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Miniscule and Might Predators: A Cautionary Tale of the Power of Mosquitoes in California and the Greater United States

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Abstract

This thesis investigates how the growth of mosquito populations within the United States, and California specifically, poses unique threats both to public health and socio-political conditions. Mosquito species that are native to the country, *Anopheles punctipennis* (*An. Punctipennis*) and *Anopheles freeborni* (*An. freeborni*) exist in a uniquely threatening position, bolstered by the introduction of invasive species (*Ae. aegypti*) and *Aedes albopictus* (*Ae. albopictus*). A focus on tracing introductions of invasive species and the resulting spread of zoonotic diseases such as yellow fever, dengue, and chikungunya are valuable indicators of how the insects are influenced by human actions. This relationship between humans and these four mosquito populations in the United States is explored through historical events such as environmental change in an effort to maximize potential of irrigation in the early twentieth century, disease eradication through disease vector eradication throughout the twentieth century, and education surrounding risks posed by the insect in the late twentieth and early twenty-first centuries. As climate change brings about possible ecological change which might facilitate further opportunities for population growth and disease spread, the full capabilities of these species are highlighted, and with them, how factors such as

nomenclature and racialized common names can contribute to even greater risks to human populations. Specifically, this thesis introduces discourse around the common name of *Ae. albopictus* being the “Asian Tiger Mosquito,” and how this racial relation of the invasive disease vector indicates the potential for increased anti-Asian racism in the United States.

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Introduction

Aedes albopictus, or the Asian Tiger Mosquito, is one of the dominant mosquito genera in the United States that is noticed as an imported, invasive species in the last two centuries. This species poses a number of challenges to populations in the United States and worldwide, and its role as an invasive species poses even more threats in terms of human and non-human relationships. The interaction between species, especially those regarding disease vectors, are of critical importance when inspecting the future of public health.

Another genus, *Aedes aegypti,* or the Yellow Fever Mosquito, exists as one of the most dangerous species due to its disease carrying ability.[1] I focus on *Ae. aegypti* in this paper because of its established role in discourse surrounding the dangers of mosquito populations, while *Ae. albopictus* is highlighted for its more recent emergence as a threatening species of mosquito. Additionally, *Ae. albopictus*'s ranking as the fourth worst invasive species in the world presents it as a necessary centerpiece for an investigation that examines the mosquito's role and risk in a modern, changing environment.[2] Diseases born of a mosquito vector are known widely across the continent, with malaria being the most prominent proponent, though zika's headline resurgence fueled increased fears in 2016, and dengue & yellow fever both being influential factors in historical and modern health records. The increased tensions surrounding disease transmissions and pandemic risks makes mosquitoes a key player

[1] Willoughby, "Domesticated Mosquitoes," 66.
[2] Global Invasive Species Database (2023)

to study. This paper synthesizes historical reviews, literature comparisons, as well as entomological findings to compare the veteran worldwide actor *Ae. aegypti* to the recent spotlight performer *Ae. albopictus*. Topics to be investigated include living habits and ideal habitats, Importation timeline for both genera, in depth examination of literature that describes the appearance of the two, past efforts of eradication, future methods of mitigation, as well as posed critical risks on the horizon.

The *Anopheles* genus, with some species native to North America, is known for its massive role as a vector of malaria, amongst other arboviruses. *An. freeborni* and *An. punctipennis* are the two most prominent species within the western and southern United States, as elucidated by numerous scholars in the early twentieth century. *An. quadrimaculatus* is the most prominent species within the Eastern United States, but because this paper focuses greatly on the western region of the country, it is not examined with the other species. As the *Anopheles* genus is the only genus of mosquito capable of transmitting malarial parasites to human hosts, their role in North America and in California, specifically, are of incredible importance. The history of these two species is well-studied and provides numerous points of comparison to that of the invasive *Aedes* genus.

The introduction of *Ae. aegypti* through the transatlantic slave trade to North America makes it a key species to study as a comparison point for *Ae. albopictus. Ae. aegypti*'s introduction to the Americas is credited to the trans-atlantic slave trade, and the broader European colonialist expansion in the 16th century.[3] The increasingly large sedentary communities provided an ideal habitat for the *Aedes* species as it relies on man-made structures for their habitat; wells, barrels, trenches, etc. Moreover, the heavy

[3] Willoughby, "Domesticated Mosquitoes" 66.

emphasis on plantation use around these newly built societies offered more stagnant water and structures to facilitate the growth and power of *Ae. aegypti* populations. Very quickly after their introduction, the rise of yellow fever, and dengue cases can be seen in health records, in the Caribbean and along the North American Atlantic Coast, and similar trends can be seen in Brazil.[4]

Ae. albopictus spread more recently and widely through global trade, carried by used tires, as well as the product import of "lucky bamboo."[5] Its arrival to The United States is estimated to be in the 1980s, at the same time as Europe and Brazil. The mosquito was first seen arriving in California, and it shares many similarities with *Ae. aegypti* in terms of the arboviruses it can transmit (e.g., yellow fever, dengue fever, etc.), though it stands out as far more dangerous for its global spread. It resides in both manmade and non-human environments, allowing for it to survive and spread diseases more rapidly and extensively, positing it as a far more dangerous genera of disease vectors.[6] Moreover, its global spread has highlighted its role as an invasive species.

Ae. albopictus's appearance is distinct, with its striking white marks and stripes along its black body giving reason for its common name "Asian Tiger Mosquito." *Ae. aegypti* is similar morphologically, with its body being decorated by white marks, though they are slightly less conspicuous. However despite the similarities between species, the common name distinction between *Ae. aegypti* and *Ae. albopictus* as Asian Tiger Mosquito and Yellow Fever Mosquito indicates a more racially charged background for *Ae. albopictus*. Research indicates that origin points in the form of countries and

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[4] Willoughby, "Domesticated Mosquitoes," 66.
[5] Kraemer et al., "The global distribution of the arbovirus vectors *Aedes* aegypti and *Ae. albopictus.*"
[6] Webb "The long arc of mosquito control," 52.

nationalities being used for the common names of invasive pests can result in a racialized connection being created between the species and its origin point, and can even progress to a point of facilitating a rise in racism directed at that origin point should diseases be introduced by them.[7]

Eradication methods have accelerated through the twentieth and twenty-first centuries, with species sanitation efforts, sterilization, and disease-based eradication versus vector-based eradication taking headlines in ecological debates.[8] Fred L. Soper, an epidemiologist in the 20th century, was focused on eradication methods that targeted mosquito populations directly in order to mitigate malaria progression.[9] These methods were centered on *Ae. aegypti*, but his previous works included an investigation into some *Anopheles* genus and some various other species. Dichlorodiphenyltrichloroethane (DDT) was enacted on city limits and habitats most suitable to the *Ae. aegypti* species.

Further eradication methods have been invented in more recent years using more intricate designs than widespread spraying of chemicals. Gene manipulation within lab-grown mosquito populations is undertaken to disable the reproductive capabilities within the species as well as to make the mosquitos infertile.[10] These modified mosquito populations would quickly replace the disease vectors *Ae. albopictus & aegypti.* These eradication designs, however, as being based around manipulating species' reproductive success, brings up ethical debates within the scientific realm.

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[7] Shinozuka, J. N. *Biotic Borders*
[8] Webb, "The long arc of mosquito control," 53-55.
[9] Stepan, "Could we/should we eradicate mosquitoes?," 80-84.
[10] Rajagopalan, "Designer mosquitoes?," 239.

Evolving eradication methods indicate increased drive to overcome the risks posed by such a prominent disease vector. Moreover, the differing capabilities of the *Aedes* and *Anopheles* genera pose different risks for human populations to face. It is said, however, that:

> At the same time, this mosquito, as a sentinel device older than humans, also offers a form of 'radical hope' in our age of global environmental degradation through its capacity to adapt to climate change and counteract violent human efforts to propel it to extinction.[11]

Investigations into the developing world of mosquitos, specifically *Ae. albopictus,* are key to understanding the future of ecology and human-nonhuman relationships.

Methods

Interpretation of historical narratives is the centerpiece of this work. Close readings and comparisons of textual evidence by early twentieth century scholars such as Stanley Freeborn, Leland Ossian Howard, Harrison Gray Dyar, and Frederick Knab are used to create a baseline of knowledge. This baseline is investigated by exploring the world of the California Department of Public Health as well as numerous contemporary scholarly works in order to construct a timeline of two major topics. The first being population growth of Indigenous mosquitoes belonging to *Anopheles* genus,

[11] Beisel and Wergin, "Understanding multispecies mobilities," 34.

specifically *An. freeborni* and *An. punctipennis*. The second is the introduction and spread of invasive species belonging to the *Aedes* genus, specifically *Ae. aegypti* and *Ae. albopictus*.

Evidence is also used to illustrate the habits of these four mosquito populations. The feeding habits, preferred habitats, breeding behaviors, as well as ecological influences are explained using the synthesized findings of scholars from the twentieth and twenty first centuries. These studies are focused on the United States region of North America, and become increasingly more narrow towards the state of California.

This project interprets sociocultural reflections of migrating mosquitoes to the United States based on invasion biology critiques as well as historical narratives such as Jeanie Shinozuka's book *Biotic Borders*. This work incorporates interdisciplinary perspectives in order to facilitate discourse regarding the potential future consequences of disease spread through the four mosquito disease vectors, and most specifically that of *Ae. albopictus*.

Past eradication methods, as described by departmental documents from the California Department of Public Health, as well as descriptions provided by scholarly works are explored in order to grasp the full weight of these efforts. Moreover, the ethical dilemmas brought about by these methods are explored in reference to proposed eradication methods of the future, and how mosquito species might be looked at as a baseline for understanding species elimination. Mentions of climate change-based effects are included to fortify the role that mosquito populations will play in the near future within California, and the United States as a whole.

