer and Susan L. Palchick

Metropolitan Mosquito Control District
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St. Paul, Minnesota 55114

ABSTRACT

Punt® (57% permethrin - Vectec Inc., Orlando, FL) is applied to wooded (harborage) areas by the Metropolitan Mosquito Control District (MMCD) to control *Aedes vexans* (Meigen). A 10-14 day effective residual period is assumed for Punt as applied by the District. Two studies were done in 1990 and 1991 in Bloomington, Minnesota, to determine the residual effects of Punt, the distance Punt droplets penetrate into a harborage area, and the degradation of Punt in ultraviolet (UV) light.

In 1990, *Ae. vexans*, a non-colonized species, was used as the test mosquito. Results from this study indicated that an LT_{50} was reached after 18 days. In 1991, the colonized mosquito, *Aedes aegypti* (Linnaeus), was used; thus, a constant age was maintained throughout the experiment. Bioassays of 0.25% permethrin were done to compare mortalities of *Ae. vexans* (LT_{50} = 0.120 hr) and *Ae. aegypti* (LT_{50} = 0.363 hr).

To test the assumption that Punt does not penetrate beyond the perimeter of a harborage area, we measured the distance Punt penetrated into a site by counting droplets on Teflon-coated slides. Slides located one or more meters into the site had significantly fewer droplets ($P < 0.05$) than those located on the perimeter; thus, verifying the assumption that Punt does not penetrate beyond the perimeter of a treated site.

To examine the effectiveness of Punt over time, leaves were picked from treated (Punt) and control (soybean oil and mineral oil) sites every four days, and mosquitoes were exposed to the leaves for 30 minutes. At least 50% mortality was maintained for four days. After the fifth day, mortality decreased to below 50%. Leaf type, Virginia creeper (*Parthenocissus quinquefolia*) or grapevine (*Vitis* spp.), did not affect the mortality of *Ae. aegypti* ($P > 0.05$); suggesting that differences on the surface of the leaves have no residual effect.

Since Punt is degraded in UV light, we examined direction of leaf exposure as well. This, too, was not a significant factor ($P > 0.05$) in the effectiveness of Punt.

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AN ALTERNATIVE METHOD TO TRADITIONAL MOSQUITO CONTROL: THE MOUNTED SURVEILLANCE UNIT

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San Bernardino, California 91410

The objective was to develop an efficient and cost-effective method of mosquito surveillance and control in the Santa Ana riverbed by the San Bernardino County Vector Control Program (SBCVCP). This river originates in the San Gorgonio wilderness and flows southwest through San Bernardino, Riverside, and Orange Counties into the Pacific Ocean. The portion of the river we are concerned with involves the area from Redlands to the Riverside County line (approximately 12 miles). This area is adjacent to residential, commercial, industrial, and recreational properties. Mosquito control here benefits the cities of Redlands, San Bernardino, Colton, and Grand Terrace.

Definition of the Problem.

Variations in the terrain make it inaccessible to most vehicles. Four-wheel drive vehicles can become stuck in the sand and afford access to only a limited portion of the river. Inspection by foot is time consuming and pesticides must be hand carried. Other specialized equipment was proposed, but rejected as potentially unsafe. As a result, this work had not been performed in a timely manner.

Intent and Goals.

The SBCVCP Mounted Equestrian Unit was established and activated in May of 1991. The use of horses for this purpose is practical and time efficient. The benefits of using horses include:

1. Low environmental impact - the California Department of Fish and Game has endorsed the use of horses as they are less disruptive than vehicles to sensitive or endangered species habitat.
2. Better view than on foot - approximately three feet increase in height of eye level.
3. Allow a faster rate of travel than by foot - the average walking speed for man is 1-3 mph, for a horse 3-5 mph.
4. Increased ability to carry insecticides and equipment.

Some concern was expressed regarding the potential for mosquito breeding in impressions left by horses' hooves. Areas where these impressions were left were reinspected periodically. No mosquito breeding was observed, and in most cases the impressions did not retain water due to percolation.

In developing this program, the first step was to make a proposal addressing all aspects of the policy, procedure, safety, and qualifications. Having no other mosquito districts using horses for this purpose to pattern our program after, we incorporated elements from mounted police, Sheriff's Department Mounted Patrol and the U.S. Forest Service Volunteers Association. It was reviewed by San Bernardino County's Departments of Environmental Health Services and Risk Management, who found it to "..... meet established standards for participant safety and health."

It was decided that use of horses and their transportation would be on a voluntary basis, meaning no expense would be incurred by the County. Feed, board, tack, farrier, and veterinary expenses are the responsibility of the horse owner.

The primary concern in this program is safety, not only to the inspector but also to the horse and to the public.

Operation and Procedures.

In order to participate, each person must complete a qualification test on horseback and show evidence of approved training or experience. They must demonstrate safe and proper horsemanship skills in equitation and from the ground. Each participant must possess current vector certification and first aid certification from the American Red Cross. A participant can be summarily removed from the unit for unsafe behavior, misuse of duty time, or any violation of a departmental rule or regulation.

Horses participating in this program are required to qualify under guidelines used by the City of Riverside Police Department's mounted patrol. Each horse must be examined for soundness by a veterinarian. Any horse that exhibits unsafe behavior will be dismissed from the program.

The operations of the mounted unit are overseen by the mounted unit coordinator who reports all activities to the Program Manager. It is the responsibility of the participants to keep tack and equipment clean and in good working order, to report any injury or incident and to see that their mount is kept at least ten feet away from any citizen.

Participants are not permitted to allow any citizen or unqualified person to ride their mount, to allow visitors to a duty assignment, to leave a mount unattended, or to work without a partner.

Prior to starting, the team signs out at the vector control operations center, leaving the location of the vehicle and the area to be surveyed. Each team consists of no less than two persons with one member carrying a hand held radio. They inspect all potential mosquito breeding sources and if necessary treat with larvicide. Bactimos® briquets (*Bacillus thuringiensis* Berliner var. *israelensis*, Serotype H-14) are used because they fit easily into saddle bags, do not require equipment to apply and are least hazardous to the environment. Sources are mapped for reinspection. A pesticide treatment record and inspection report are filed detailing the locations inspected and treated and the amount of time spent.

Any violations or hazardous conditions that may be observed are reported to the appropriate agency (ie. fire, hunting, hazardous materials, or illegal dumping).

Discussion.

The SBCVCP Mounted Unit has proven to be a valuable resource for mosquito surveillance and control. In 1991, the SBCVCP Mounted Unit spent approximately 164 manhours patrolling the riverbed and applied 430 *Bti* briquets. It is our hope that by maintaining this increased level of surveillance, the result will be a decrease in the mosquito population and the potential for encephalitis transmission in San Bernardino County.

In addition, the Mounted Unit may be beneficial in desert, foothill and mountain regions; particularly in wilderness areas where no vehicles are permitted. Other possible uses may include survey of plague, Lyme disease, and relapsing fever.

Acknowledgements.

We thank Detective Al Kennedy of the Riverside Police Department and Kent Ellsworth D.V.M. for their expertise and input. We also thank Lesli Ainsworth of the SBCVCP for her support and participation in this program.

EVALUATION OF FOUR FEED TYPES ON MORTALITY, GROWTH, AND REPRODUCTION OF THE MOSQUITOFISH, *GAMBUSIA AFFINIS*

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155 Mason Circle
Concord, California 94520

ABSTRACT

The effects of four feed types (*Artemia* nauplii, decapsulated *Artemia* cysts, trout and salmon starter, and "crushed" floating catfish/35) were evaluated on mortality, growth, and reproduction of the mosquitofish, *Gambusia affinis* (Baird and Girard).

Mosquitofish, less than 24 hours old, were obtained from our production facility. Three groups of 10 fry each were randomly assigned to each of the four feed types and a group of 42 fry was used to estimate initial mass and length. Fish were measured for wet mass and standard length at the initiation of the study, 30, and 70 days. Fish were measured for standard length by individually placing them in a sealable plastic bag with tank water and gently cornering the fish in the bag and placing on a rule. Wet mass was determined by tarring a beaker of tank water, netting out the fish, allowing excess water to drain before placing the fish in the beaker. Mean initial wet mass of individual fry was 7.0 mg. and mean initial standard length was 7.88 mm.

This study was conducted in an environmentally controlled room at a temperature of 25° C under a florescent light photoperiod of 15L:9D. The fish were cultured in twelve 11.36 L plastic aquaria which were partially filled with 7.57 L of unchlorinated well water (1.32 fry/L of water). Initially, water was monitored for dissolved oxygen and ammonia. It was determined that by the fourth day ammonia was at an unacceptable level (>0.5 mg/L). Therefore tanks were cleaned, by siphoning tank bottoms, and partial water changes (1/2 tank volume) were conducted every third day.

Brine shrimp eggs (O.S.I.® brand, Hayward, CA) were purchased and decapsulated and/or hatched. Trout and salmon starter and floating catfish/35 feeds where purchased from Rangen Inc., Buhl, Idaho. Each tank was feed 0.05 grams of the respective feed type twice daily. This amount was chosen to provide excess feed at all feedings. This amount was adjusted after the 30-day measurements to correct for growth. At 30 days, fish sex was not determinable and the fish were grouped and weighed by tank. At 70 days, sex was easily determined and fish were grouped by tank and sex and measured. Fish were held for 72 days at which time the experiment was terminated.

At 30 days of age, there was no significant difference in survival of fish fed the four feed types but there was a significant difference in fish length in the fish fed *Artemia* versus those fed the other two feed types. At 60 days of age, there was a significant difference in survival, fish mass, and fish length in fish fed *Artemia* versus those fish fed the other two diets. Parturition occurred at 55, 70, and 71 days in the three tanks fed *Artemia*. No signs of embryo development (gravid spot or abdomen enlargement) occurred in tanks fed either trout and salmon starter or catfish feeds during the study.

C.M.V.C.A. YEAR-END COMMITTEE AND REGIONAL REPORTS: 1991

Michael J. Wargo

CMVCA Vice President
Coachella Valley Mosquito Abatement District
83-733 Avenue 55
Thermal, California 92274

The following reports reflect the activities of the regions, standing committees, and ad hoc committees of the California Mosquito and Vector Control Association (CMVCA) for the year 1991 as submitted by the chairperson(s) of each committee or representative of each region.

COMPUTER COMMITTEE

Bruce F. Eldridge (Chair)
David A. Brown, Craig W. Downs, Jack E. Hazelrigg, Ronald D. Keith, Barbara A. Kuzusko, Marilyn M. Milby, Fred C. Roberts, Patrick S. Turney and Charles E. Taylor (Consultant)

The year was one of great excitement and satisfaction for the Committee. The principal achievement was the completion of recommendations for a statewide computerized information system for mosquito control and the authorization by the CMVCA Board of Directors for monetary support over a 5-year period for the system. The equipment for the system was purchased in late 1991 and an individual (Mike Gurnee) was hired on a one quarter-time basis to maintain the software and information databases. This system became operational on a trial basis during the fall with the code-name "MosquitoNet".

MosquitoNet.
Effective January 1, 1992, MosquitoNet became on-line and operational on a 24-hour basis (Telephone 916-752-5484). An upgrade has been ordered to configure it for four simultaneous users and also to allow for its easy upgrading to even more users if demand makes it necessary. Presently four telephone lines are installed. The first of a series of newsletters devoted to MosquitoNet, edited by Craig Downs, was produced and passed out at the annual conference in Concord. The system was also demonstrated during this time and a formal presentation was made describing the system.