Historical and Contemporary Review of Humanity's Largest Small Threat: The Mosquito

The introduction of different mosquito species within the United States through the twentieth and twenty-first centuries can be followed through the works of numerous scholars. Howards et al. describe the incredibly dominant *Anopheles* genus from the early twentieth century.[12] This, paired with Stanley Freeborn's study of the same time period allows one to grasp the roles played by *An. punctipennis* and *An. freeborni*. Also mentioned in these studies is the genus *Aedes*, and the particular *Aedes aegypti* species, also known as the yellow fever mosquito.[13] More contemporary works, such as that of Urmi Willoughby, explore the history of this species, and its extraordinary interference within ecosystems.[14] Some of these works begin to describe the presence of *Aedes albopictus*, a more recent introduction to the United States, as explained by Kraemer et al. These landmark studies, as well as multitudinous others, can be incorporated into discourse describing the dominance of the four aforementioned species within the United States. Other contemporary research, such as that of Porse, narrows the focus to California, and with that narrowing, it becomes possible to holistically consider evolving migration of mosquitoes, as well as the growth of their populations. [15]

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[12] Howard, et al. *The Mosquitoes of North and Central America and the West Indies*
[13] Freeborn and Bohart, *The mosquitoes of California.*
[14] Willoughby, "Domesticated Mosquitoes," 61-72.
[15] Porse, *Emerging Infectious Diseases.*

The Yellow Fever Mosquito: Harbinger of Disease *(Ae. aegypti)*

There exist numerous pieces of literature expanding knowledge not only of the introduction of *Aedes aegypti* to North America, but also the risks posed by such an introduction. Hall and Tamir explore how the disease carrying capabilities of the yellow fever mosquito contributes a great deal to the recognition of the species as dangerous.[16] This description of introduction is expanded upon by Lounibos, as he provides a more complete timeline of transport for the species, and gradually maps out the degree of invasion.[17] These findings allow for this thesis to go more in depth with the presence and growth of the species in California. The studies of Slosek in 1986 offer a unique lens to look at this timeline as well, as it investigates initial transport of mosquitoes from the 1800s through the late twentieth century.[18] Willoughby shines light on how anthropogenic factors contribute immensely, and often unknowingly, to this spread of these invasive species.[19] Her work is absolutely crucial in understanding the global and more niche factors that influence the spread of disease vectors, and the subsequent diseases. Moreover, her findings emphasize the importance of the origin of mosquitoes.

Walker and Foster describe *Ae. aegypti* mosquitoes as being the primary disease vector of dengue, urban yellow fever, chikungunya, and zika viruses.[20] Lounibos explains the way in which *Ae. aegypti* bolstered the devastating effectiveness of yellow fever in the New World following their transfer overseas to North America.[21] Slosek

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[16] Hall and Tamïr, “Killing mosquitoes: Think before you swat,” 3-15.
[17] Lounibos,”Invasions by Insect Vectors of Human Disease,” 233–266.
[18] Slosek, “*Aedes aegypti* Mosquitoes in the Americas,” 249–57.
[19] Willoughby, “Domesticated Mosquitoes,” 61-72.
[20] Foster and Walker, ”Mosquitoes.”
[21] Lounibos,”Invasions by Insect Vectors of Human Disease,” 237.

(1986) contributes spectacular points in reference to these elements by describing other various epidemics introduced through the invasion of *Ae. aegypti* mosquitoes in the United States.[22] Porse also examines specific instances of disease spread in the forms of dengue fever and chikungunya virus by the two *Aedes* species under investigation.[23] These risk factors open the door for this paper to explore how disease introduction might be perceived and responded to within California in coming years.

Walker and Foster offer general understandings of numerous elements to consider when investigating these species, specifically preferred habitats, appetites, and habits of mosquitoes with focused discourse surrounding *Ae. aegypti, Ae. albopictus, An. freeborni, and An. punctipennis*. Analyzing the differences and similarities of the species allows for more comprehensive understandings regarding inter-species competition, as well as adaptability of each species. These findings can be synthesized with those of Willoughby and Hawkes & Hopkins to build an arsenal of knowledge regarding lifestyles of the insects.

A New Kind of Apex Predator: The Asian Tiger Mosquito *(Ae. albopictus)*

Walker and Foster expand on the *Aedes* genus by exploring *Ae. albopictus*, and its expansion globally through the transport of automobile and truck tires.[24] This work provides a basis for understanding the presence and spread of the species to California, and offers specific insights into how the growth of the species might be affected in the future. Kraemer et al., explain *Ae. albopictus*' ranking as the fourth worst invasive

[22] Slosek, "*Aedes aegypti* Mosquitoes in the Americas," 249–257.
[23] Porse, "Public Health Response to *Aedes* aegypti and *Ae. albopictus* Mosquitoes Invading California, USA."
[24] Foster and Walker, "Mosquitoes."

species in the world, and how its spread poses a unique threat.[25] Its ability to spread prolifically in new environments, specifically the southwestern United States bolsters the risks it poses as a pest. Moreover, they describe the spread of this species to the US in tandem with its spread to Europe and South America. This avenue of exploration will allow this thesis to further investigate how public perceptions of the mosquito might be affected due to increased risk factors and its more recent presence. Hall and Tamir's work describing the preferred habitats of *Ae. albopictus* as being more variable coincides with this work as it emphasized how risk can be perceived.[26] Christophers' monumental work characterizing the life stages and morphology of mosquitoes offers knowledge here regarding the more detailed biological traits of the *Ae. aegypti* species.[27] This historical piece dives into geographical distribution as well, which contributes incredible knowledge to how species spread has occurred since the mid-twentieth century. This piece is incredibly important as I investigate the past growth of *Aedes* mosquitoes in North America, and specifically California. Kraemer et al.'s work explores modes of transportation, like that of Walker and Foster, and can help build a more holistic understanding of modes of invasion. This work is further built on by Holfhuis et al. which explores the role of "lucky bamboo" as a mode of transportation in the twentieth century.[28] Scholars have explained the origin of these mosquitoes' transport further, which is a specific consideration when thinking about their introduction to North America. Beisel and Wergin continue this thread of thought as they look at historical evidence of mosquito populations in global locations, both the native locations

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[25] Kraemer et al., "The global distribution of the arbovirus vectors *Aedes* aegypti and *Ae. albopictus.*"
[26] Hall and Tamir "Killing mosquitoes: Think before you swat," 3-15.
[27] Christophers, *Aedes aegypti (L.) the Yellow Fever Mosquito.*
[28] Hofhuis et al., "The hidden passenger of lucky bamboo," 217-220.

of the species and other areas of invasion.[29] Looking at origin points allows for a further understanding of preferred habitats, as is talked about in Hall & Tamir's text, and compounded by the findings of Willoughby.

The Western and Woodland Malaria Mosquitoes *(An. freeborni* & *An. punctipennis)*

Hawkes & Hopkins do an excellent job of comparing *Aedes* and *Anopheles* mosquitoes and emphasize how the two differ.[30] Specifically, they introduce the disease transmitting capabilities of both, such as the ability of *Anopheles* to transmit malaria, while *Aedes* cannot. These details, combined with the different habits, habitats, appetites, etc. as introduced by Willoughby and Walker and Foster, create room to describe the differences between the genera. Coates describes the species An. atroparvus which was a major malaria vector in Britain in the twentieth century.[31] This connects to the more global understanding of the role of *Anopheles* mosquitoes. Specifically, the way in which risks posed by *Anopheles* mosquitoes have been recognized on a global scale, spread by numerous species, and so it is far more reasonable to interpret their capabilities here in the United States. *Aedes* mosquitoes pose a larger risk due to their broader capabilities in terms of habitation and transport, while *Anopheles* mosquitoes are much more constricted.

[29] Beisel and Wergin, "Understanding multispecies mobilities," 32-46.
[30] Hawkes and Hopkins, "The mosquito: An introduction," 16-31.
[31] Coates, "Fighting nuisance on the northern fringe," 87-106.

Howard, et al. describe habitats of mosquitoes in the *Anopheles* genus as early as 1912, elucidating the early studies of the American mosquitoes.[32] The findings which were present at the time developed a great deal of knowledge surrounding mosquito populations, which can now be used in tandem with modern findings to show the advancement of entomological knowledge. However, these findings were focused in the northeastern areas of the United States, and as such is an incomplete puzzle that can be filled in with findings of other more modern scholars regarding the West coast.

Historical Accounts

Howard et al. provides spectacular background regarding mosquito populations in the late 19th and early twentieth centuries in the United States. Their discussion of the importance of agricultural advancement, and specifically the utilization of drainage techniques proved wondrous information to consider when thinking about the past and future prevalence of disease spread by mosquito vectors.[33] Furthermore, Howard et al., state "The idea that mosquitoes carry disease is not only very old historically, but occurs among primitive nations in various parts of the world. References have been found in the very early literature of India, in writings that are practically prehistoric, that indicate that the idea was held in those early days, especially with reference to malaria."[34] This work feeds into that of Willoughby in its depictions of historical narratives surrounding mosquito presence and the spread of malaria in the Northeastern United States. The

[32] Howard et al., *The Mosquitoes of North and Central America and the West Indies.*
[33] Howard et al., *The Mosquitoes of North and Central America and the West Indies,* 218-222.
[34] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 186.

findings of these scholars provide excellent frameworks upon which I will explore how the inland spread of irrigation for agriculture might influence the growth of mosquito populations in California.

Cultural studies

It is critical to recognize public health responses to the introduction of different disease vectors. Beisel & Wergin explore the framing of invasive mosquitoes, and how such a relation can influence racially charged perceptions of the species.[35] Their work also examines how movement of species, specifically disease vectors, contribute to socio-cultural reactions to these species in the form of eradication methods and public awareness programs. This work coincides with that of Shinozuka, who directly studies insect migrations and the link to Anti-Asian Racism that arises due to it in the United States.[36] One of the most important considerations of her work comes in the form of recognizing the role of origins when considering an invasive or imported species. These pieces are key for me delving into the future of invasive mosquito species, specifically *Ae. albopictus* might influence public perceptions and reactions, with particular reference to the role of anti-Asian racism in the US. The common name of *Ae. albopictus* being the Asian Tiger Mosquito holds a crucial role in influencing socio-cultural outcomes, and these works provide a framework for expanding discourse around them.

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[35] Beisel and Wergin,"Understanding multispecies mobilities," 32-46.
[36] Shinozuka, *Biotic Borders.*

Porse looks intricately at the state of California, using this lens of public health responses regarding disease spread by the mosquito vector.[37] This work provides descriptions of general mosquito control plans while integrating a timeline of importation and action by the California Department of Public Health (CDPH). These elements are necessary when traversing the discourses of Beisel & Wergin, and Shinozuka, as it offers landmarks which denote possible key moments that swayed public perceptions. Moreover, it involves the presence of the CDPH, which is a key player in the overall discussion of the future of mosquito control. Reactions by the CDPH can also be differentiated using the works of Hawkes & Hopkins in their comparison of *Aedes* and *Anopheles* mosquitoes.

Eradication

Eradication methods of the past hold a great amount of knowledge to glean regarding perceptions of mosquitoes, as well as opportunities to understand new and developing methods. Stepan explains in depth eradication campaigns in the twentieth century and highlights the driving factors behind such methods.[38] His highlighting of the works of Fred L. Soper's eradication programs and the subsequent use of DDT in the US provides a backbone upon which the hindered growth of mosquito populations can be understood. Coates describes past efforts abroad in Britain, offering extensive contextual evidence that fortifies driving factors for these programs run by the British

[37] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."
[38] Stepan, "Could we/should we eradicate mosquitoes?," 73-86.

Mosquito Control Institute. By comparing these methods to those written about by Rajogopalan and Webb, techniques are highlighted that allow for more consistent predictions of how populations could be affected in the future. Gene manipulation of mosquitoes, as discussed by Rajogopalan, for example, brings up ethical debates that mirror those of Soper's use of pesticides in the twentieth century.[39] The comparison and contrasting of past and future eradication efforts will prove to be key in understanding public perceptions, and more specifically, how risk factors are perceived by institutions such as the California Department of Public Health.