Near Future Plans.
During the coming year the Committee will concentrate on working out the smooth functioning of the Subject Operators (SubOps) with their respective committees to insure that the best and most current data are maintained on MosquitoNet. We will also stress training of first-time users and furnishing advice on computer purchases and communication software installation. This will be done through the newsletter and by presentations made at regional meetings and, upon request, at any district. The Committee will also have to work out policies as to who can use the system. Should it be an open system or should we configure it on a "need to know" basis? The Committee would appreciate guidance from the Board of Directors on this issue.

More Distant Future Plans.
The Committee is working with Mr. James Kalin of Simulation Laboratories to produce a graphical interface for the system to be used with a mouse. A prototype of this interface was also demonstrated at the conference. The Committee is also working with Mr. Kalin to obtain venture capital needed to produce a fully operational interface. We are especially interested in producing software which can be used with systems in other states as well as national organizations such as the

Centers for Disease Control with their vector-borne disease information system. This system could be much more than an interface and could be developed into a full-blown mosquito control operational system which could include training, mapping, ecological simulation, and communication functions. We believe that CMVCA could eventually market such a product, and in so doing, could solidify our reputation as the national leader in mosquito abatement innovation. After a year of operation we will probably prepare an article for Wing Beats describing the system.

Finally, we will want to think about obtaining faster modems at some time in the future. Communication presently is determined by the slowest modem of either the host computer or the remote computer. The host modems are presently 2400 baud.

CONTINUING EDUCATION COMMITTEE

B. Fred Beams (Chair)
Vic Baracosa, Glenn E. Bissell, Thomas A. Buser, David G. Farley, Stan R. Husted, Leo F. Kohl, Lal S. Mian, John R. Stroh, Bruce F. Eldridge (Consultant) and Minoo B. Madon (Consultant)

The Committee has held several very successful and well-attended regional continuing education programs this period; the most recent of which was conducted last Monday, concurrent with the opening day of this conference.

Coastal Regional Training Coordinator Stan Husted is to be congratulated for his efforts as over 150 local vector control technicians took part in a very interesting program.

There have been four committee meetings in the year during which over 100 continuing education (CE) programs were reviewed for continuing education unit (CEU) credit. Other committee charges acted upon in 1991 were as follows:

1. Three of the five regions have the computerized record keeping program on-line and the remaining two are expected to go on-line shortly.

2. Streamlining the continuing education curriculum will be more difficult than originally thought due to some legal questions associated with existing regulations. The Committee recommends that if these legal questions are resolved, the following amendments be reviewed by other impacted organizations for their concurrence before submission to the State Department of Health Services for amendment to Title 17:

   For each two year training cycle:

   a. Increase requirements from 10 to 16 CEU's for Category A, Pesticide Use.
   b. Eliminate category A-II and include that information in Categories B, C, and D without a separate requirement.
   c. Require 8 CEU's for Category B, Mosquito Control.
   d. Require 8 CEU's for Category C, Terrestrial Invertebrate Vector Control.
   e. Require 8 CEU's for Category D, Vertebrate Vector Control.
   f. We also recommend that agency administration be allowed to conduct up to 2 CEU's of in-house training for each category. This amounts to a total of 8 hours (20%) of the total requirement that can be met in-house for a fully certified vector control technician.

   We believe this proposal, if it can be legally implemented through Title 17 amendment, will streamline the program, give agency managers more flexibility and latitude in staff training, and still maintain program quality as requested by this Board at the inception of the program several years ago.

3. The Committee decided not to accept registry as a professional entomologist (ARPE) in-lieu of CEU training. We felt that while ARPE-required training is excellent, it may not parallel the scope of the continuing education training requirements as they now exist.

4. There has been no reported progress on the training film production by Chico State University since last report.

5. Finally, the Association's *C.E. Certification and Training Guide* has been revised and distributed to all member agencies.

MANAGEMENT COMMITTEE

Gilbert L. Challet (Chair)
Mitchell J. Bernstein, Lue Casey, Dennis D. Boronda, David A. Brown, James A. Camy, Elizabeth A. Cline, Major S. Dhillon, Craig W. Downs, Carol Evkanhian, David G. Farley, Ronald L. McBride, Theresa Stratton, John R. Stroh, James Wandersheid, David B. Whitesell and Charles M. Myers (Consultant)

The Management Committee had a very successful year in 1991. Three important goals were accomplished during the year: 1. The Committee held a Management Seminar for Managers and Trustees which focussed on administrative policies and practices, 2. The Committee wrote a Redevelopment Handbook for District Managers, and 3. The CMVCA Resource Directory was updated.

One goal left undone is the Management Guidelines Handbook which will be worked on during the next year.

The Management Seminar was very well attended and enthusiastically received. It is the plan of the Committee that a similar seminar be held yearly from now on with the subject matter varied according to the needs of the Association.

PUBLICATIONS COMMITTEE

Peter B. Ghormley (Chair)
John C. Combs, Stephen L. Durso, Donald A. Eliason, Ernest E. Lusk, Wesley R. Nowell, Linda M. Sandoval and Bruce F. Eldridge (Consultant)

The Publications Committee fell short of the goals outlined for 1991. The following list of publications was intended to be completed during 1991:

1989 Proceedings
1990 Proceedings
1991 Proceedings
Identification of the Mosquitoes of California
Fishes in California Mosquito Control
CMVCA Trustee Reference Manual
California Vector Control Training Manual

The *1989 Proceedings* and *1990 Proceedings* were, indeed, published and distributed. The *1991 Proceedings* will be published and distributed during the month of March, 1992.

Identification of the Mosquitoes of California should be completed in late Spring of 1992. Extensive rewriting of the original document was required.

Fishes in California Mosquito Control has been published and will be distributed at the 1992 Conference.

The revision of the *CMVCA Trustee Reference Manual* is to be distributed at the 1992 Conference or shortly thereafter.

The *California Vector Control Training Manual* has not progressed during the past year due to the apparent lack of interest on the part of committees of the CMVCA. The Editor of this document has yet to receive a single revision of the manual from the respective committees.

The rewriting of the *Publication Policies and Information for Contributors to the Proceedings of the CMVCA* and the *Policies and Information for the Editor, Proceedings of the CMVCA* was completed. These documents will be submitted to the CMVCA Board of Directors for adoption during the January meeting.

Finally, it is the intent of the Publications Committee to accomplish two goals during 1992. The first is the establishment of the necessary guidelines to facilitate the publishing of pertinent materials on a timely basis. This should be realized during the January meeting of the Board of Directors. Secondly, the elimination of the backlog of items awaiting publishing. Once the guidelines are in place and we are back on schedule, the two year effort will be complete.

ENTOMOLOGY SUBCOMMITTEE

Stephen L. Durso (Chair)
Jack E. Hazelrigg, Ronald D. Keith, Edward Magoon, Richard P. Meyer, Marc R. Pittman, James P. Webb, Glenn M. Yoshimura, Lucia T. Hui (Consultant), Charles M. Meyer (Consultant) and Michael Stimmann (Consultant)

The Entomology Subcommittee was initially given but a single charge for 1991- develop a system for the exchange of reference collection arthropods between agencies. While the groundwork and methods for that system were developed, no further progress was made on this charge and it will have to be completed by next year's committee.

The committee did progress on two charges subsequently assigned to it- revision of the entomological chapters in the *California Vector Control Training Manual* and a revision of the field guide for identifying the mosquitoes of California.

ENVIRONMENT AND BIOLOGY SUBCOMMITTEE

Charles H. Dill (Chair)
Ralph T. Alls, Major S. Dhillon, Allen R. Hubbard, Keith R. Kraft, Eugene E. Kauffman, Vicki L. Kramer, David Mandeville, Richard P. Meyer, Thomas Miller, Lewis E. Risley, Fred C. Roberts, Larry Shaw, John R. Stroh, Robert K. Washino and Kenneth R. Townzen (Consultant)

The Committee had three specific charges in 1991. Two dealing with the growing impact of the Endangered Species Act on mosquito and vector control and the third was to write a position paper on the Association's responsibility for wildlife and ways to establish cooperative relations with wildlife and planning agencies.

The first two charges quickly gave way to addressing "wetlands". Following committee meetings in San Diego and Fresno, it was decided that two things were needed: a statewide policy on wetlands and regional criteria for wetlands planning and management. By necessity, the policy issue was addressed first. A two-day workshop was hosted by the Fresno Mosquito and Vector Control District and interested committee members were invited to attend, to hammer out a draft policy. Fred Roberts facilitated the group in producing a first draft. Following a review of the draft at the quarterly Board of Directors meeting in Concord, the Committee set in motion a series of revisions that produced a third generation draft that hopefully will be adopted by the Board of Directors at the quarterly meetings in April.

Next year's committee, chaired by Fred Roberts, will tackle the difficult problem of integrating the general statewide wetlands guidelines with the more specific regional guidelines for use by member agencies. An initial planning meeting will be held at the Sacramento/Yolo Mosquito and Vector Control District on February 27, 1992, at 10:00 a.m.

BIOLOGICAL CONTROL SUBCOMMITTEE

Craig W. Downs (Chair)
Ralph T. Alls, Robert L. Coykendall, Jean Kovaltchouk, Vicki L. Kramer, Marc R. Pittman, Richard T. Ramsey, Gary Reynolds, Stan A. Wright, Werner P. Schon and Joseph J. Cech, Jr. (Consultant)

The Committee completed the revision of the publication *Fishes in California Mosquito Control*. This updated reference is broken down into three major sections; The Fishes, Operational Techniques, and Aquaculture Techniques. The section on The Fishes includes a summary on each known larvivorous fish in California. Each summary is broken down into a section on identification, names, distribution, life history, and status. The section on Operational Techniques includes such topics as aquaria and holding systems, capture equipment and methods, transportation equipment and methods, anesthetics and chemical transport agents, mosquitofish applications, and parasites and pathogens. The last section, Aquaculture Techniques, is broken down into incidental production, extensive culture, and intensive culture.

An expansive reference and literature cited section is also included, as well as appendices on recommended readings, products and services, and useful mathematical equivalents.

Two issues of BioBriefs were distributed during the year. The first, in June, contained information on albino mosquitofish, the use of gypsum in ponds, and triploid grass carp. The second, issued in December, contained information on wetlands regulations and aquaculture and the status of chemicals for use in warmwater fish production.

Finally, we kept apprised of the registration status and availability *Lagenidium giganteum*, which may finally be approved in 1992, although no commercial producer has been identified.

CHEMICAL CONTROL SUBCOMMITTEE

David A. Brown (Chair)
Michael W. Alburn, Carol Evkhanian, Harmon L. Clement, Jerry M. Davis, William E. Hazeltine, Ronald D. Keith, Leo F. Kohl, Ed Lucchesi, Steve Mulligan, Frank W. Pelsue, David B. Whitesell, Jim Wandersheid, Perry Coy (Consultant), Eugene E. Kauffman (Consultant), Mir S. Mulla (Consultant), Charles H. Schaefer (Consultant), Malcolm A. Thompson (Consultant) and Burnell Yarick (Consultant)

The Chemical Control Subcommittee continued to review and report to the Association on the "Hazardous Waste Response Plan" requirements. All member districts were polled as to their compliance with these requirements and generic plans were sent to districts who needed assistance in meeting these legislative mandates.