Stepan goes in depth about the possibility of eradicating diseases worldwide, specifically looking at the role of eradicating disease vectors.[40] This pairs with Webb Jr., who continues to elucidate how eradication methods have accelerated in the twentieth and twenty-first centuries, which contributes a great deal to synthesizing findings regarding the introduction of species and responses to such, as well as how the fight against diseases has advanced. Moreover, Webb's comparison of methods targeting the *Aedes* genus versus the *Anopheles* genus is monumental in addressing the role of invasive species and narratives. A major component of this came from investigating the difference in preferred habitats between the two so that reduction of potential habitats could be effective based on which genera was being targeted. The difference in location required different approaches for eradication techniques, as *Aedes* mosquitoes reside in urban areas, and so techniques such as fumigation of gathering areas and mandates for cities to follow regarding upkeep of control had to be formally introduced.[41]

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[39] Rajagopalan, "Designer mosquitoes?," 234-247.
[40] Stepan, *Eradication: ridding the world of diseases forever?*.
[41] Webb "The long arc of mosquito control," 52.

Meanwhile *Anopheles* based eradication techniques relied more on environmental change projects such as drainage of marshlands and oiling of bodies of water Slosek offers more time-specific understandings of these methods, specifically focusing on the Pan American health organization's *Aedes aegypti* Eradication Program. Howards et al. discuss naturally occurring predators for the mosquitoes, including plants, fungi, bacteria, and other animals. This offers discourse to explore surrounding what non-anthropogenic approaches to eradication might be considered. It is also explained that conceptions regarding the presence of mosquitoes have shifted a great deal since the late 19th century, the details of which offer many points of exploration while trying to understand motivations behind mosquito eradication.

Another subtle consideration of this paper is the future of mosquitoes outside of the realm of eradication. Beisel and Wergin explain how this insect offers insights into climate change adaptations, and proposes that its role as a center of study could offer numerous advances in scientific understanding of resilience in the face of climate change. The evolving interactions between humans and mosquitoes is addressed by numerous scholars. Slosek describes how this interaction is interdisciplinary at its core, which emphasizes how further studies on the future of mosquitoes can also lead to interdisciplinary findings. Coates illustrates the habitats that were common for *Anopheles* mosquitoes in Britain, and the ways in which these wells and pools were treated with pesticides. This piece reconnects with Stepan in showing past efforts and how recognition of habitats has proven especially effective in forming eradication methods. With this evidence, it is possible to infer that as climate change alters

geography by forming more wetland areas, eradication methods will simultaneously have to be altered.

Chapter 1: Patriotic Expansion: Mosquito Populations in the United States

Introduction

The United States has developed as a land filled with multitudinous environments, people, and of course, animals. Mosquitoes, and insects generally, are not exactly used as the cover image for the country, and yet they hold an immense amount of power in determining public health, immigration policies and attitudes, and cultural responses. This chapter focused on explaining the differences and similarities between four especially prominent species in the Western US, including investigations in preferred habitats, life patterns, as well as breeding habits. In this way, the capabilities of each species can be better understood so that as questions arise regarding the future spread and success of the insects, context can be given around the validity of the risks they pose to human populations.

North American *Anopheles* Species

Anopheles mosquitoes are well studied worldwide, in numerous environments from India to Britain to all corners of North America. These *Anopheles* are the sole mosquito vectors of malaria, and therefore present unique threats to environments, as exhibited by historical descriptions of malarial outbreaks in the sixteenth and seventeenth centuries. The risk posed by this genus in the form of endemic disease

spread within the United States is described in numerous works. It wasn't until the late 19th century, when Sir Patrick Manson's findings relating the spread of malaria and mosquito prevalence were published in the *British Medical Journal* that the scientific knowledge of how malarial parasites traveled to humans was explored in medical and scientific literature.[42] The following year, in 1898, this work was expanded by Giovani Battista Grassi to cement the knowledge that only *Anopheles* mosquitoes could be responsible for the transfer of malarial parasites to humans.[43]

The presence of *Anopheles* mosquitoes in North America is well studied, with the history of the genus being noticed through numerous texts. It is proposed that these native mosquitoes grew in population in tandem with human populations, and that anthropogenic constructions contributed a great deal.[44] For example, the creation of maize fields, drainage ditches, and other built waterways provided new and more copious suitable habitats for the insects. Other factors that came with these developments contributed to population growth in North America as well. These factors being increased transportation through construction of roads, as well as growing sedentary human populations upon which the mosquitoes could feed. Here it is important to note that, while *Anopheles* mosquitoes can transfer malarial parasites to humans, these parasites were not introduced to North America until the sixteenth and seventeenth centuries with the arrival of British colonists.[45] The trans-atlantic slave trade and increasing development of plantation agriculture that ensued contributed immensely in propelling mosquito population growth, specifically *Anopheles* species. This resulted

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[42] Howard et al., *The Mosquitoes of North and Central America and the West Indies,* 195-197.
[43] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 196.
[44] Willoughby, "Domesticated Mosquitoes," 61-72.
[45] Willoughby, "Domesticated Mosquitoes," 61-72.

in greater malarial presence, along with other diseases such as yellow fever (mostly transmitted through *Aedes* mosquitoes) which readily infected and killed populations of Indigenous peoples, colonists, and enslaved people alike.

Howard, et al. explicitly explain:

> It may briefly be stated that malaria rarely exists in this country above an elevation of one thousand feet or in the dry climates of certain of the western and southwestern States, except where irrigation has been introduced.[46]

Thus one can gain an understanding of how irrigation development can and has contributed to facilitating mosquito spread, and allowing malaria to continue to spread. Moreover, endemic malaria zones were able to spread and become established due to the rise in irrigation usage. Humans, in forming environmental changes that allow for more expansive agriculture, to name just one example, have not only been allowing greater success for our own species' growth, but also that of mosquitoes. The opposite of this is true as well however, as the ways in which humans have adapted their environments have also been responsible for restricting the spread of malaria through these insects. The drainage of marshes and wetlands, specifically, somewhat halted the progression of malaria within the US around the start of the twentieth century.[47]

Anopheles punctipennis is one species of mosquitoes with immense research examining it. Being one of the species that is native to North America, the historical narratives describing it are numerous, especially in the early twentieth century and beyond. A second species of potent importance along with *An. punctipennis* is *An. freeborni*. This species was named after Stanley Freeborn in 1930. Before this, it was

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[46] Howard et al., *The Mosquitoes of North and Central America and the West Indies,* 236.
[47] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 237.

categorized as *An. maculipennis*. These two species share a great deal of similarities, and for the sake of discussion are referred to generally unless a difference is noted. A great portion of work is centered around the taxonomy of these species, but there exists a good deal of other considerations including the feeding habits, preferred habitats, and capabilities of the species.

Mosquitoes within the *Anopheles* genus in the United States have been found, historically, in a great variety of habitats. It is incredibly important to note, however, that there are preferred climates for the species. As the previous quote from Howard et al. points out, there are certain regions where it is most common to find malarial trends. The relation of malaria prevalence to mosquito presence is key as it shows a major tracking methodology of *Anopheles* mosquitoes in the United States. While the species is capable of existing and succeeding in numerous environments, there do exist bounds on its ability to spread. Future climate change altering environments could have an effect on this, which is investigated later on in this text.

The profound capability of this species to live in these environments exhibits its power in spreading diseases in the early years of colonization in North America. In the early twentieth century, researchers expanded upon the habitation of species, finding that "*An. punctipennis* shows a predilection for spring-fed pools, and, in localities where these abound, is the chief species."[48] This time period of the early twentieth century heeded numerous other advancements in the study of *Anopheles* mosquitoes. The one major confining factor for the genus is the presence of water in its habitats. An. punctipennis is recognized as being moderately abundant throughout all of the US, with specific hot spots in the southwestern United States, as well as the mountain west and

[48] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 222.

California. It is found mostly along the foothills of California, and in Northern California specifically, but struggles to find a foothold in the more arid areas of Southern California. *An. freeborni*, however, is highlighted as being the most abundant within California as a whole.[49] The flight distances of the species was a massive point of contention at the time, with scientists and scholars working worldwide on different *Anopheles* species. It was found, with replicated results through numerous studies, that these mosquitoes have a maximum travel distance of 300 meters.[50] Furthermore, it is found that *Anopheles* mosquitoes are recognized for their use of multiple, short flights, rather than a single long flight.[51]

These studies shined a light on how some species might be better tracked and combated, as their habitats and breeding areas would have to be within a certain range of where their feeding was being noticed. This brings us to another key element of the mosquitoes to be recognized: the breeding patterns of *An. punctipennis* and *An. freeborni*. *Anopheles* mosquitoes as a whole have been found to deposit their eggs on standing water in several different batches, so to speak. These eggs are all known for having hydrostatic organs, or a specific mechanism that keeps the egg afloat and balanced until hatching.[52] This explains the importance of water in the habitats of the species. *An. freeborni*'s egg-laying habitats have been found "in seepage water, in roadside pools, in rice fields and in other similar habitats."[53]

Most of this species' eggs are laid around February by the females who survive through the winter. At this time, their range of flight is expanded, and their feeding habits

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[49] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico),* 41.
[50] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 211-213.
[51] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 214.
[52] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 143.
[53] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico)*, 41.

grow more aggressive as they try to deposit eggs.[54] *An. punctipennis* eggs are found in broader environments, and while they are often found in human-made structures, they are also somewhat abundant in natural features such as springs, streams, and ponds, away from the constructions built by humans.

The mosquitoes hatch quickly after being laid, and then they feed within the water system where they hatch. *Anopheles* mosquitoes are known for remaining on the surface of the water and simply filtering food from the surface.[55] This is their larvae stage, which advances to their pupal stage quickly after, which only lasts 36-48 hours.[56]

The male *Anopheles* mosquitoes are known to have short lifespans, never surviving the winter after hatching. The females, however, have been found to stay alive and wait out the cold winter months, sometimes biting during these times, but no oviposition takes place. This enables the females of *An. freeborni* to have that period of far-reaching, aggressive feeding around the month of February.[57] The populations of *An. freeborni* are immense from mid-March through the end of September, when the males begin dying and the females retreat for the winter.[58]

Once they have reached the adult stage of their lives, mosquitoes fall into their feeding habits. Influenced by their flight range, as mentioned earlier, *An. punctipennis* and *An. freeborni* differ here in their qualities. Entomologists have shown that *An. freeborni* specifically are incredibly aggressive in their feeding, particularly in the later months of winter.[59] As pointed out earlier, this is because of the drive by the females to

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[54] Freeborn and Bohart, *The mosquitoes of California*, 32.
[55] Foster and Walker, “Mosquitoes.”
[56] Freeborn and Bohart, *The mosquitoes of California,* 54-56.
[57] Howard et al., T*he Mosquitoes of North and Central America and the West Indies,* 119.
[58] Freeborn and Bohart, *The mosquitoes of California*, 321.
[59] Freeborn and Bohart, *The mosquitoes of California*, 32.

lay their eggs far and wide. During their normal feeding activities, the females have been known to hunt in homes, and are often found most abundantly around man-made structures such as bridges, homes, and cellars.[60] Aside from this moment of difference, *Anopheles* mosquitoes are often crepuscular, meaning they feed at twilight around dawn and dusk. *An. punctipennis* generally only feed outdoors, but have been found to eat at different times, sometimes during daytime hours, but mostly after dusk.[61] However, it is noticed in studies that temperature change can play a role in influencing the feeding habits of the mosquitoes.[62] That is to say, if temperature were to drop significantly, this would hinder mosquito feeding. Other factors such as strong winds and weather events also play a role in controlling the presence of mosquitoes. Conversely, if temperatures were to rise, which is more likely, it is likely that mosquito feeding opportunities would increase.

An. freeborni is recognized as a key player in the spread of malaria throughout the twentieth century, and by the middle of the century it was found that the species has a particular susceptibility to infection than other *Anopheles* species.[63] It is clearly labeled as “the most dangerous malaria carrier in California” .[64] Their reliance on human-made structures makes their ability to spread even more dangerous, as it becomes easier for humans to be the victims of attacks that can lead to infection.[65] *An. punctipennis*, while it is capable of transmitting the disease, has not been heeded as a major disease vector in this regard. The history of malaria transmission holds a number of accounts pointing

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[60] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico)*, 41.
[61] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico)*, 50.
[62] Howard et al., *The Mosquitoes of North and Central America and the West Indies,* 118.
[63] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico),* 42.
[64] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico)*, 50.
[65] Freeborn and Bohart, *The mosquitoes of California*, 321.

to the suspicion of it being the result of mosquito bites for ages. Following the discovery that malarial transmission occurred through *Anopheles* mosquitoes, efforts became much more widespread to protect human populations from contracting the disease. This came in the form of more fortified households as well as anti-mosquito efforts. The latter form of control will be investigated further later in this work.

The two species are somewhat indistinguishable in their appearances throughout their larval stages of life. Once they have entered their adult stage, both are described as medium-sized mosquitoes, and the females of the species have more noticeable coloring. *An. punctipennis* adults have yellow spots on their wings which can be bright in their hue, especially when recently hatched (Figure 1.1). The abdomen and thorax of this species is a dark brown to black, and the coloring on its wings gives the mosquito a slight checkerboard appearance. *An. freeborni* adults, on the other hand, are almost entirely light brown, although they can have some dark brown spots on their wings (Figure 1.2).

Fig 1.1- *Anopheles punctipennis* mosquito [66]

[66] Thurlow, "*Anopheles punctipennis.*"

Fig 1.2- *Anopheles freeborni*[67]

North American *Aedes* Species

Ae. aegypti

Ae. aegypti mosquitoes first migrated to North America in the sixteenth and seventeenth centuries, carried mainly by vessels involved in the transatlantic slave trade.[68] Indigenous to Africa, their journey to the United States was long, but supplied with numerous bodies for the insect to feed on. They resided in man-made water vessels that were necessary for the oceanic journeys, such as barrels, allowing them to infect those on the ships as well as populations once they reached North America. The

[67] Vitanza, "Female, *Anopheles freeborni*."
[68] Willoughby, 'Domesticated Mosquitoes," 66.

broader European colonial expansion in the seventeenth century played a massive role in its transport as well. Following the introduction of this species to North America, health records indicate a clear rise in cases of dengue and yellow fever up and down the Atlantic Coast.[69] Also referred to as the Yellow Fever Mosquito, this species contributed a great deal to bolstering the devastating effects of yellow fever spread, of which it is a leading vector. It also acts as a leading disease vector for zika virus and chikungunya. Furthermore, this is an incredibly persistent species, and has shown that despite past efforts to eradicate it through the use of pesticides, resurgences of the insect are still possible.[70] This poses a unique threat within the lens of disease spread, as it posits Ae. aegypti not only as a major disease vector, but one that has resisted past eradication methods. Therefore, future considerations of its effect on environments take on a new, more challenging light.

Ae. aegypti mosquitoes are dependent on man-made structures, and are even described as being on the verge of being domesticated due to their constant interactions with humans.[71] This is, by definition, an invasive species, and since its transport to North America, the species has spread throughout the United States. Generally the mosquito is found in tropical and subtropical regions and within the US is found most commonly in the Southern states.[72] Presently, populations of the species can be found from East to West coast in Southern regions where temperatures fall in ideal ranges, however it first arrived in port cities along the Atlantic Coast. The preferred habitats of this species can be described as directly linked to human activity. It

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[69] Lounibos, ”Invasions by Insect Vectors of Human Disease,” 233–266.
[70] Slosek,“*Aedes aegypti* Mosquitoes in the Americas,” 251.
[71] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 205.
[72] Foster and Walker, “Mosquitoes.”

tends to reside in houses, as well as structures such as wells, ditches, barrels, and other areas that are influenced mainly by human activity. For centuries this species was the dominant mosquito present in human-made containers. Centuries later, when *Ae. albopictus* arrived in the US, its capability of adapting to new environments and to settle into both urban and natural environments further emphasized the invasive power of the *Aedes* genus as a whole.[73]

These mosquitoes are strictly diurnal, feeding during the day and occasionally in artificial light at night. Their most active feeding times have been identified as mid-morning as well as late afternoon.[74] The time of day matters less to the species than the amount of light present, and more specifically that the temperature range was the most important factor.[75] This means that on days that were especially sunny and hot, the mosquito would be less active during the hottest times, waiting for temperatures to decrease somewhat before leaving their nesting places to feed. However, as is the case with most animals, sometimes hunger will drive *Ae. aegypti* mosquitoes from their resting places to feed at nighttime. The ideal temperature range for these mosquitoes falls between 27 and 30 degrees celsius. At temperatures higher than 39 degrees, the species will die and below 15 degrees they will become slower and refuse to bite.[76]

These mosquitoes deposit their eggs in the spring, but they sit waiting for water to rise and for conditions to be right for hatching. Some can stay in the egg for a full year waiting for these conditions. That is to say, these eggs wait for temporary environmental attributes to allow hatching and growth. Once deposited, the eggs lay

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[73] Webb, “The long arc of mosquito control,” 58.
[74] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 263.
[75] Foster and Walker, “Mosquitoes.”
[76] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 271.

there waiting for the presence of water to facilitate their progression to a pupal stage. This can be imagined as the filling of a canal, or the flooding of a ditch during spring when precipitation or runoff increases. It is common for the eggs to be laid within soil in depressions that are commonly filled by rainwater, runoff, or flooding, but they also are known to specifically find human-made containers to lay their eggs in.[77] This is true of most *Aedes* species. The prominence of *Aedes* mosquitoes in man-made environments makes this breeding and hatching timeline much more variable.[78]

Activity of the *Ae. aegypti* mosquitoes are less affected by weather conditions such as strong winds, however due to their proximity to humans in their resting places, they're estimated flight capacities are much decreased. There is little need for the populations to travel far in order to find food sources, and therefore instances of far flying *Ae. aegypti* are rare.[79]

Ae. aegypti mosquitoes are much more recognizable in their appearance than those belonging to the *Anopheles* genus. These mosquitoes are discernable by their black bodies with white dots littering the underside of their abdomen and thorax. These dots also show up on their legs, making them both somewhat beautiful in their appearance, as well as very noticeable (Figure 2.1).

[77] Carpenter and La Casse, *Mosquitoes of North America (North of Mexico)*, 136.
[78] Foster and Walker, "Mosquitoes."
[79] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 275.

Fig 2.1- *Aedes aegypti*,[80] the yellow fever mosquito

The United States Yellow Fever Commission in Havana, Cuba discovered in 1900 that *Ae. aegypti* was the leading vector of yellow fever.[81] The continued growth of this species' populations in the United States are a growing concern considering this finding. In the twentieth century, numerous steps forward in scientific fields propelled eradication methods through a series of changes. The developing military complex in the US in the face of global conflicts contributed greatly to biomedical knowledge and the scope of risks posed by chemical treatments became far more understood. Therefore, chemically based strategies of eradication had to be reconsidered, weighing the benefits and consequences of large-scale pesticide use..[82]

[80] Vitanza, "Females, Aedes aegypti."
[81] Foster and Walker, "Mosquitoes."
[82] Slosek, "*Aedes aegypti* Mosquitoes in the Americas," 251.

Ae. albopictus

Ae. albopictus mosquitoes are a much more recent introduction to the United States. Their presence within the country was traced back to introduction through automobile trading, specifically the movement of tires across the Pacific Ocean from Asia.[83] In addition to this, studies have shown that transportation methods of the species also included the global trading of "lucky bamboo." These mosquitoes are known as the Asian Tiger Mosquito, and are incredibly powerful disease vectors. Its history in the United States traces back to only the late twentieth century, with its arrival being dated around 1985.[84] This is around the same time that the species was brought to countries such as Brazil and Europe from China. Similar to *Ae. aegypti* mosquitoes, *Ae. albopictus* mosquitoes are capable of transmitting dengue, yellow fever, zika, and chikungunya. The replacement of *Ae. aegypti* by *Ae. albopictus* in the United States is evidence of interspecies competition, and shows how this more recently introduced mosquito is capable of infiltrating environments on a rapid and powerful scale.[85]

The habits of this species are moderately comparable to those of *Ae. aegypti*, as it is similarly related to human activity. Its habitat preference being human-made containers and environments allows it to spread wildly, as it has since its first appearance in North America. It is, however, also known to dwell in environments away from humans.[86] While *Ae. aegypti* was prominent in the US for several centuries, this new species overtook it as the prominent species involved with human activity in only a

[83] Kraemer et al., "The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus."
[84]Foster and Walker, "Mosquitoes."
[85] Kraemer et al., "The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus."
[86] Webb "The long arc of mosquito control", 56.

few decades, illustrating its power as an invasive species. This is one consideration that contributed to it being ranked as the fourth most dangerous invasive species in the world.[87] This ranking, in tandem with factors surrounding the power of its disease transmission makes this species an absolutely crucial point of investigation within the parameters of growing mosquito populations within California and the US as a whole.

The incredible evolution of transportation methods and travel have allowed this species to quickly infiltrate numerous areas of the US, particularly the Western regions. The preferred climate of the species being tropical and subtropical areas, these environments were best suited for the mosquito to settle into. The importance of such a point is emphasized when thinking about the ways in which environments are changing due to climate change and related factors. How they might spread even further as temperatures rise due to climate change is a thread of thought to be later explored, however, it is easy to infer that it would lead to more expansive effects being felt in a northward trend.