The Committee worked in conjunction with the Legislative Committee to make it known to regulatory bodies the hardships public health agencies will face if pesticides are further removed from use. Senate Bill (SB) 950 requires all pesticide manufacturers to submit "data gap" information, and many manufacturers have elected to drop registrations for minor use pesticides rather than comply. This will be a continuing problem, and one that requires close attention.

We also worked on clarification of pesticide labels and how these pesticides may be used in wetland sites. Certain pesticide products have what appear to be conflicting statements as to their use in or around water sites for larval control. We received a letter from the Regulatory Section of the California Department of Food and Agriculture clarifying the use of these products for larval mosquito control as directed on the label in and around wetland sites. This letter has been made available to the member districts who have requested it.

The Committee also utilized the IR-4 program to support registration of pesticides for minor use in public health programs. The IR-4 program was contacted concerning the uses of both malathion and *Lagenidium giganteum*. The Committee will continue to use this program to support minor uses for public health agencies.

Work was also begun on the chemical control portions of the *California Vector Control Training Manual*. The Committee will continue to seek help from the appropriate authorities to incorporate the latest technology available into the update of this manual.

Finally, we will continue to support and encourage the development of pesticides, both chemical and biological, for use in public health operations.

DISEASE CONTROL SUBCOMMITTEE

William K. Reisen (Chair)
James R. Caton, Arthur E. Colwell, Jerry M. Davis, Ronald D. Keith, Robert L. Kennedy, Lal S. Mian, Melvin L. Oldham, Allan R. Pfuntner, Harvey I. Scudder, Robert A. Murray (Consultant), William C. Reeves (Consultant), Vern Reichard (Consultant), Ron R. Roberto (Consultant) and Charles W. Smith (Consultant)

The specific charges of the Disease Control Subcommittee for 1991 were:

1. Review the statewide encephalitis virus surveillance (EVS) program and recommend any necessary changes, if needed.

2. Complete the guidelines for interagency response to vector-borne diseases.

3. Complete epidemiological and control guidelines for interagency responses to imported and locally transmitted malaria.

Considerable progress was made towards the completion of our charges, due largely to the efforts of the Committee with excellent support from the Executive Director, Research Foundation Committee, and several branches of the California Department of Health Services. Our progress on each charge may be summarized as follows:

1. The statewide EVS program in 1991 consisted of 10-20 sentinel leghorn hens deployed in each of 85 flocks that were bled monthly from May to September - November for seroconversion to WEE and SLE viruses, and >4,500 pools of *Culex* mosquitoes tested for WEE or SLE antigen. Budgetary constraints on the Viral and Rickettsial Diseases Laboratory for the 1992 mosquito season required that some of the cost for specimen testing be borne by the CMVCA.

   To provide the most sensitive EVS system for the least cost, the Committee revised that statewide system based on the following assumptions: A. Sentinel chickens are more sensitive in detecting low-level viral activity than are pools of mosquitoes; B. Chicken sera cost half as much as mosquito pools to process in the laboratory ($3.44 vs. $6.88); and C. *Culex tarsalis* Coquillett is the primary amplifying vector of both WEE and SLE viruses and testing can be limited to this species.

   The revised EVS program recommended a reduction in sentinel chicken flock size to a standard 10 hens per flock, an increase in the frequency of sera testing from 4-week to 2-week intervals, a lengthening of the sampling period in southern California from April to November, and a reduction in the numbers of mosquito pools to be tested. Although a statewide program was recommended, each CMVCA region modified this original plan to suit local needs and resources. Program funding was shared by the CMVCA member districts on a per sample basis.

   Research was initiated by the Viral and Rickettsial Diseases Laboratory and University of California Arbovirus Research Program to develop improved and cost effective methods for collecting and processing chicken sera.

2. A final draft of the interagency cooperation guidelines for plague was completed and will be submitted to the Board of Directors at the April, 1992, meeting. Plans to prepare guidelines for Lyme disease were hampered by the dissolution of programs by the CDHS.

3. The malaria guidelines have been accepted by the CMVCA Board of Directors and will be distributed to collaborating agencies in 1992.

Committee activities for 1992 will emphasize the revision of interagency guidelines for arbovirus surveillance and control. Most needed are the revision of surveillance methodology and indicators, and the recommended responses by mosquito control agencies to different levels of arbovirus activity.

VECTOR CONTROL RESEARCH COMMITTEE

William C. Hazeleur (Chair)
James R. Caton, Arthur E. Colwell, Jack E. Hazelrigg, Vicki L. Kramer,
John R. Stroh and Bruce F. Eldridge (Consultant)

Each committee member evaluated written research proposals in early February, prior to attending a mosquito research conference organized by Dr. Bruce Eldridge, Director of the University-wide Mosquito Research Program. The conference, a joint meeting between the CMVCA Vector Control Research Committee and the University of California Mosquito Research Technical Committee, was held on March 25 and 26 in Berkeley. At this meeting, individual researchers made oral presentations of their research proposals and answered questions.

On March 27, following the verbal presentations at the Mosquito Research Conference, the CMVCA Vector Control Research Committee met and evaluated each research proposal and each committee member applied a numerical rating to that proposal. Two criteria - relevance to the needs of California mosquito control and past performance record - were used to rate each research proposal on a scale of 1 to 5, with 1 having the highest value and 5 having the lowest value. The rating for relevance was based on the value of these proposals as viewed by California mosquito control. The rating for past performance encompassed whether the researcher prepared an annual report, whether the research reported on in the annual report related to the research proposal which was funded, and whether the comments made by the CMVCA Vector Control Research Committee the previous year were taken into consideration. The researcher's collaboration with mosquito control personnel, attendance at the CMVCA conferences and other meetings of mosquito control people in California, as well as publication of past results were also taken into consideration for rating the research proposal on performance. Committee members' ratings were combined to arrive at an average rating within the 1 to 5 range for each proposal. Comments were also prepared for each research proposal. The comments, individual committee member's ratings and the combined average numerical ratings were compiled into a written report.

Chairman Hazeleur represented the CMVCA at the University of California President's Advisory Committee on Mosquito Research on April 26 at the University of California at Davis. The CMVCA Vector Control Research Committee's written report was submitted and reviewed at this meeting to determine mosquito research funding for the 1991-1992 year.

There were twenty-seven mosquito research proposals submitted for funding in the 1991-1992 fiscal year. Funds requested from the twenty-seven proposals totaled $647,221. Approximately $367,000 was available for funding mosquito research projects in the 1991-1992 year, which was a significant reduction from funds available in previous years. This reduction in funding available for mosquito research projects resulted in several good research projects receiving very limited or no funding in the 1991-1992 fiscal year.

The chairman of the Research Committee also serves on the Board of Directors of the CMVCA Research Foundation, as the Research Committee of the CMVCA is charged with the responsibility to advise that Board "... on all projects and expenditures of the Foundation." This advisory capacity recognized that the Research Committee is composed of representatives from each region in the CMVCA and that the committee members were responsible to be both current in the needs of California mosquito control and to evaluate research proposals.

President Beesley chose to utilize an Ad Hoc Foundation Committee to assess the needs for and recommend changes to the encephalitis surveillance program, including costs, memoranda of understanding, service fees, etc. Although the chairman of the Research Committee was a member of the Ad Hoc Committee, the Research Committee, which was responsible for technical guidance, was left out of this process. The same was true of the evaluation and recommendation of the new chicken bleeding protocol and the granting of research funds from the Foundation.

It is strongly recommended that, in the future, needless duplication, overlap and confusion be avoided by not charging an ad hoc committee to fulfill the existing charges of a standing committee of the Association.

WAYS AND MEANS COMMITTEE

Allan R. Pfuntner (Chair)
Dennis D. Beebe, Lue Casey, Gilbert L. Challet, Elizabeth A. Cline, Charles P. Hansen, Norman F. Hauret, William C. Hazeleur, J. Don Layson, Herbert J. Marsh, Grant W. McCombs, and Donald A. Eliason (Consultant)

During 1991, the Committee addressed five specific charges as requested by the President:

1. The *Trustee Reference Manual* was revised with input solicited from the Trustee Corporate Board and the CMVCA Regions. The manual is to be produced in an 8 1/2" X 11" loose-leaf format and distributed at the 1992 Conference, or shortly thereafter.

2. With input from the membership, a recommendation was made to amend the Trustee Bylaws to reflect the changes in the titles of the Chairman and Vice-Chairman to President and Vice-President. Recommendations were also made to modify the Corporate Bylaws to clarify the status of Associate Members and the definition of those persons allowed to serve as Regional Representatives.

3. After discussion with the various Regions, the Committee recommended that the current method of regional representation be retained.

4. Again with input from the Regions, it was suggested that the current structure of the various CMVCA committees be retained.

5. Upon reviewing the CMVCA office policies, the Committee determined that the personnel policy and related items should be examined by legal counsel. Policies related to office procedures will be discussed with the Committee when presented by the Executive Director. To address certain legal requirements, the Committee tendered a resolution to the Board of Directors designating the Executive Director as the CMVCA Corporate Secretary.

VECTOR CONTROL FOUNDATION (AD HOC) COMMITTEE

Jerry M. Davis (Chair)
Dennis D. Beebe, Gilbert L. Challet, David G. Farley, William C. Hazeleur, Earl W. Mortenson
and Donald A. Eliason (Consultant)

The Committee charges for 1991 and the determinations and/or actions taken on each one were as follows:

1. Review the articles of incorporation, recommend any changes, if needed, by the fall Board of Directors meeting.
   The Committee reviewed the articles of incorporation and found that no changes were required at this time.

2. Recommend terms and conditions, if any, to be applied to research grants.
   The Committee is working on the second draft of the CMVCA Research Funding Policy. The Committee anticipates approval of the policy at the April, 1992 meeting of the CMVCA Board of Directors.

3. Review whether or not this fund is the appropriate mechanism to fund the statewide viral surveillance laboratory.
   The Committee found that the CMVCA Research Foundation is the appropriate agency to provide funding and oversight for the statewide encephalitis surveillance program. The Committee presented the 1992 Statewide Mosquito-Borne Encephalitis Surveillance Program and proposed adoption of stand-by/service fee for 1992 to properly fund the program to the CMVCA Board of Directors at the December meeting. The statewide program and proposed stand-by/service fee were approved by the Board at that time.

The Chairman appreciates the work done by all Committee members. Also special appreciation goes to Bill Reisen, Disease Control Subcommittee Chairman, and members of the Disease Control Subcommittee for developing bases for the statewide Mosquito-Borne Encephalitis Surveillance Program; CMVCA Executive Director, Don Eliason for his efforts in developing the statewide plan and providing input for developing the foundation policy regarding request for research funding; and Bruce Eldridge for his efforts in drafting the CMVCA Research Foundation Funding Policy.

NORTHERN SAN JOAQUIN VALLEY REGION

Jerry M. Davis (Regional Representative)

The Northern San Joaquin Valley Region met on many occasions during the 1991 calendar year. The following are major items discussed and concerns of the Region expressed:

Continuing Education.