Ae. albopictus gets its common name of the Asian tiger mosquito due to its very striking appearance. The body of this species is brown, with white markings resembling stripes covering its thorax, abdomen, legs, and the frames of its wings (Figure 2.2). These strips, resembling those of a tiger, led to its nomenclature, and its origin point being Asia led to the naming of this species as such, The common name raises numerous questions, including why its point of origin is so important as to include in the name it is most commonly known by. These are looked into further later on in this work, but it is important to note here that the racialized name of this species is a massive element to consider when thinking about the aforementioned risks associated with it.

[87] Global Invasive Species Database.

Fig 2.2- *Aedes albopictus*, the Asian Tiger Mosquito[88]

Ae. albopictus resides in both manmade and non-human environments, allowing for it to survive and spread diseases more rapidly and extensively, positing it as a far more dangerous species of disease vectors.[89] This species of mosquitoes was imported directly to California from Asia, as opposed to *Ae. aegypti*, which was imported to the East coast from Africa. This allows for interesting comparisons to be drawn regarding the persistence and success of the two species in two different climate regimes. For example, *Ae. albopictus*' ability to adapt and thrive in the semi-arid environments of

[88] Scholnik "Asian tiger mosquito- *Aedes albopictus*."
[89] Hall and Tamïr, "Killing mosquitoes: Think before you swat," 9.

Southern California, specifically areas surrounding Los Angeles, elucidates the capabilities of this species to spread in less favorable conditions for the mosquito. However, this species is also known to have a more narrow range of temperatures in which it can thrive compared to *Ae. aegypti*.[90] Therefore, studying how the species has gained such a prominent hold on Western and Midwestern states is specifically intriguing. Its role as the dominant species in these environments also shows how it has risen to become so critical in urban and suburban areas.

It is shown that *Ae. albopictus*' ability to survive despite having more constraints based on temperature and climate comes from its ability to enter periods of diapause, or the temporary slowing of development in its egg stage, when temperatures are not suitable for it.[91] As mentioned earlier on, eggs are often laid in artificial containers or areas that are often filled by rainwater, runoff, or flooding, and they wait there to hatch. The eggs are capable of surviving long dry periods before water is introduced, demonstrating the longevity of the species.

This ability of the species is one of the key recognitions of the species regarding how it succeeds as well as, if not better than *Ae. aegypti* in the US. In the near future, *Ae. albopictus* will likely overtake or outright replace *Ae. aegypti* in the US due to its ability to rapidly move from one area to another, and to adapt to a wide range of geographical constraints. It specifically refers to the ability for the species to spread to more temperate regions as opposed to the tropical and subtropical biomes within North America. Furthermore, this species feeds quite moderately on animal species as well as

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[90] Ding et al., "Mapping the spatial distribution of Aedes aegypti and Aedes albopictus," 155-162.
[91] Brady, et al., "Global temperature constraints on Aedes aegypti and Ae. albopictus persistence and competence for dengue virus transmission," 1-17.

humans.[92] Its more expansive diet, coupled with its ability to enter diapause in egg form give it an ecological advantage. It is particularly interesting considering how the species, if deposited in egg form within more Northern states of the US, might be able to survive longer waiting for favorable periods of temperature. When one includes considerations of climate change and the temperature rise that is likely to be exhibited globally, the full extent to which this species might spread is intimidating.

This species is similarly diurnal, feeding during the day, with an obvious preference for human blood. However, its feeding habits indicate that it feeds less often, and takes less blood during its feeding times than *Ae. aegypti*.[93] Both *Aedes* species have limited flight ranges, averaging flights of around 100 to 200 meters.[94]

What's The Difference?

These four species of mosquitoes all differ in some way or another. The Indigenous *Anopheles* genus holds a trove of information regarding the history of mosquito success in North America, while the invasive *Aedes* genus offers up opportunities to understand how new species might take advantage of that success, or even be more successful.

The disease transfer capabilities of the four are quite different, however in totality, the risks posed by the possible spread of malaria through *Anopheles* and then the several diseases that can be carried by *Aedes* are numerous. Differing habitat

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[92] Foster and Walker, "Mosquitoes."
[93] Brady et al., "Global temperature constraints on Aedes aegypti and Ae. albopictus persistence and competence for dengue virus transmission," 1-17.
[94] Guerra et al., "A global assembly of adult female mosquito mark-release-recapture data to inform the control of mosquito-borne pathogens," 1-15.

preferences as well as survivability and persistence of the different species gives insights regarding how their populations might continue to grow in the face of developing irrigation methods and factors such as climate change. Furthermore, the interactions between humans and these different mosquitoes demonstrate modes of growth and expansion that have created the opportunities for mosquito population growth. The increase in residential and commercial development, agriculturally based irrigation methods, as well as human population growth within small areas all provide excellent conditions for mosquitoes to thrive.

The intersection of insect and human activity is wide and clear when examined closely. In regards to mosquito population control within the US, it is said that “Targeted species sanitation seemed feasible once basic entomological research revealed that the number of truly dangerous mosquito species was very small. Much of the world's heavy burden from mosquito-borne disease was carried by just a few dozen *Anopheles* and ever fewer *Aedes* species.”[95] *An. freeborni, An. punctipennis, Ae. aegypti, and Ae. albopictus* are four of these dangerous species, and their disease introduction is already shown to be devastating. Their continued study is crucial in understanding their roles within the ecosystems of the United States.

[95] Webb “The long arc of mosquito control,” 49-60.

Chapter 2: The Golden State Bloodsuckers: The Many Roles of Mosquitoes in California

As mosquito populations have grown throughout the United States in the last few centuries, numerous factors have both facilitated and hindered their success. Increased human movement and development have provided numerous opportunities for different species to grow in number and presence, while human-led campaigns driven around disease control and eradication have worked to eliminate the threats posed by the insect. Moreover, developing healthcare and infrastructure systems have allowed humans to withstand the risk of disease contraction far more successfully. These varying anthropogenic components have determined the rate at which mosquito populations have developed, demonstrating the way in which both human and non-human are intertwined deeply. This chapter centers on elucidating this connection, and providing historical examples of how it has manifested in California.

Retracing History through Eradication Campaigns

Perhaps the best way to illustrate the history of mosquito species in California is to investigate past eradication efforts and their intersection with developing irrigation methods. On both large and small scales, these eradication regimes serve as landmarks in time where the populations of the insects became enough of a nuisance to garner attention and action from state, federal, and international groups. In the late 19th century, as irrigation infrastructure was constructed around the Central Valley of

California, ideal habitats for *Anopheles* mosquitoes were created as a byproduct.[96] These vectors of malaria rapidly settled into the ecosystems which offered a respite from what was previously an incredibly difficult environment to survive in. The introduction of malaria itself, however, is credited as being introduced by fur traders in the 1830's. Following its introduction, it caused high mortality among Indigenous peoples and colonizer populations during the Gold Rush in the mid nineteenth century. There was a resurgence following the mass arrival of workers for the Central Pacific Railway.[97]

The specific action that facilitated further spread of the disease and disease vector was the unrefined act of draining generally wet environments and creating new wet areas in the Central Valley.[98] This is the act of artificially taking water from certain areas to then be used as irrigation in other places. The potential of the central valley in terms of agricultural progress was recognized early on, leading to very rapid development plans to implement irrigation techniques in order to take advantage of the land, a classic colonial pursuit. In many cases, areas were drained entirely, which actually limited mosquito habitation, and therefore limited the spread of malaria. However, the lack of drainage in certain areas as well as the newly constructed bodies of water made by excessive irrigation existed as utopias for *Anopheles* mosquitoes to migrate into.[99]

The insect's preference for freshwater was endorsed unknowingly by settlers in California. In this way, the spread of the mosquitoes can be directly attributed to

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[96] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 239.
[97] Freeborn and Bohart, *The mosquitoes of California*, 92.
[98] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 239.
[99] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 240.

anthropogenic environmental changes. Following their settlement into the area, malarial cases rose rapidly as the mosquitoes fed on the congregated human populations in the region.[100] As quickly as these environmental changes bolstered malarial spread, further development similarly halted it. Changing agricultural practices, such as the focus on grain which required less water usage, as well as technological advancements in the design of irrigation systems quickly debilitated the suitable environments for the previously rampant *Anopheles* mosquitoes.[101] This is a particularly fascinating course of events because the control of malaria and its vector came about purely from the human pursuit of efficiency. There was no formal plan to limit malaria at the time, and yet the utopia inhabited by *Anopheles* mosquitoes was rapidly morphed to a dystopia for the genus.

Eradication methods that were intentional in the area to limit the spread of *Anopheles* mosquitoes and malaria can be considered in three categories: engineering, chemical, and biological. Engineering strategies include the intentional draining of stagnant waters and the limiting of small bodies of water in which the mosquito thrives. Chemical methods include the use of pesticides such as Dichlorodiphenyltrichloroethane (DDT) and the use of substances in waterways. Biological methods include the ability and employment of natural predators in ecosystems to limit population growth. Beyond this it includes potential interspecies competition amongst different species of mosquitoes.

By the early twentieth century, engineering methods were in place where workers built and maintained drainage systems consistently to limit the number of potential

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[100] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 240.
[101] Freeborn and Bohart, *The mosquitoes of California*, 99.

habitats for the mosquitoes.[102] At the same time, chemical methods were used such as the act of oiling, in which workers would spread oil over the surface of water where drainage was not possible. This was a temporary method of limiting spread as opposed to a permanent method of control, effectively suffocating mosquito eggs and larvae in the water.[103] At this time as well, biological efforts were focused on the introduction of specific flora that could hinder mosquito populations, such as chara, a type of algae. *An. freeborni* mosquitoes were more difficult to target with biological methods due to their fondness for small, intermittent bodies of stagnant water as opposed to environments such as ponds. Other natural predators for the mosquitoes include bats, newts, and dragonflies.[104] The first formal, organized mosquito control project in California was implemented in 1903 in the San Francisco Bay marshlands.[105] This effort was a grand undertaking enacted to both further understand the ecology of marshlands but also what techniques within the environment could provide the most effective control of mosquito populations. It focused primarily on engineering methods that would drain stagnant waters in the marshland to reduce potential habitats for the mosquitoes. It also investigated the biological elements of the region that contributed to either the success or failure of mosquito spread in marshland environments. A critical obstacle which this undertaking faced was the financial backing of control methods, which at the time were based around raising funds through insecure methods such as offered contributions by community members.[106] Quickly following the success of this formalized venture, there

[102] Freeborn and Bohart, *The mosquitoes of California*, 107.
[103] Freeborn and Bohart, *The mosquitoes of California*, 110.
[104] Freeborn and Bohart, *The mosquitoes of California*, 120.
[105] Freeborn and Bohart, *The mosquitoes of California*, 121.
[106] Freeborn and Bohart, *The mosquitoes of California*, 122.

were established taxes that were routed to fund further projects in the following decade which introduced procedures to be adapted by future mosquito abatement districts.

In 1915, the Mosquito Abatement Districts Bill was passed, which was a form of providing funds for mosquito control efforts in different counties.[107] To this day, abatement districts work to provide data regarding mosquito populations throughout California and the United States as a whole, in order to organize formal control methods.

By 1910, agricultural production in California had grown to a point where it existed as a major contributor to national food security.[108] With this increase in agricultural success came an influx of migrant populations to work the farmland. This positioned the increasingly large presence of California agricultural lands in a scenario where more irrigation techniques were in place, and more humans were populating the area, making it appear as a golden opportunity for mosquitoes to concurrently grow. The Central Valley, specifically, felt this phenomenon as malaria persisted within the region throughout the 1930s.[109] At this point, intensification of farming towards root vegetables and cotton in California transformed the state's food and crop supply system, and more mechanized methods of farming were introduced.[110] On the national scale, this came mainly in the form of tractors, and with the lessened need for numerous human bodies to be on the farmland, feeding opportunities for whatever mosquito populations might have existed were dramatically reduced. However, while in the midwest agricultural labor declined, California's emphasis on fruit, vegetable, and nut farms, labor grew, and

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[107] Mosquito and Vector Control Association of California.
[108] Olmstead and Rhode, "A history of California agriculture."
[109] Humphreys, *Malaria: poverty, race, and public health in the United States*, 38.
[110] Olmstead and Rhode, "An overview of California agricultural mechanization, 1870-1930," 89.

so mosquitoes still had a large pool of food sources. Furthermore, in the first decade of the twentieth century, multitudinous migrant workers from Asian countries including Japan, Korea, and China, entered the United States primarily looking for work around railroads and farms.[111]

Environmental Change as a Byproduct of Eradication

Following World War II, scientific and technological advancements facilitated the implementation of more large-scale, intense control efforts on a global scale. The most notable of these followed the formation of the Global Malaria Eradication Program (GMEP) in 1955. This program dove headfirst into chemically based control schemes, largely based on the use of DDT on mosquito-inhabited areas. The most important outcome of this effort, however, did not come in the form of eradication progress, but rather the widespread adaptation of mosquitoes to resist the effects of DDT.[112] The early successes killing mosquitoes through its use were short lived as resurgences occurred. In the United States, specifically, this intense focus on pesticide did little to affect the progression of malaria. Instead, it was the ensuing interdisciplinary approaches that looked at social perceptions of malaria as well as political and economic factors that arose in the United States that allowed for improved control. These factors include increased financing of healthcare programs, and the perpetual development of industrial agriculture.[113] California's growing role as an agricultural hub positioned it uniquely as

[111] Guerin-Gonzales, *Mexican workers and American dreams: Immigration, repatriation, and California farm labor, 1900-1939*, 21.
[112] Beisel and Wergin, "Understanding multispecies mobilities," 37.
[113] Beisel and Wergin, "Understanding multispecies mobilities," 37.

an area where these interdisciplinary understandings were key, both to safeguard the success and productivity of farms, but also to protect the massive number of people that control methods were created for.

The campaigns of Fred L. Soper in the mid-twentieth century are excellent examples of how eradication regimens have evolved. His original focus on aggressive insecticide usage demonstrated the way in which many important factors can be overlooked, such as inaccurately reported population sizes and locations, as well as a holistic understanding of malarial vectors. Moreover, Soper contributed massively to the formation of strategies based around eradicating disease vectors, as opposed to previous blueprints based on targeting the disease geographically.[114] This work proceeded to illustrate how eradication methods differ for Indigenous mosquitoes, such as *Anopheles* in the United States versus for invasive species, like *Ae. aegypti* and *Ae. albopictus*. That is to say, it was shown that it is somewhat easier to control an invasive species that has not become fully entrenched in a local ecosystem through chemical intervention than one that is well established.[115] In either case, however, total eradication is not only difficult, but in many cases, improbable.

Not only is the difficulty of eradication a key concern, but the arduous process opens the space for discourse referring to the ethical bounds of this act. Looking specifically at the use of DDT in early eradication events, modern scientific knowledge tells us that DDT has detrimental effects on the environment For example, it can kill flora and fauna as it is carried from where it was applied through runoff and general elevation change, often ending up concentrating in large bodies of water. Its effects have notably

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[114] Stepan, “Could we/should we eradicate mosquitoes?,” 75.
[115] Stepan, “Could we/should we eradicate mosquitoes?,” 76.

caused reproductive issues at horrifying rates due to its prolific use.[116] The resurgences of mosquito populations following the development of chemical resistance encouraged the use of even more pesticides, creating environmental degradation on an immense scale.[117] Effects on animals, plants, and entire ecosystems caused by DDT are overwhelmingly negative, with damages that persist on very long timelines. This is just one pesticide that is shown to have these effects, though the input of artificial chemicals aimed at hurting a specific species has shown a widespread trend of resulting in damages felt by species far beyond just the one targeted. In reference to this, one is led to consider how, in this particular case of DDT use, extreme environmental and public health crises were created by a tunnel-vision pursuit of ridding human populations of malaria. To this end, ethical dilemmas arise regarding the threat to human and nonhuman populations of profound health risks while trying to destroy a single target. Luckily, Rachel Carson exposed the true terror of DDT in her monumental book “Silent Spring” in 1962, and a decade later the United States banned it from agricultural use.[118] The main danger with DDT lies in its ability to persist in environments over a long period of time, thus the consequences of its use are still felt more than half a century since it was removed from agricultural use.[119] Following its ban, other pesticides were implemented within agriculture as well as for household use to compound pest control, including forms of pyrethroid pesticides, as well as organophosphates and carbamates.[120] Interestingly enough, *Ae. aegypti* and *Ae. albopictus* are both centerpieces of studies investigating insecticide resistance, indicating that control

[116] Webb, “The long arc of mosquito control,” 56.
[117] Stepan, “Could we/should we eradicate mosquitoes?,” 81.
[118] Stepan, “Could we/should we eradicate mosquitoes?,” 81.
[119] Beard and Australian Rural Health Research Collaboration, “DDT and human health,” 78-89.
[120] National Center for Biotechnology information.

methods for these species are particularly difficult.[121] As we explore possible future eradication methods, the intersection between disease eradication and possible public health problems is crucial to keep in mind. As this thesis proceeds, I plan to elucidate that eradication is a far stretch of humanity's ambition, and that there is not a trade off that exists to justify massive ecological change in the form of total species removal. Furthermore, as more historical examples are provided, the classic thread of thought regarding humanity's hubris concerning our environments are explored. Furthermore, as more historical examples are provided, the classic thread of thought regarding humanity's hubris concerning our environments is considered.

In the evolution of malarial control, the intense chemical focus of the twentieth century gave way to a return to the engineering focus on irrigation and drainage to try and keep a lid on the potential of *Anopheles* spread in California. In this case, it is shown that the small scale, intentional innovations in environmental change are the superior techniques in terms of sustainability and effectiveness. At the very least, they avoid the risk of introducing new artificial poisons to ecosystems. Examples of methodology include creating more efficient systems of water transport in irrigation which limit the creation of stagnant bodies of water, as well as more intentional drainage of areas which could serve as habitats for the mosquitoes. And yet, anthropogenic climate change threatens to make even these deliberate actions pale in the face of rapid environmental change. One has to consider the increasing availability of destinations for mosquitoes to inhabit due to extreme weather events and human mobilization to

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[121] Mazzarri and Georghiou, "Characterization of resistance to organophosphate, carbamate, and pyrethroid insecticides in field populations of *Aedes aegypti* from Venezuela," 315-322, Marcombe et al., "Insecticide resistance status of United States populations of Aedes albopictus and mechanisms involved."

previously uninhabited areas.[122] In these scenarios, future mosquito control is a massive consideration. After all, if there are no proactive plans to transfer successful methods of control to areas previously unconsidered, there exists a risk of resurgence in disease spread.

The fact that mosquitoes have existed long before humans, and have managed to not only survive but thrive in the harsh changing environments developed by humans presents them in a more flattering light.[123] Surviving numerous eradication techniques, and still being prevalent where new methods are continuously arising highlights this particular insect as incredibly admirable in its persistence.

Control over Invasion: Limiting the Yellow Fever Mosquito in California

As stated previously, *Ae. Aegpyti* mosquitoes, the yellow fever mosquitoes, were introduced to the United States on the East Coast during the transatlantic slave trade in the sixteenth through eighteenth centuries. Now, they are copious in California. Their journey across the continental United States likely coincides with the migration of European populations westward. It's likely as well that the mosquito benefited greatly from the transcontinental railroad expansion in the mid-19th century. Prior to the twenty-first century, however, detections of *Ae. aegypti* mosquitoes were rare in California.[124] In cases where they were noticed, their presence was limited in size and frequency. However, there are accounts of the mosquito being recognized as far north as San Francisco by the early twentieth century.[125] In the last two decades, however, it

[122] Stepan, "Could we/should we eradicate mosquitoes?," 75.
[123] Beise and Wergin, "Understanding multispecies mobilities," 34.
[124] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."
[125] Howard et al., *The Mosquitoes of North and Central America and the West Indies*, 294.

appears that the species has become well established in areas of arid Southern California. More environmental change and suburban development leading to manmade built environments likely attracted *Ae. aegypti*, and with its spread, incidents of dengue and chikungunya viruses have been noted.[126] While it has likely existed in areas of California sporadically and in smaller numbers for over a century, it appears that it only recently was able to settle into the developed Golden State. This can be expanded upon by thinking about the preferred habitats of *Ae. aegypti* versus those of *An. freeborni* and *An. punctipennis*. *Anopheles* mosquitoes had a wider variability of habitats in the early twentieth centuries due to the rise of irrigation, while the human-made environments preferred by the yellow fever mosquito took longer to develop in a way that allowed for large-scale growth of the species. This is just one possible reasoning behind *Anopheles* being more prominent in research from the twentieth century. The aforementioned incidents of malaria outbreaks in the central and southern valleys of California points to their presence, while there were minimal incidents of yellow fever, dengue, or chikungunya being reported. Other explanations include temperature constraints restricting the movement of the species to California, and low survivability of those that did make the journey.

Eradication history of *Ae. aegypti* is based around a number of key considerations, the first of which is the way in which this mosquito is capable of becoming resistant to chemical pesticides, such as DDT.[127] Secondly, this species especially has a history of resurging in areas that have been thought to be freed of its

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[126] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."
[127] Slosek, "*Aedes aegypti* Mosquitoes in the Americas," 253.

presence.[128] This leads to rapidly-changing accounts of where the insect resides. Finally, most eradication or control strategies for the species historically exist internationally, with populations being more established than in the United States. Similar to those used against *Anopheles* mosquitoes, DDT application and oiling bodies of water were two of the main methods used against Ae. aegypti mosquitoes. Furthermore, public engagement became a very critical component of the fight against *Ae. aegypti*. Encouragement for people to empty any water-filled receptacles worked to limit the possibility of the yellow fever mosquito to breed.[129] While he was head of the RF-Brazilian yellow fever service, Soper's work followed a streamlined, militaristic format in its pursuit of removing *Ae. aegypti* through mainly chemical techniques. While there have been large-scale efforts to remove the yellow fever mosquito in global contexts, California has not been a specific focus in those campaigns.