The Region approved a two year continuing education program for the second cycle. The Region will conduct one day training programs in the fall and spring of each year.

There is concern over the lack of a system to track certificated employees. The Region believes fees for maintenance of the system should be paid by all individuals who are certified. The tracking of continuing education units is another area the Region would like to see cleared up. Once a system is approved, every one can use the same system.

Funding for Statewide Encephalitis Program.

As a result of the shortfall in funds for the VRDL, the Region met and developed a surveillance network to reduce overlap and improve sensitivity of the existing system.

Wetlands.

The Region has been affected by the development of wetlands. There is much concern within the Region as adequate mosquito control in wetlands is difficult to achieve. The Region believes that the CMVCA should develop a statewide policy on wetlands that supports the membership.

Participation of Department of Health Services - Environmental Management Branch.

The Region is concerned about the loss of services that the Districts traditionally receive from the E.M.B. Priorities need to be set and funding provided for services the membership feels are necessary.

Election of Regional Representative and Alternate.

The Region elected Jerry M. Davis, Manager of Turlock M.A.D., as Regional representative and Allen Inman, Manager of Merced County M.A.D., as alternate for 1992.

CMVCA Research Foundation Policy for Research Funding.

As sources of funding for research dry up, the Region believes that Districts will have to fund research projects if they want the research done. The settling of project priorities and funding mechanisms need to be in place this coming year.

Redevelopment Agencies.

During this last year every district in the region was affected by redevelopment agency projects. The Region would like to see standards set in the future for determining financial burden and detriment. Guidelines need to established through the CMVCA.

SOUTHERN CALIFORNIA REGION

Allan R. Pfuntner (Regional Representative)

During 1991, the Region met four times (2/28, 5/8, 7/29, and 11/4). The most important items of discussion were as follows:

1. The pro's and con's of VCJPA/CMVCA joint membership.

2. The status of the various insurance coverages provided by the VCJPA and the "rebates" enjoyed by most agencies.

3. Changes to the Trustee and Corporate Bylaws, and the revision of the Trustee Manual.

4. The problems with the State budget and its effects upon EMB.

5. A funding mechanism for the VRDL to allow adequate EVS activities.

6. The inception of a regional approach to Public Education and the production of "generic" pamphlets and cable-ready video tapes.

7. The nomination of Norm Hauret of L.A. County West M.A.D. for Honorary Membership.

8. The selection of Bill Boynton of Orange County V.C.D. as Trustee Representative for 1992 and Wayne Stringer of West Valley V.C.D. as alternate.

9. The selection of Major Dhillon of Northwest M.A.D. as Regional Representative for 1992.

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MOSQUITONET - A NEW STATEWIDE COMPUTER INFORMATION SYSTEM

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Introduction.

Starting in January, 1992, mosquito control professionals and others interested in the biology and control of mosquitoes in California can dial into a new statewide computer information system. Although the system will operate in 1992 with fairly modest capabilities, we expect the system to expand its scope and usefulness extensively in the years ahead. The system will be demonstrated throughout this conference.

The CMVCA Computer Applications Committee was first appointed in 1988 to design and implement a statewide computerized information system for mosquito abatement agencies: the State Department of Health Services, and the University of California. The Committee provided CMVCA with its recommendations in 1990. In late 1991, the CMVCA Board of Directors authorized the expenditure of funds to purchase a host computer and software, and for the continued maintenance of the system. The equipment and software has been obtained, and a U.C. graduate student, Michael Gurnee, has been hired on a quarter-time basis to maintain the system. The system has been coined "MosquitoNet".

Hardware.

The host computer is a Zeos 80486-33 microcomputer with 8 MB of memory and a 210 MB hard disk. Presently, two 2400-baud Everex modems are installed. Four dedicated voice-quality telephone lines have been installed and are hard-wired to the modems. The telephone lines have searching capability, so that if the first number is busy, the system automatically tries the second number, and so on.

Software.

MosquitoNet is operated as a modified "bulletin board" using the Gallacticom Major BBS. Initially, a two-user version is being used, but soon the software will be upgraded to a four-user version to take full advantage of the four telephone lines. The present configuration of the software is what is called "plain vanilla" in the computer business, i.e., without embellishment or enhanced menus. As such, it may be accessed from any type of microcomputer in the field using a modem (up to 2400 baud) and some type of communication software. We use ProComm, but there are many other programs which will work just as well. When the MosquitoNet number is called (916-752-5484), an initial screen appears and new users are asked to select a user identification and a password. If Mike Gurnee, the system operator (SYS-OP) recognizes the caller as someone associated with mosquito control, he will assign user credits.

After being recognized by the SYS-OP, users have access to seven "subject areas". These are: News (system information), Chemical (information of public health pesticides), Disease (vector-borne disease information), Laws (pending legislation), Research (information on research on mosquitoes and researchers), and Species (endangered species information).

Each of the seven subject areas is maintained by subject area managers (SUB-OP) who have connection with an appropriate CMVCA committee to insure that the information contained in the system is kept current. As an example, Dave Brown is Sub-Op for Chemical, and is also Chairman of the Chemical Control Committee. Don Eliason is Sub-Op for the Laws subject area, and places legislative digests obtained periodically from Mr. Ralph Heim, CMVCA Legislative Analysis, in the Laws subject area.

In addition to the subject areas, any user may leave messages and files to any other user on the system. I have already sent a long manuscript to a co-worker via this route without any difficulties.

Graphical Front End.

The Computer Committee is working with Mr. James Kalin of Simulation Laboratories, Concord, California, to produce a graphical front end for the system which will present the user with a colorful graphic interface usable with a mouse. The interface uses an office as a metaphor and will make it unnecessary to deal with the character-based interface of the bulletin board software at all. We will demonstrate a limited capability interface which runs under Microsoft Windows version 3.0 at this conference. For anyone with an MS-DOS computer which can run Windows, I recommend use of the graphical interface, especially if users in your organizations do not have extensive computer experience. You will be able to use all of the systems features, and in addition, will have some features, such as key word searching, not available on the character-based version. We hope to obtain grant funding to develop an even better interface which will have advanced features such as computerized mapping, report generation, and database searching.

Although the system should get better in time, I hope you will agree that even in its present form there is a lot of useful information available on the system. The Computer Committee stands ready to help with any questions about hardware or software you might have, and is committed to making the system usable and useful. Try it - you'll like it!

THE FIVE-YEAR PLAN FOR THE C.M.V.C.A.

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The California Mosquito and Vector Control Association (CMVCA) has been attempting to develop long range planning goals for some time. During the past three years, several Board and Executive Committee meetings have addressed long range planning, most notably the retreat at Granlibakken held October 23-25, 1989, and the Board of Directors' workshop in Sacramento on June 25, 1991. The Five-Year Plan is a summary of these meetings and is intended to provide a framework for more effective Board direction and action. The plan has four components, as follows:

ANNUAL WORKSHOPS

Two events in 1991 reinforced the need for annual workshops by the Association: the Board of Directors' retreat in Sacramento and the management workshop in Santa Rosa. The Sacramento retreat focused on the many issues impacting our Association and its member agencies. Four areas of concern were discussed: (1) how the Board of Directors should conduct business; (2) how to best interact with professional affiliations, such as the University of California, the Environmental Branch of the California State Department of Health Services, and the Directors of Environmental Health; (3) setting annual goals and periodically reviewing issues and priorities; and (4) having an annual workshop for the Board of Directors shortly after the conference to maintain continuity from one presidency to the next.

The management workshop in Santa Rosa was open to all member agencies, employees, and trustees. The focus was on how to conduct open meetings and manage public agencies. Topics of discussion included: (1) the general responsibilities and duties of trustees; (2) developing policies; (3) establishing goals and objectives; (4)board/management relations; (5) personnel management; (6) finance management; and (7) public relations. The list of potential subjects for future workshops is significant and is expected to grow with the ever-changing political climate in California. The Association strongly supports continued workshops of this kind to stay abreast of issues.

FINANCIAL PLANNING

Past budget activities have focused solely on two facets of budgeting: determining whether the current budget expenditures fall within adopted limits and developing "next year's budget". While the Association has built up reserves, there are no policies and objectives for how reserves should be spent, and how much should be saved. Starting in 1992, the annual budget now includes an unappropriated reserve to be set aside for reserve buildup. Approval for expenditures will require a four-fifths vote of the full board. Nevertheless, it will take a 10% annual set-aside to attain a 100% reserve fund by 1996 (Fig. 1). But as the Association expands its duties and complexity of operations, there will be increased costs of operation which will undermine the value of these reserve funds. To offset this problem, we should have budget forecasts which show the impact of any changes to revenues, expenses, and reserves. This will provide incoming presidents with the necessary information to make realistic goals without creating deficits. Furthermore, it will provide a financial framework for the Executive Director to use as a management tool to successfully direct the Association over time.

FOUNDATION ACTIVITIES

Surveillance

The CMVCA Disease Control and Ad Hoc Vector Control Foundation Committees have developed a Statewide Viral Surveillance Plan which requires a minimal amount of funding (estimated to be $53,000 for the CMVCA in 1992), which is a

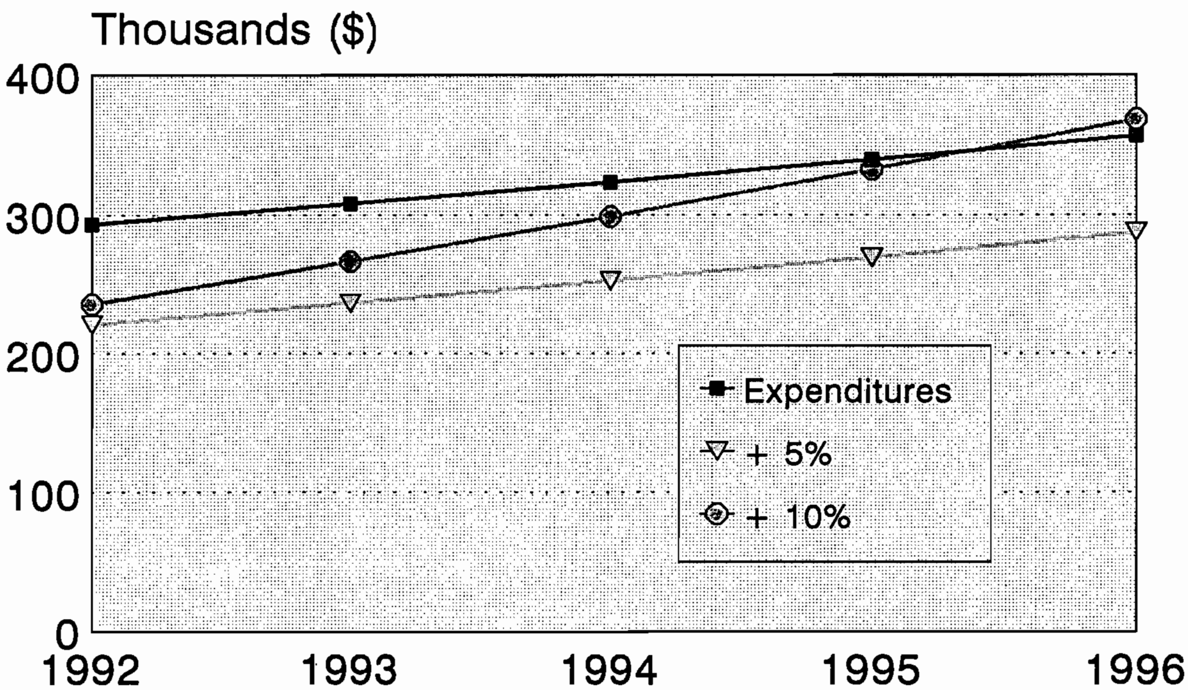

Figure 1. Five-year CMVCA budget and reserves accumulation projections at two levels of saving.