The New Champion of Species Control Discourse in California: *Aedes albopictus*

Similarly to *Ae. aegypti*, the very recent introduction of *Ae. albopictus* directly to the United States positions it as a much more recent study in pest eradication. Following its arrival, it filtered into the southern US, being noticed in states such as Texas and California very quickly, with accounts of it spreading eastward and westward sporadically. In 1985, it had not infested California to a notable point, as temperature constraints limited its movement to Northern California, and was just becoming

[128] Slosek, "*Aedes aegypti* Mosquitoes in the Americas," 250.
[129] Christophers, *Aedes aegypti (L.) the Yellow Fever Mosquito: Its Life History, Bionomics and Structure*, 85.

established in Southern California.[130] Within the last two decades, however, it has become well established in California, demonstrating the incredibly powerful capabilities of the species to adapt to new environments. This also hints somewhat at how changing climatic regimes in the last twenty years created opportunities for successful transfer of the species into more Northern areas of the state. The growth of this mosquito species, and its ability to thrive in environments already inhabited by *Ae. aegypti* champions the species as an extreme risk factor in public health considerations for the future.

Organizations such as the California Department of Public Health (CDPH) and the University of California, Davis, Center for Vectorborne Disease (CVEC) have worked diligently in the past several decades to provide large amounts of information regarding the species, as well as using strategies based on trapping and testing to investigate the risk of disease spread in the area.[131] Eradication efforts targeted at this species have been built around increased surveillance within California cities in order to accurately track progression of the species, and therefore create adaptable control plans. Due to the advancement of techniques used to spread information, the rise of *Ae. albopictus'* invasion of California was well studied and represented. As of now, the CDPH has an entire subsection on its website dedicated to spreading information about the presence of the mosquito's populations.[132] Interspecies competition and infertility caused by breeding between *Ae. aegypti* and *Ae. albopictus* are two explanations of how *Ae. albopictus* is able to become so entrenched in areas previously dominated by *Ae. aegypti.*[133] These actions can be envisioned in one way by thinking about Ae. albopictus

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[130] Lounibos, "Invasions by Insect Vectors of Human Disease," 248.
[131] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."
[132]California Department of Public Health, "*Aedes aegypti* and *Aedes albopictus* mosquitoes."
[133] Lounibos, "Invasions by Insect Vectors of Human Disease," 249.

mosquito larvae taking over breeding containers as both species prefer man-made environments for breeding. Moreover, this mosquito, above all others investigated in this thesis, is a model of evolving human mobility in the last half-century. Its dynamic spread was facilitated by the increased use of global trade, as well as established sedentary civilizations that provide countless potential habitats.

The increased spread of information around the species in California is due to the motivation to inform the public on how to best remove these potential habitats- including instructing people to drain standing water and avoid leaving any containers which might become breeding grounds.[134] Figure 3.1 is an example of one form of informational content released to the public in the pursuit of education. Works similar to this are the leading source of hope in targeting increasing mosquito populations, a goal fueled by rising fears regarding the immense capabilities of both *Ae. aegypti* and *Ae. albopictus* mosquitoes to transmit a wide variety of arboviruses.

[134] Dusfour and Chaney, "Success, failure and expectations in the context of arbovirus expansion and emergence. *Mosquitopia: the place of pests in a healthy world*," 215.

Figure 3.1 Potential habitats for *Aedes* mosquitoes denoted by letters I-E. Strategies for removing these habitats through intervention are labeled with numbers 1-10.[135]

Amongst these discussions of past eradication methods, a critical connection is formed between eradication campaigns and the role of invasive species narratives. Fears surrounding these two *Aedes* mosquitoes are tangible, and have reasonable backing due to the threats posed by the spread of disease in the heavily populated state of California, and the greater United States.

[135] Dusfour and Chaney, ”Mosquito control: success, failure and expectations in the context of arbovirus expansion and emergence,” 216-217.

Chapter 3: Human and Non-Human: How do Mosquitoes fit in the Big Picture?

The history of eradication methods used against this insect elucidates the evolving human-mosquito relationship, and how motivated some regimes can become to entirely remove the threat posed by them. It is incredibly easy to generalize mosquitoes as a pest, and when they are spoken about they are referred to in totality rather than with distinction for each species. For the US population, access to developed health-care mitigates the danger of disease contraction, and so knowledge of each species' disease transmitting capabilities is not necessary. As mosquitoes continue to spread and diseases become more common in future years, such knowledge could become critical, hence why public health departments are responsible for distributing further educational material regarding the insect. I argue that recognition of each individual targeted species is crucial. This can be attributed to several reasons, the most general is that increased awareness of the different habitats and capabilities of the species allows for more successful mitigation of risk. The main reason under investigation in this chapter, however, comes in the form of addressing the common name of *Ae. albopictus*: "The Asian Tiger Mosquito."

The Power of Nomenclature: Inherent Risks in Racialized Common Names

The common name distinction between *Ae. aegypti* and *Ae. albopictus* as Yellow Fever Mosquito and Asian Tiger Mosquito respectively indicates a more racially charged background for *Ae. albopictus*. Seeing as the mosquito originates from Asia, this name is logical at first glance. However, the potency of risk around this invasive species poses a certain threat when it is associated with a racialized nomenclature. This is but one example of how using origin points of invasive species has intensely troubling consequences. Specifically, there is a connection established through this technique of naming that links high-risk invasive species to an entire human demographic.[136] Constant reinforcement of the threat of the species, and its existence as an invasive species in the United States, works to create negative associations with Asian people living in this country. Past historical reports regarding the species invading certain areas in the Caribbean went as far as simply crediting the presence of the mosquito to migrating Asian populations.[137] In this format, the identity of the mosquito risks becoming entirely intertwined with that of Asian populations. Luckily, developed research into the transport of the mosquito by automobile tires in global trade has debunked these early assumptions about the insect's movement.[138] Social anxieties are influenced somewhat by risk factors, and we have seen just how incredible the risk factor of *Ae. albopictus* is.[139] The increased efforts by organizations to spread awareness of this risk, in the form of classifying the species as one of the most dangerous globally, as well as constant updates of disease spread works in a

[136] Beisel and Wergin, "Understanding multispecies mobilities," 34.
[137] Beisel and Wergin, "Understanding multispecies mobilities," 33.
[138] Lounibos, "Invasions by Insect Vectors of Human Disease," 239.
[139] Ernwein and Fall, "Communicating invasion: understanding social anxieties around mobile species," 157.

particularly damaging way here. Acknowledgement of the risk, and the consistent dispersal of such can contribute to social anxieties directed at Asian populations due to the association created between the mosquito and the group of people. Historically,. the ways in which Asian migrant workers came to California to specifically work on farms and railroads positioned them uniquely to be at risk of contracting diseases through mosquito transmission, specifically malaria.

The diseases transmitted by these mosquitoes are zoonotic diseases. That is, they are passed from animals to humans through a disease vector: the mosquito. Zoonotic diseases are important to understand in this context, as they highlight how the risk posed by disease spread is not simply born out of the presence of mosquitoes. Rather, the mosquitoes' ability to transfer the diseases from animal to human populations is what makes the small insect such a powerful species on earth. Without a proper understanding of how zoonotic diseases function, blame for infection falls solely on the mosquito. In this case, that blame falls on Ae. albopictus, and due to its common name, diseases such as dengue, chikungunya, and yellow fever are linked to Asian origin. Jeannie Shinozuka highlights the history of the link between human and non-human immigrants to the United States:

> Biological invasions in the form of dangerous insects and plants were viewed in much the same way as Asian bodies— sometimes valued for the economic gain they offered, while often reviled for the menace they posed to the environment and to White Americans.[140]

Mosquitoes, generally, offer a massive risk to economic endeavors as well as health conditions, as they pose a threat of disrupting the functionality of agriculture by

[140] Shinozuka, *Biotic Borders,* 174.

introducing sickness to workers.[141] On a business level, the break in productivity created by the spread of sickness threatens success, but more importantly, this break could also translate to a disregard for the health of those who are working. Disease transmitting mosquitoes act as a catalyst for a variety of risks within the agriculture sector. Mosquitoes as an insect are often generalized, considered to simply be one type of pest. The intricate differences between them are highlighted components of education. This includes the different disease-carrying capabilities of the genus versus those belonging to the *Aedes* genus.[142] However, to the naked eye, it is quite difficult to tell whether that mosquito on your ankle is a Yellow Fever mosquito, or the Woodland Malaria Mosquito. A worst case scenario where *Ae. albopictus* becomes the dominant species of mosquito in California, leading to the generalization that all mosquitoes belong to this species, could lead to profound consequences.

This is a critical example of the way in which invasion biology, and the narratives surrounding the idea of invasion contribute to the human-non-human interaction. The categorization of certain species as not belonging to, or being inherently harmful to new areas contributes greatly to animosity based around them. The Japanese beetle examined by Shinozuka exists as a spectacular example of how, when the negatively connotated invasive species is associated specifically with a racial identity, the bridge connecting humans to non-humans becomes far more easy to build.[143] In this way, as Shinozuka argues in her book, political elements such as immigration policy and mass media narratives are heavily influenced. As expressed earlier in this thesis, mosquitoes

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[141] Greater Los Angeles County Vector Control District, “Mosquito Borne Diseases.”
[142] Porse, “Public Health Response to Aedes aegypti and Ae. albopictus Mosquitoes Invading California, USA.”
[143] Shinozuka, *Biotic Borders,* 28.

have navigated through the United States through the movement of humans. The insect has been led by a theoretical leash built on human invention and migration through the country, and therefore humans and mosquitoes cannot be viewed as entirely separate.

Looking to the future, increasing prominence of *Ae. albopictus* mosquitoes in the United States could facilitate mosquitoes and diseases carried by them being directly connected to an identity of "Asian." Americans have a distinct habit, historically, of blaming immigrating human populations for foreign pathogens.[144] We've learned how climatic changes to environments could initiate further spread of the species. Moreover, we've seen how state groups such as the CDPH emphasize raising awareness of threatening species. The ways in which the rest of the United States will react to the Asian tiger mosquito increasing in number and risk is likely to affect perceptions of Asian populations. The generalization of mosquitoes previously mentioned is one particular result of these effects. Despite efforts by state and federal organizations to spread information about different species of mosquitoes, it is still an evolving process of disseminating facts. Ae. albopictus is already ranked as an incredibly dangerous invasive species, and yet recognition of the species is not common knowledge.

The COVID-19 pandemic unleashed a great deal of xenophobia within the United States aimed at Asian communities.[145] The origin point of the disease being in Asia contributed to a great number of incidents fueled by the assumption that it was, itself, an Asian disease. Quite obviously, this was a fabrication of links that allowed persistent racism in the United States to flourish. This country has a long standing history of anti-Asian sentiment, with the 1882 Chinese Exclusion Act and the 1924 Immigration

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[144] Shinozuka, *Biotic Borders,* 5.
[145] Chen et al., "Anti-Asian sentiment in the United States–COVID-19 and history," 556.