"pay-as-you-go" approach, requiring annual commitments by agencies before the vector season starts. This surveillance fund will probably increase gradually over the next five years as agencies gain confidence in the Foundation and member participation increases. The major problem yet to be resolved is whether or not costs should be the same for member and nonmember agencies.

Research Proposals

One of the Foundation's goals is to review, approve, and fund research proposals of interest to the CMVCA. In order to do this consistently and effectively, a policy should be adopted regarding requests for research funding. For example, proposals could be sent to the Executive Director, who would then forward them to the Vector Research Committee (VRC) for their review and approval. The VRC would then make a recommendation to the Board of Directors of the Foundation. Once approved, funds would then be solicited from corporate or other members. Within five years, the Foundation's budget could very easily double, not from cost increases, but from increased participation as agencies gain confidence in the program.

ASSOCIATION'S ROLE

Support Services

At the Sacramento workshop, it was evident that support agencies such as the State Department of Health, Environmental Management Branch (EMB) and University of California (University), are under severe financial pressures. To date, the University has been able to make adjustments and continue to provide mosquito research funds. This is not true of the EMB. It is very apparent their role is being severely curtailed as field biologist positions continue to be cut from the program. The Association responded by filling some of these gaps, most notably by creating the CMVCA Foundation for statewide viral surveillance, which was historically a function of EMB. If these cuts in service continue, the Association must decide just how many of the EMB functions it may wish to provide. If we decide to replace these lost services, new programs would need to be implemented, which may include expansion of the current CMVCA committee duties. Otherwise, these statewide EMB services will probably disappear, and their absence severely felt when the next vector-borne crisis occurs.

Direct Services

Public Awareness: In the past, the EMB provided statewide public relations and funding (subvention) coordination when vector-borne outbreaks occurred. With the cuts in EMB services, we can no longer depend on their help. At the same time, the Association does not have a statewide communications program or education plan. Outbreaks of vector-borne diseases at the local level are not coordinated statewide through the Association and corporate members often learn about these outbreaks too late for effective program adjustments. By having direct participation and involvement of the Executive Director, information could be quickly disseminated to corporate members for their individual or regional use. Before initiating this type of coordination, the Association should determine what public relations or management role the Executive Director should perform in the event of a vector-borne outbreak.

Legislation: Contact with local, state, and federal lawmakers is increasingly important to our survival, for legislation affects our abilities to conduct business. The Association, through the Trustee Corporate Board, has developed a basic legislative network which is a list of legislators that the Executive Director, President, chairperson of the Legislative Committee, and trustees may contact in the event proposed legislation requires action on our part. However, this is just one facet of our overall response process. The Association also relies heavily on committee review of legislative bills, involvement by the Executive Director, and most importantly, professional legislative advocacy. The next few years will see a continued proliferation of new bills affecting public agency financing, pesticide usage, and regional government - to name a few - which will require continued vigilance by the Association to ensure vector control agencies have legislative input. Otherwise, the state and federal governments will continue to draft and pass legislation that overlooks vector control. The Association can now monitor legislative bills through a computer telephone link to "MosquitoNet" at the University of California, Davis. This should expedite our response capabilities to legislative changes. The Executive Director, in conjunction with the Board of Directors and the Trustee Network, should provide the lead role in representing our policies and position papers with state and federal legislators and professional affiliations.

Professional Affiliations

The Association interacts with two sister associations: The California Conference of Local Health Officers (CCLHO) and the California Directors of Environment Health (CDEH). The Board of Directors has historically appointed two members of the Association as representatives, and has also relied on the EMB to review and influence the development of policies within these organizations. With the probable loss of EMB's support, these liaisons are now threatened. The Executive Director can best fill this role for the Association and has been appointed by the Board of Directors to be our official representative.

SUMMARY

The Association is concerned with a wide array of public policy issues and is responsible for coordinating many statewide activities. To keep abreast of issues we should have annual management workshops for the general membership, as well as an annual retreat for the Board of Directors to review current issues, establish priorities, and reaffirm five-year commitments. We need to establish fund management policies and five-year budget goals to effectively manage our resources and ensure adequate reserve buildup. The Foundation's influence will continue to grow as agency confidence and participation improve, as exemplified by the development of a Statewide Encephalitis Surveillance Plan. The combination of these events will result in a more dynamic role for the Association and its members, requiring greater participation and coordination. Our Executive Director will be the key person to coordinate these many events, represent us professionally, and manage our Association. We need to give him our full support and commitment as we forge ahead for the next five years and beyond.

EXECUTIVE DIRECTOR'S ANNUAL REPORT FOR 1991

Donald A. Eliason

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Much work was accomplished by the California Mosquito and Vector Control Association (CMVCA) during 1991 under the leadership of President Chuck Beesley and the very active participation of committee members and others in committee activities. Much of the progress during 1991 was made possible by the decisions and commitments made by the Association in previous years, especially from the 1989 retreat at Granlibakken. This report only briefly outlines some of the accomplishments.

A full-time Executive Director was employed and came on duty on January 4, 1991. The help and assistance provided during the transition by former Executive Director John Combs, is greatly appreciated. The CMVCA is a complex organization attempting to deal with an ever increasing number of technical and legal challenges faced by its member agencies. John's wealth of historical knowledge and perspective and his political insight have served the Association well and his willingness to assist in the transition has been invaluable.

The beginnings of a statewide computer information network, MosquitoNet, was initiated by Bruce Eldridge and his Computer Committee following the purchase of a computer and its installation at U.C. Davis. Development of the network will provide the opportunity for improved exchange of information and interaction in many areas of CMVCA and member activities.

Some improvements were made in coordination of the efforts of the Legislative Committee and those of our lobbyist, Ralph Heim. Committee Chair Bill Hazeltine and Executive Director Don Eliason worked on grouping legislative bills of possible interest to the CMVCA into different categories before they were assigned to committee members for initial review and comments. A form was developed for use by the committee members in providing Ralph with the Association's position on each bill along with our reasons for taking that position. Although the system was far from perfect, it did help to organize efforts and Ralph indicated that there was improved input from the Association.

Also important to the Association's legislative efforts was the development of a list of district trustees who have contacts with state legislators. In practice, one or more trustees on the list are contacted in the event help is needed on a bill of importance to the CMVCA which is being heard by a state legislature committee. The only trustees called are those who have previously indicated they have contacts with legislators on the committee hearing the bill.

The Association appears to be in good financial heath. The amount of unappropriated reserves increased from $206,214 on January 1, 1991, to $221,667 on December 31, 1991. There were 49 Corporate Members at the end of the year and the number of Associate Members grew from 93 in 1990 to 172 in 1991. While the new Associate Members were certainly welcome, the increase in numbers was not entirely beneficial to the Association since Associate Member dues are only $30 per year while the cost of the publications and mailings they receive throughout the year is nearly double that amount. An adjustment of dues and/or benefits should be considered.

The Annual Conference in Sacramento in January, 1990, was the largest ever with a total of 440 registered participants. During the year, there was also good participation in other meetings. In addition to the quarterly meetings in Fresno, Monterey, and Concord (which were well attended), a workshop on Public Health Emergency Exemption under the Endangered Species Act was held in Sacramento and a management workshop was held in Rohnert Park.

The Annual Conference ending the CMVCA 1991 calendar year was held in Concord in January, 1992, with 363 registrants attending.

Committee meeting schedules were carefully scheduled by Vice President Mike Wargo to provide the least possible conflict for committee members who served on more than one committee. Also, arrangements were made to provide meeting rooms with adequate space for committee members as well as others who were interested in committee activities. Most committee meetings were very well attended. In some cases, the amount of discussion made it difficult to complete business in the allotted time.

Publications in 1991 included the *Proceedings and Papers* for 1990 and 1991, *Fishes in California Mosquito Control*, a brochure entitled "Lyme Disease in California" that was provided by the Santa Clara County V.C.D., and the 1992 Yearbook. This considerable achievement was due to the diligent efforts of many individuals including Peter Ghormley and his Publications Committee, Craig Downs and his Biological Control Subcommittee, and especially the hard work and dedication of Stephen Durso, Glen Yoshimura, and Linda Sandoval.

During 1991, the encephalitis surveillance effort was dependent on donations from a small number of member districts. As an alternative to this unpredictable funding method, a "pay as you go" plan was developed and approved for future years which involves all participating members and non-members signing a memorandum of understanding in which they agree to pay for support of the laboratory work in proportion to the number of samples they plan to submit during the coming year. This should provide a predictable source of funds for the State of California's Viral and Rickettsial Diseases Laboratory (VRDL) which will allow them to plan for and provide trained workers when they are needed. Jerry Davis and his Vector Control Foundation Ad Hoc Committee deserve credit for their dedicated efforts in accomplishing this task.

The Board of Directors held an important retreat in Sacramento on June 25-26, 1991. In addition to the Board members, CMVCA Treasurer Alan Hubbard as well as Bruce Eldridge, U.C. Director of Mosquito Research, and Don Womeldorf, Environmental Management Branch Chief, also participated in the retreat. The group developed a conceptual framework for the future in the form of a Five Year Plan. Included in this plan was a goal to achieve financial reserves equal to 100% of annual budget in five years. The importance of the Granlibakken retreat in 1989 was discussed and formed a background for the 1991 retreat.

WILLIAM C. REEVES NEW INVESTIGATOR AWARD

The William C. Reeves New Investigator Award is given annually by the California Mosquito and Vector Control Association in honor of the long and productive scientific career of Dr. William C. Reeves, Professor Emeritus, School of Public Health, University of California at Berkeley.

The award is presented to the outstanding research paper delivered by a new investigator based on quality of the study, the written report, and presentation at the annual conference.

Darold P. Batzer was the recipient of the 1992 award at the 60th Annual Conference held in Concord. The other finalist was Michael A. Gurnee. The two finalists' papers are printed on pages 202-210.

Previous William C. Reeves New Investigator Award Winners:

1991 - David R. Mercer
1990 - Gary N. Fritz
1989 - Truls Jensen
1988 - Vicki L. Kramer

1992 WINNER

WILLIAM C. REEVES NEW INVESTIGATOR AWARD

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RECOMMENDATIONS FOR MANAGING WETLANDS TO CONCURRENTLY ACHIEVE WATERFOWL HABITAT ENHANCEMENT AND MOSQUITO CONTROL

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ABSTRACT

Reviewed are results of experiments that examined responses of invertebrate populations to the management of water depths and vegetative cover in Suisun Marsh, Solano County, California. The manipulations that provided the open water to emergent plant-cover ratios preferred by waterfowl further enhanced waterfowl habitats by increasing densities of the invertebrates important in waterfowl diets. These manipulations concurrently reduced densities or habitat availability for mosquitoes.

Introduction.

California wetlands that are managed to benefit waterfowl can, unfortunately, also be sources of mosquito breeding (Garcia and Des Rochers 1984). However, the use of pesticides or habitat manipulations that target mosquito populations is often discouraged by wildlife officials because they are concerned that these techniques may inadvertently harm wildlife.

Therefore, rather than developing new wetland management techniques to control mosquitoes, our project has investigated how the water level manipulations (Batzer and Resh 1992a) and plant-cover management techniques (Batzer and Resh 1991, 1992a, 1992b), which are already used by wildlife officials to enhance waterfowl habitat quality, can also be used to control mosquitoes.

Invertebrates are important as protein-rich food resources for California waterfowl as they prepare for migration and reproduction (Connelly and Chesemore 1980, Euliss and Grodhaus 1987, Miller 1987). Therefore, we also examined responses of these invertebrates to wetland management. The relative densities of these species will influence the quality of wetlands as waterfowl habitat.

Study Area.

All experiments reviewed in this paper were conducted in wetlands of Grizzly Island Wildlife Area (GIWA) in Suisun Marsh, Solano County. Most wetlands at Suisun Marsh are seasonally flooded from autumn through early-spring to provide habitat for over-wintering waterfowl. The pestiferous mosquito species that are abundant in the brackish wetlands of Suisun Marsh include *Aedes melanimon* Dyar, *Aedes dorsalis* (Meigen), *Culex tarsalis* Coquillett, and *Culiseta inornata* (Williston). The invertebrates of Suisun Marsh that are important in diets of local dabbling ducks

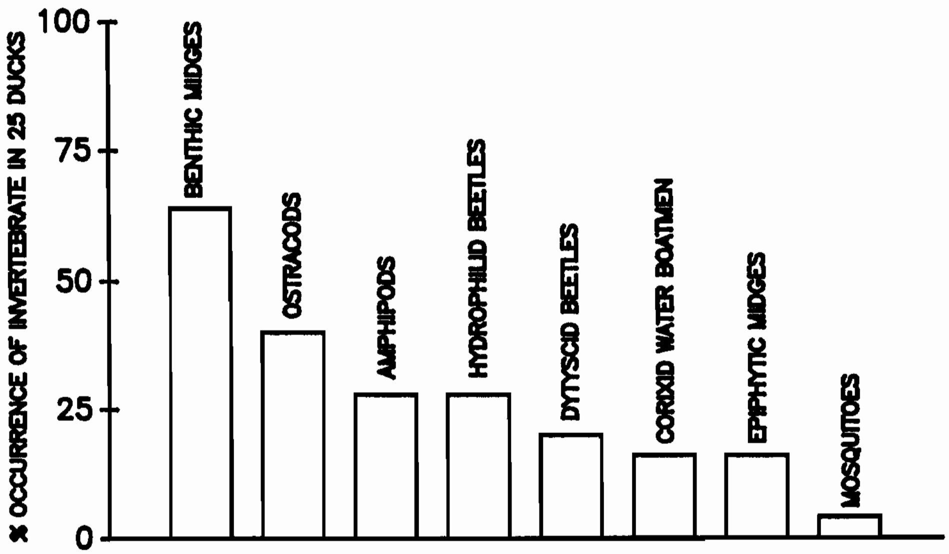

Figure 1. Insects and crustaceans found in esophageal contents of 25 dabbling ducks (19 mallards and 6 green-winged teals) collected from GIWA wetlands by Calif. Dept. Fish and Game employees during the winters of 1989 and 1990.

include chironomid midges (Diptera), Ostracoda, Amphipoda, hydrophilid and dytiscid beetles (Coleoptera), and corixid water boatmen (Hemiptera) (Fig. 1).

Wetland Management Techniques.

Influence of Manipulating Water Depths on Waterfowl Habitat Quality and Mosquito Populations:

Our experiments indicate that manipulating water depths can influence waterfowl habitat quality and *Cs. inornata* mosquito populations (Batzer and Resh 1992a). Three depths (20, 40, and 60 cm) were provided in a series of experimental ponds at GIWA (for details of ponds see Batzer and Resh 1988). Of these three depths, 20 cm depths had (1) the least amount of open water (<25%) available to waterfowl in the dense stands of emergent pickleweed, (2) the lowest densities of epiphytic midge larvae (*Cricotopus sylvestris*) and water boatmen (*Trichocorixa verticalis*), both waterfowl food items, and (3) the highest densities of *Cs. inornata* larvae (Batzer and Resh 1992a)(Fig. 2).

In contrast, 60 cm depths had (1) the most (about 75%) open-water available to waterfowl, (2) the highest densities of water boatmen and midges, and (3) the lowest densities of mosquitoes (Fig. 2) (Batzer and Resh 1992a). However, 60 cm depth habitats should be drawn down slowly in late-February or March in order to provide access for ducks to benthic invertebrates.

Thus, for wetlands with thick vegetation, flooding to deep depths may be a management option that yields high quality waterfowl habitat and low numbers of *Cs. inornata* mosquitoes. Perhaps wetlands with severe *Cs. inornata* problems or those near human population centers should be prioritized to be among the subset of habitats flooded to deeper depths.

California wetlands that do not have dense emergent vegetation do provide quality waterfowl habitat despite having shallow water (Euliss and Harris 1987), but these habitats probably will not produce large numbers of *Cs. inornata*. The responses of these mosquitoes to water depth in our experiments were likely related to levels of surface plant-cover and not water volume. Below we show how shallower areas with dense pickleweed cover can be further manipulated to enhance densities of invertebrates important in waterfowl diets and to reduce densities of mosquitoes.

Influence of Manipulating Plant-Cover on Waterfowl Habitat Quality and Mosquito Populations:

Vegetation mowing is typically used by managers of California waterfowl habitats to increase the amount of open water available to ducks (Rollins 1981). We compared habitats that had plant-cover reduced 50% by mowing to unmown areas in both experimental ponds (Batzer

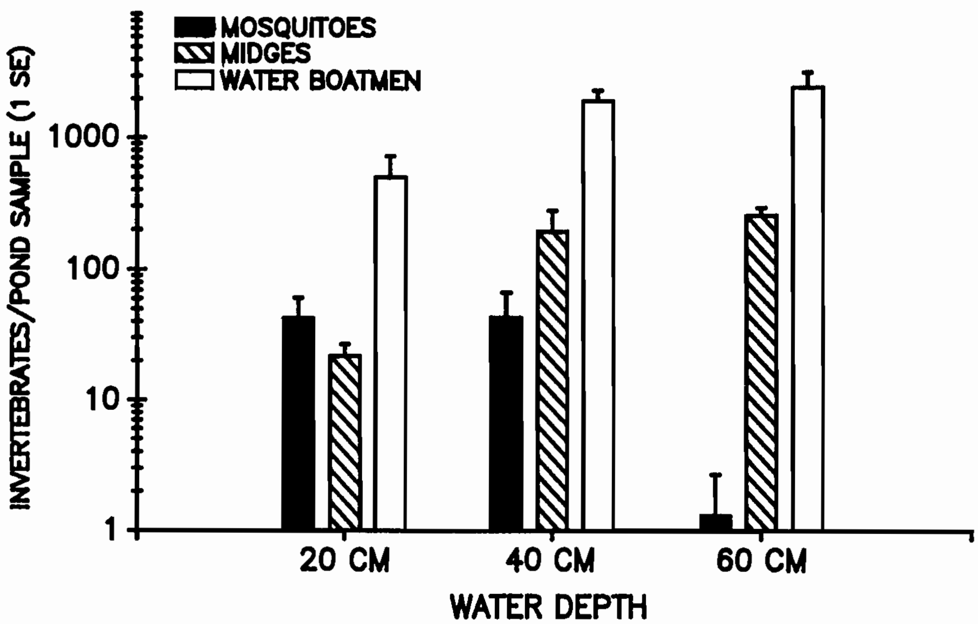

Figure 2. Mean densities (± SE) of larval mosquitoes *(Cs. inornata)*, midges (*C. sylvestris*), and water boatmen (*T. verticalis*) collected in ponds flooded to 20, 40, or 60 cm (N=3 ponds/treatment) from January - March, 1988.

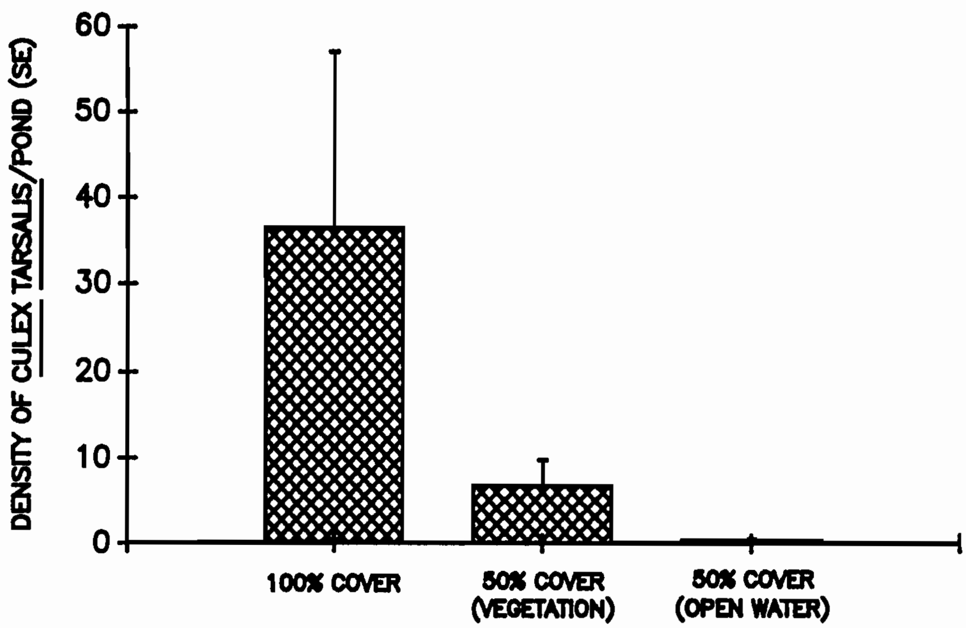

Figure 3. Densities (± SE) of *Cx. tarsalis* found at various locations within 11 experimental ponds located at GIWA. One-half of each pond had the plant-cover of pickleweed reduced by 50% by mowing.

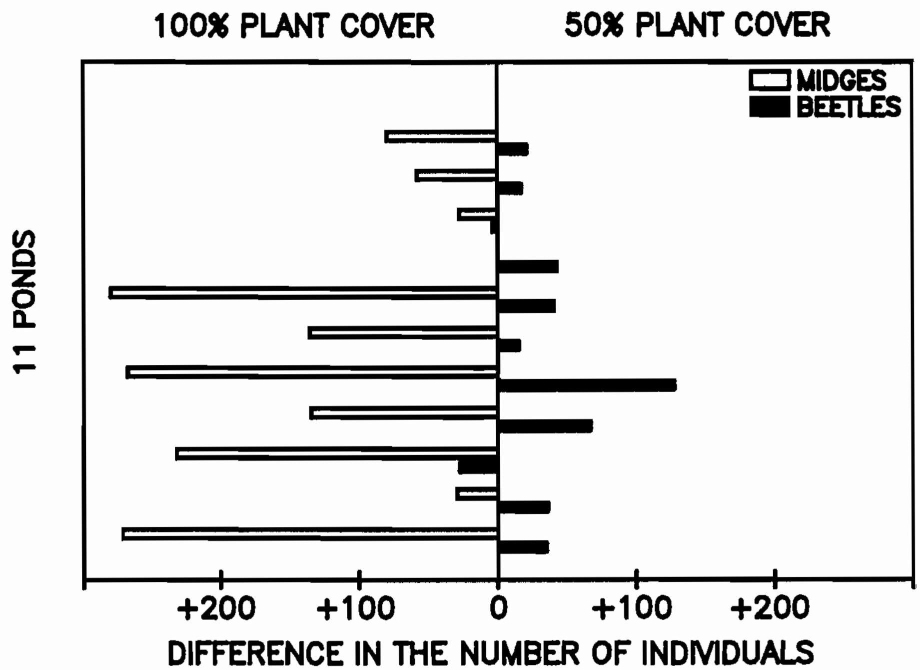

Figure 4. Relative differences in numbers of epiphytic beetle larvae (*B. ingeminatus*) and midge larvae (*C. sylvestris*) collected in 100% and 50% plant-cover portions of 11 experimental ponds during November 1989.

and Resh 1991, 1992b) and the larger-scale setting of a pool managed by officials of GIWA (Batzer and Resh 1992a). In both instances, mowing further improved the wetlands as waterfowl habitat by increasing numbers of the invertebrates consumed by ducks and also reduced densities or the amount of habitat availability for mosquitoes.

In the experimental ponds, mowed habitats had significantly ($P < 0.05$) higher densities of waterfowl food items such as hydrophilid beetles (*Berosus ingeminatus*), water boatmen (*T. verticalis*), and amphipods (*Eogammarus confervicolus*) than unmown habitats (Batzer and Resh 1992b). In contrast, densities of *Cx. tarsalis* larvae were higher in unmown habitats than mowed habitats (Batzer and Resh 1992b)(Fig. 3).

The direct influences of manipulating vegetative cover on predaceous hydrophilid beetle larvae, however, further influenced trophic interactions among the beetle larvae, their midge prey, and periphyton (the food supply for midges) (Batzer and Resh 1991). Because of beetle larval predation, autumn densities of epiphytic midge larvae in mowed areas were significantly reduced (Fig. 4). However, after these beetles migrated to benthic substrates in winter, densities of the epiphytic midges rebounded. The suppression of midges in autumn apparently allowed their food supply of periphyton to accumulate, which then benefitted midges in winter.

Midge densities in mowed habitats were significantly ($P < 0.05$) higher in winter than autumn. Alternatively, in unmown habitats with few predaceous beetles, midge densities in autumn were often high (Fig. 4). However, grazing by these midges reduced the amount of periphyton available for food in winter and midge densities then declined. Thus, in the late-winter period when invertebrates are most important to foraging ducks, the mowed habitats (which also had fewer mosquitoes) provided more epiphytic midges for waterfowl consumption than unmown habitats [see Batzer and Resh (1991) for more detail on these interactions].

In preliminary studies in larger wetland settings, similar over-all patterns to those observed in the experimental ponds have been observed (Batzer unpublished data). In a separate large-scale study where flooding was delayed until late-October (wetlands in the previous studies were flooded in September), we still observed that mowing enhanced densities of invertebrates consumed by ducks and provided benefits to mosquito control. However, because varying flood date can affect invertebrate species composition (Batzer unpublished data), the species that were affected by mowing in this experiment differed from those discussed above. Benthic midges (*Chironomus stigmaterus*) and dytiscid beetle larvae (*Agabus distintegratus*) had higher densities in the 50%-mowed habitats than in unmown habitats (Batzer and Resh 1992a). Although densities of mosquitoes (*Ae. melanimon* and *Cs. inornata*) were not significantly decreased by mowing here, these larvae concentrated along upland edges of the wetland in 50%-mowed habitats but remained dispersed throughout unmown habitats (Batzer and Resh 1992a). Thus, specific mosquito management in the mowed habitats could be restricted to upland edges.

Conclusions.

The above experiments indicate that management of water levels and plant-cover can enhance wetlands as waterfowl habitats and concurrently reduce problems from *Culex*, *Culiseta*, and *Aedes* mosquitoes in a California seasonal wetland. Another of our experiments, as yet unpublished, indicates that manipulating flooding date of Suisun Marsh seasonal wetlands can also achieve habitat enhancement for waterfowl and concurrently reduce mosquito problems.

In addition, our experiments in Minnesota wetlands indicate that *Coquillettidia* mosquitoes can also be controlled with a technique that enhances waterfowl habitat (Batzer and Resh 1992b). This control approach may be useful in many habitats where mosquitoes and waterfowl co-exist.

References.

Batzer, D.P. and V.H. Resh. 1988. Waterfowl management and mosquito production in diked salt marshes: preliminary considerations and mesocosm design. Proc. Calif. Mosq. Vector Control Assoc. 56:153-157.

Batzer, D.P. and V.H. Resh. 1991. Trophic interactions among a beetle predator, a chironomid grazer, and periphyton in a seasonal wetland. Oikos 60:251-257.

Batzer, D.P. and V.H. Resh. 1992a. Wetland management strategies that enhance waterfowl habitat quality can also control mosquitoes. J. Amer. Mosq. Control Assoc. 8(2):117-125.

Batzer, D.P. and V.H. Resh. 1992b. Macroinvertebrates of a California seasonal wetland and their responses to experimental habitat manipulation. Wetlands 12:(in press).

Connelly, D.P. and D.L. Chesemore. 1980. Food habits of pintails, *Anas acuta*, wintering on seasonally flooded wetlands in the northern San Joaquin Valley, California. Calif. Fish and Game 66:233-237.

Euliss, N.H. and G. Grodhaus. 1987. Management of midges and other invertebrates for waterfowl wintering in California. Calif. Fish and Game 73:238-243.

Euliss, N.H. and S.W. Harris. 1987. Feeding ecology of northern pintails and green-winged teal wintering in California. J. Wildl. Mgmt. 51:724-732.

Garcia, R. and B. Des Rochers. 1984. Studies on the biology and ecology of mosquitoes in relation to the development of integrated control measures at Gray Lodge Wildlife Refuge, Butte County, California. University of California Mosquito Control Research Program, Davis, Misc. Publ. 42 pp.

Miller, M.R. 1987. Fall and winter foods of northern pintails in the Sacramento Valley, California. J. Wildl. Mgmt. 51:405-414.

Rollins, G.L. 1981. A guide to waterfowl management in Suisun Marsh. California Dept. Fish and Game, Misc. Publ., Sacramento, CA. 109 pp.

1992 Proc. Calif. Mosq. Vector Control Assoc. **60: 207-210**

THE COLLECTION AND SEPARATION OF SNOWPOOL MOSQUITO EGGS: SOME TECHNIQUES AND APPLICATIONS[1]

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Snowpool mosquitoes of the genus *Aedes* present some difficult challenges for research. By definition, snowpool mosquitoes live and breed in and around pools formed by melted snow. Since most snowpool species are univoltine and rarely mate in the laboratory, colonization of these species is difficult and often unsuccessful (Brust 1971). In addition, the eggs of snowpool *Aedes* undergo a long period (6-9 months) of obligatory diapause which can only be terminated by proper "conditioning", or the exposure of eggs to certain environmental conditions before hatching will occur (Bidlingmayer and Schoof 1956, Horsfall 1956). For some species, optimal hatching occurs when eggs are stored for long periods at temperatures approaching 0°C under short day photoperiods (McHaffey and Harwood 1972; Kardatzke 1977, 1979; Horsfall and Fowler 1961). As of yet, all attempts at early termination of diapause have resulted in no, or very low, hatching.

Our laboratory is investigating egg diapause and oviposition of the snowpool mosquito *Aedes tahoensis* Dyar, a member of the *Aedes communis* (De Geer) complex. Like all snowpool *Aedes, Ae. tahoensis* lays its eggs in the top layer of the soil, presumably upon or underneath plant material and other detritus. It is not known whether this species prefers certain soil moisture levels, plant material, soil types, or other factors that have been shown to stimulate oviposition. It is presumed that such factors exist judging by the results of oviposition studies done on floodwater species (Russo 1977, 1978; Horsfall 1963; Ritchie and Johnson 1991). These studies show a distinct tendency for floodwater *Aedes* to lay their eggs along a horizontal band located midway between the pool bottom and the maximum floodline. Corbet (1975) showed that some mosquito species have significant preferences for pools with specific emergent plants around the edges. It is likely that there are certain oviposition cues to which snowpool species like *Ae. tahoensis* are attracted as well. Our primary goal is to elucidate those cues and use that knowledge to collect large amounts of diapausing eggs for studies on diapause termination.

Collecting and separating mosquito eggs and eggshells from soil can be very challenging. Since we are unsure of the distribution of *Ae. tahoensis* eggs within a given breeding site, we chose to maximize the sample size by using a golf hole cup driller which yields samples about 10 cm in diameter and 3.5 cm deep. Since fresh mosquito eggs are usually found in the top 2.5 cm of soil (personal observation) our core depth is deemed sufficient for collecting both viable eggs and eggshells from previous hatchings. Once taken, samples are stored in a cool, humid place until examined.

Many of the current separation techniques are very time consuming and labor intensive. Since *Ae. tahoensis* is primarily found in areas shaded by ponderosa pine, soil samples collected in these areas have a high organic content and are covered with a thick layer of pine needles and sticks. Therefore, direct flotation of soil samples in water or a salt solution and sight-sifting are inadequate techniques for egg separation. Ritchie and Addison (1991) found that the sieving/bleaching method of Ritchie and Johnson (1989) was more efficient and required less labor than either selective sieving or flotation in

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either water or a saturated salt solution. These authors first thoroughly rinsed the sample with a shower head into a set of nested sieves with pore openings of 0.30, 0.185, and 0.170 mm. The bottom sieve retains all eggs and fine particles which are then placed into a beaker filled with a 5% solution of commercial bleach. The sample is left in the bleach for two minutes and then thoroughly rinsed with water for approximately 30 seconds. Since the chorion of a mosquito egg bleaches at a slower rate than other organic material, mosquito eggs can easily be extracted from the bleached sample. This method worked very well for alpine soil samples of low volume, but since we want to collect large numbers of eggs from the field, a more efficient, preferably mechanized, method had to be developed.

Several authors have developed machines for egg separation. Horsfall (1956) introduced a separation device consisting of a cylindrical water bath containing a set of three concentric screens partially immersed in water. A hand-powered crank rotates the cylinder to provide enough agitation for the eggs to be dislodged and drop through the screens to a pan below. Horsfall reported an 81-89% recovery rate for the rather complex machine. A method introduced by Husbands (1952) for collecting eggs in grassy habitats consists of mowing the grass, raking the soil and then vacuuming mosquito eggs and other debris with a portable vacuum cleaner. Eggs were then sieved out and identified. Other machines including converted washing machines (Trpis 1974), soil washing machines (Service 1968) and sonic sifters (Miura 1972) have also been shown to be effective, albeit complicated, and of varying efficiencies (Table 1).

Alternatively, we have found the methods and apparatus presented by Ritchie (1991) combined with a modified seed cleaner (Fig. 1) as the best solution for recovering eggs from alpine soil. The procedure begins with breaking samples up with a strong jet of water for moist samples or by gently crushing the sample with a mortar and pestle for relatively dry samples. Since the seed cleaner requires that samples be somewhat dry in order for it to operate properly, samples that are collected in late spring, when the soil is still moist, must be dried first before the next step. We have bypassed this problem by collecting samples in late summer when the soil is already dry enough for the machine to process.

After breaking up and drying (if necessary) the sample, it is loaded into the seed cleaner. The core of the seed cleaner consists of two flat, removable, metal sieve plates (38.1 cm x 25.4 cm) which are layered into inclined slots on the jostling mechanism (Fig. 1). The jostling mechanism is connected to the middle of an axle on a motor driven pulley. The axle is slightly bent in the middle so that the whole mechanism shakes back and forth in an asymmetrical rotation pattern, providing enough agitation to move the sample across the sieves. Smaller soil particles (and eggs) placed on the upper sieve will readily drop to the second sieve, which then further segregates the soil particles and

Table 1. Methods and relative efficiencies of egg separation procedures. Efficiencies are calculated by processing a representative sample using a known number of planted eggs.

Method	Reference	Efficiency
Wet Sieve Machine	Horsfall 1956	80-89%
Salt-Hollick Machine	Service 1968	83%
Mowing and Vacuuming	Husbands 1952	unknown
Sonic Sifter	Miura 1972	~91%
Selective Sieving	Ritchie and Addison 1991	~34%
Water Flotation	Ritchie and Addison 1991	~62%
Sieving and Bleaching	Ritchie and Johnson 1989	~78%
Modified Seed Cleaner	Gjullin 1938	~90%
Seed Cleaner with Sieving	Gurnee (unpublished)	89-92%

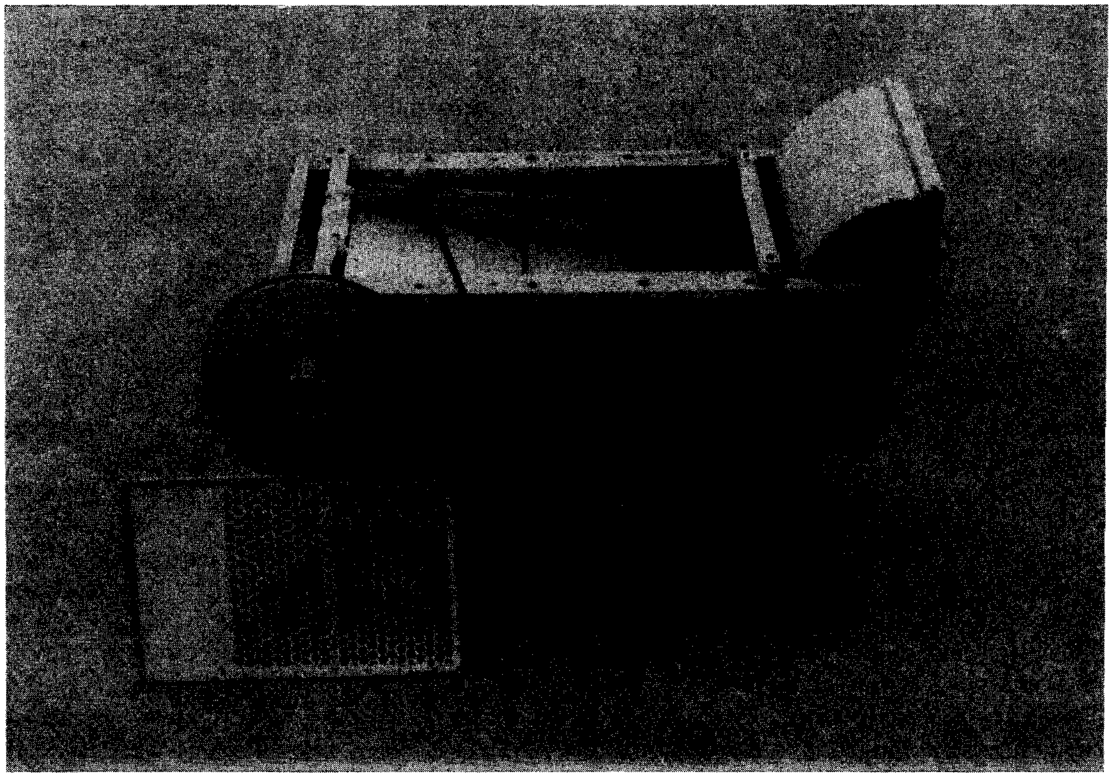

Figure 1. Seed cleaning machine used for separating mosquito eggs from soil samples.

eggs according to size. Each size class exits the machine by different paths. The largest particles move down the top sieve into a tray which empties to the left of the machine. Particles caught on the second sieve slide down a cylindrical shoot past a pulley-driven fan which blows dust and other fine particles up into the exhaler. Here the particles are separated by their relative weights. Heavier particles not blown out of the machine by the fan drop into a tray below the exhaler.

The smaller soil particles and eggs drop through the second sieve onto an inclined, smooth metal sheet. This sheet empties into a tray by which the remaining soil particles and eggs exit to the right of the machine. By choosing the right sizes for the top and bottom sieve we were able to filter out all soil particles that were larger than a typical mosquito egg. A complete description of a similar machine used for separating mosquito eggs from soil was presented by Gjullin (1938). The seed cleaner we use has a variety of sieve plates with varying hole sizes. We start with sieve plates having larger diameter holes (0.635 cm) and reduce to the smaller diameters (0.101 cm). Unfortunately, the seed cleaner could only eliminate 90% of the soil with the available sieve plates. Since the final step involves sight-sifting the sample, even a 90% efficiency is too low. Additional steps are needed to eliminate as much soil as possible from the sample.

After all machine sieving is done, the remaining soil is placed in a 2 L separation funnel with 1 L of saturated salt solution (Ritchie 1991). By this time, much of the organic matter in the sample has been separated out and the volume of soil has been greatly reduced. All organic matter, eggs, and eggshells will float to the surface and the heavier soil particles will sink. These heavy particles are then drained out the bottom of the funnel through the stopcock leaving just the lighter materials. Then a 5% sodium hypochlorite solution is added to the flask for two minutes to bleach the remaining organic matter (Ritchie and Addison 1991). Afterwards, the funnel is drained into a 100 mesh sieve and rinsed thoroughly to prevent bleaching of the eggs. Eggs be can examined under a dissecting microscope and removed with a fine pipette. Trial tests of this method obtained up to a 92% recovery rate of planted eggs (Table 1).

After isolation, the eggs are identified using the keys presented by Myers (1967) and Kalpage and Brust (1968). Of the snowpool mosquito species known in California, only the eggs of *Aedes cataphylla* (Dyar) have not been described, so voucher eggs from gravid *Ae. cataphylla* females should be kept for comparison with eggs collected in soil samples taken from areas where *Ae. cataphylla* occurs. Since both egg keys can be difficult to use and some subpopulations of the same species lay dissimilar eggs (Kalpage and Brust 1968), keeping voucher eggs is a good idea. Given enough time, patience, and information about the diapause and hatching requirements of a particular snowpool species, it is possible to first condition and subsequently flood the eggs in order to rear the larvae for identification. Better still would be a method that terminated diapause early, allowing researchers to rear the larvae year round.

At present, our laboratory is hoping to use recovered eggs not only to gain valuable insight into the ovipositional history of known breeding sites, but also to experiment with chemicals that may terminate diapause and thus aid our research of the general biology of snowpool mosquitoes.

References.

Bidlingmayer, W.L. and H.F. Schoof. 1956. Studies on the viability of salt-marsh mosquito eggs. Mosq. News 16:298-301.

Brust, R.A. 1971. Laboratory mating of *Aedes diantaeus* and *Aedes communis* (Culicidae). Ann. Entomol. Soc. Amer. 64(1):234-237.

Corbet, P.S. 1975. Egg laying habits of mosquitoes in the High Arctic (Diptera: Culicidae). Mosq. News 35(1):8-14.

Gjullin, C.M. 1938. A Machine for Separating Mosquito Eggs From Soil. U.S. Dept. Agric. Bureau Entomol. and Plant Quarantine; ET-135 4 pp.

Horsfall, W.R. 1956. Eggs of floodwater mosquitoes (Diptera: Culicidae) III. Conditioning and hatching of *Aedes vexans*. Ann. Entomol. Soc. Amer. 49:66-72.

Horsfall, W.R. 1963. Eggs of floodwater mosquitoes (Diptera: Culicidae) IX. Local distribution. Ann. Entomol. Soc. Amer. 56:426-441.

Horsfall, W.R. and H.S. Fowler. 1961. Eggs of floodwater mosquitoes VIII. Effect of serial temperatures on conditioning of eggs of *Aedes stimulans* Walker (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 54:664-666.

Husbands, R.C. 1952. Some techniques used in the study of *Aedes* eggs in irrigated pastures in California. Mosq. News 12:145-150.

Kalpage, K.S. and R.A. Brust. 1968. Mosquitoes of Manitoba I. Descriptions and a key to *Aedes* eggs (Diptera: Culicidae). Can. J. Zool. 46:699-718.

Kardatzke, J.T. 1977. Hatching of northern *Aedes* at low temperatures. Ann. Entomol. Soc. Amer. 70(5):663-664.

Kardatzke, J.T. 1979. Hatching of eggs of snow-melt *Aedes* (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 72:559-562.

McHaffey, D.G. and R.F. Harwood. 1972. Photoperiod and temperature influences on diapause in eggs of the floodwater mosquito, *Aedes dorsalis* (Meigen) (Diptera: Culicidae). J. Med. Entomol. 7(6):631-644.

Miura, T. 1972. Laboratory and field evaluation of a sonic sifter as a mosquito egg extractor. Mosq. News 32:433-436.

Myers, C.M. 1967. Identification and descriptions of *Aedes* eggs from California and Nevada (Diptera: Culicidae). Can. Entomol. 99:795-807.

Ritchie, S.A. 1991. Collecting Eggshells From Soil. Dept. of Health and Rehabilitative Services' Office of Entomology Services, State of Florida. Technical bulletin No. 3. 6 pp.

Ritchie, S.A. and D.S. Addison. 1991. Collection and separation of *Aedes taeniorhynchus* eggshells from mangrove soil. J. Amer. Mosq. Control Assoc. 7(1):113-115.

Ritchie, S.A. and E.S. Johnson. 1989. Use of sodium hypochlorite to detect aedine mosquito eggs in mangrove soils and insect feces. J. Amer. Mosq. Control Assoc. 5:612-613.

Ritchie, S.A. and E.S. Johnson. 1991. *Aedes taeniorhynchus* (Diptera: Culicidae) oviposition patterns in a Florida mangrove forest. J. Med. Entomol. 28(4):496-500.

Russo, R.J. 1977. Substrate moisture effects on oviposition in *Aedes vexans*. Mosq. News 37(4):712-717.

Russo, R.J. 1978. Substrate texture as an oviposition stimulus for *Aedes vexans*. J. Med. Entomol. 15(1):17-20.

Service, M.W. 1968. A method for extracting mosquito eggs from soil samples taken from oviposition sites. Ann. Trop. Med. Parasit. 62:478-480.

Trpis, M. 1974. An improved apparatus for separation of mosquito eggs from soil. Zbl. Bakt. Hyg. 226:418-423.

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