Act being two specifically targeted national landmarks that restricted the movement of Asian immigrants.[146] While these acts themselves are shocking in their blatant discrimination towards a certain group of people, they are examples of racism on a large-scale. Additionally, from 1900 to 1906, the plague pandemic within San Francisco led to public health officials blaming Chinese populations for the outbreak, criticizing their sanitary habits with racist language, as well an imposing a total quarantine on Chinatown, followed by numerous threats to burn the entire area as well multiple efforts to limit the movement of people to or from the region.[147] In this instance, the mayor even specifically pointed the finger at Asian populations to place blame for the outbreak. The anti-Asian sentiments that arose in the United States following the outbreak of COVID-19 highlighted the aforementioned habits of Americans to blame immigrant populations, or even more specifically, non-White populations, for threats to public health. In this case, the president at the time, Donald Trump followed in the footsteps of the San Francisco mayor, labeling COVID19 as things such as the “Chinese virus” and “kung flu.”[148] Moreover, it demonstrated the ways in which Asian ethnicities have historically been generalized by privileged, White populations in the US, as if Asia exists as a single homogenous population, rather than multitudinous different ethnicities and cultures.[149] Furthermore, not only is there a generalized habit exacerbated by people within the United States to discriminate against Asian populations, but political leaders

[146] Chen et al., “Anti-Asian sentiment in the United States–COVID-19 and history,” 556.
[147] Risse, “‘A long pull, a strong pull, and all together’: San Francisco and bubonic plague, 1907-1908,” 260-286.
[148] Viala-Gaudefroy and Lindaman, “Donald Trump’s ‘Chinese virus’: the politics of naming,” 21.
[149] Chen et al., “Anti-Asian sentiment in the United States–COVID-19 and history,” 557.

publicly making statements which shift blame for large-scale public health crises demonstrates a tolerance, and even a support base for such an attitude in the country.

Underlying racist attitudes in American politics stem a great deal from the notion that the United States exists as a pristine, wild land in itself. The American dream itself is built upon the ideas of having freedom to achieve whatever you set your heart to, and the country would provide whatever is needed to do it. However, the barriers built around this dream are constructed with exclusions and an expectation that it is an inherently White dream. For non-White immigrants coming into the country, countless obstacles in the form of immigration law, racial discrimination, and mass media oratory immediately create a starting line leagues behind that which a White immigrant would begin at. Thus, the danger posed by a racialized invasive species that holds the capacity for immense public health threats is fuel for an already raging fire that can contribute to a profoundly hostile living experience for non-White populations.

Future transmission of diseases such as dengue, chikungunya, and zika virus by *Ae. albopictus* poses a sociocultural risk wherein the mosquito would similarly offer fuel for anti-Asian racism due to its racialized common name. However, race is a purely sociological conception: it is based on creating hierarchies and clearing a path for White supremacy.[150] Present-day science can understand that race is such a social construction, but at the time of the Chinese Exclusion Act, scientists truly believed there was merit to biological differences being its basis. The build up of racism, specifically anti-Asian racism, is based on a history of believing in a difference between races, and more categorically, between White and non-White. The focus on eugenics in the United States in the early twentieth century as well compounded the emphasis on trying to

[150] Humphreys, *Malaria: poverty, race, and public health in the United States.*

maintain a Whiteness to the country. With this horrific spotlight in science came a conviction that non-White populations were inherently lacking in areas such as morality, cleanliness, and trustworthiness, while also being genetically more unhealthy, lacking intelligence, and morally challenged.[151] The basis of the United States is fundamentally White, and White-empowering, which can only come at the expense of non-White populations.

As COVID became a racialized disease, so too can *Ae. albopictus* become a racialized species, further perpetuating these harmful connotations. Because of this, *Ae. albopictus* presents risks that *Ae. aegypti* simply is not associated with, and so while the two differ slightly in terms of effectiveness of disease transfer and general habits, the total risks of *Ae. albopictus* outweighs those of *Ae. aegypti.*

The history of eradication provided earlier in this chapter was intended not only to provide context of past recognition of mosquito populations, but also to highlight the intensity of operations targeted at mosquitoes. Most modern methods rely on limiting habitat availability, but even that is somewhat of a losing battle considering the numerous ways in which climate change will affect ecosystems and the mobility of humans. This being said, the future of eradication efforts falls into a precarious zone of ethical debate.

With the amelioration of scientific research on diseases and biology emerged the ability to shift control methods away from external weapons to internal changes. For one thing, vaccine development for illnesses such as dengue and yellow fever offer a certain type of protection, at the very least, from certain diseases which mosquitoes carry.[152]

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[151] Silber, "Eugenics, family & (and) immigration law in the 1920's," 859.
[152] Galbraith and Barrett, “Yellow Fever,” 288-313.

Beyond this, a more recent evolution is the act of gene manipulation within lab-grown mosquito populations.[153] This method is undertaken to disable the reproductive capabilities within mosquito species as well as make the mosquitos infertile. Introducing the sterile insects to ecosystems would allow for the gene to be passed down through the mating between wild females and lab-raised males. Over time, it is hypothesized that the mosquitoes in an entire ecosystem might die off on their own.[154] These eradication designs, however, are based around manipulating species' reproductive posterity, introducing intense ethical debates within the scientific realm. On one side of the argument, the success of control techniques such as pesticides are becoming less and less effective and humanity is being backed into a corner in the fight against public health threats.[155] However, this process is intricate, and of course, expensive, bringing up concerns regarding equality from the ways in which socioeconomic divides might be intensified through its use.[156] For example, if it were enacted in one area that is predominantly wealthier, costs of healthcare centered on disease treatment would likely decrease, as would the required funding for other control methods that are in place. Meanwhile other areas that might not be able to allocate funds for such eradication programs would still require healthcare treatments, as well as funding for abatement districts and control methods. Furthermore, if a certain group of mosquitoes exists in an area but is not transmitting diseases to human populations (whether due to a lack of the

[153] Rajagopalan, "Designer mosquitoes?," 239.
[154] Rajagopalan, "Designer mosquitoes?," 241.
[155] Wienhues, "The innocent mosquito?: The environmental ethics of mosquito eradication," 204.
[156]Rajagopalan, "Designer mosquitoes?," 241.

disease to transfer in the first place or well developed protection methods), the debate centers around whether there is still justification for eradicating that group.[157]

The connection between human intervention into the success of mosquito populations and inequalities felt by differing human populations is beyond tangible, it is unavoidable. Such a link exists as an entirely necessary recognition when thinking about future eradication plans.

Asian populations are not the only population violently affected by the evolution of mosquito expansion, on a more physical level Black and Indigenous peoples have faced hardships as a result of the insect. Mosquitoes as a disease vector have a history of disproportionately affecting racial minorities.[158] Malaria ravaged Black and Indigenous populations through the twentieth century. Specifically, the restrictions set up around healthcare and access to housing contributed to the inordinate fatality rates amongst these groups and other minorities.[159] These constructed limitations, of course, followed centuries of enslavement, the conditions of which exposed African and Afro-American to mosquitoes, and therefore, diseases on a level completely incomparable to that of White colonizers.[160] Indigenous populations were decimated in epidemic events due to their reliance on certain environments which quickly became infested by infected mosquitoes.[161] Not only did White colonizers facilitate the introduction of diseases, but they implemented borders both physical and metaphorical that abandoned non-White populations in public health crises. Furthermore, the reaction to the effects of disease

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[157] Vythilingam, “Mosquito utopias and dystopias,” 270.
[158] Humphreys, *Malaria: poverty, race, and public health in the United States*, 127.
[159] Humphreys, *Malaria: poverty, race, and public health in the United States*, 67.
[160] Willoughby, “Domesticated Mosquitoes,” 67.
[161] Slosek, “*Aedes aegypti* Mosquitoes in the Americas,” 249.

on African children demonstrated an immense racial bias. Beisel & Wergin describe how perception affected the growth of racially targeted policymaking:

> In other words, perceived differences in vulnerability to vector-borne diseases opened the door to violence and racial segregation policies, such that African children, for example, were hypothesized to be disease reservoirs for parasites… Such long-standing socio-political entanglements of race and society provide the background against which mosquito control mechanisms, from containment to extinction, are conceived and exercised.[162]

Malarial infection disproportionately affected different demographics, harming Indigenous populations greatly prior to the twentieth century and continuing on to affect Black and poor White populations far more than wealthier White communities.[163] It existed as an Indigenous disease prior to European colonization, but not to a point where a prominent partial-immunity was developed, and so when it was brought in droves by colonizers, it still heavily affected Indigenous populations.[164] By the twentieth century, Black communities often only had access to housing in less than ideal areas, such as the outskirts of towns, in poorly constructed homes, leaving them much more vulnerable to exposure to malaria carried through mosquitoes that could easily access them.[165]

These are just some methods of viewing the intersection of racial and environmental injustices relating to mosquito-based disease spread. Racial dynamics

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[162] Beisel and Wergin, “Understanding multispecies mobilities,” 35-56.
[163] Humphreys, *Malaria: poverty, race, and public health in the United States*, 62.
[164] Humphreys, *Malaria: poverty, race, and public health in the United States*, 22.
[165] Humphreys, *Malaria: poverty, race, and public health in the United States*, 64.

and mosquito influence on human populations cannot be separated or investigated independently. *Ae. albopictus*' common name is one definitive way in which such racial injustices could be continued to be exacerbated. Future threats to racial minorities in the United States cannot always be predicted, but in this case it can most definitely be inferred, and proactive measures must be taken to address the dangerous potential.

Future adaptations to mosquito population growth is crucial for the sake of public health. Interdisciplinary approaches to mitigate disease resurgence in the United States must be enacted immediately in order to get ahead of the inevitable changes driven by climate change. At the same time, work must be done to address the risks created through racialized common names of invasive species. Similarly to how control strategies for mosquito populations in California were only successful following the inclusion of considerations within economics, sociology, and politics, holistic considerations regarding racialization of dangerous invasive species are necessary. The focus on sustainability that is emphasized by the drive to mitigate climate change also demonstrates how control methods for mosquitoes must also be structured in a sustainable manner.[166] Furthermore, fears surrounding the northward spread of mosquitoes have increased substantially due to changing climate regimes, and these fears have actually contributed somewhat to fueling action against anthropogenic climate change.[167]

In today's modern world, the rise of mosquito-borne diseases within California comes about primarily as a result of them being imported. In Southern California, the largest risk comes from travelers crossing the US-Mexico border while infected with

[166] Beisel and Wergin, "Understanding multispecies mobilities," 40.
[167] Ford et al., "LIVING WITH MOSQUITOES IN DISEASE-FREE CONTEXTS," 137.

dengue or chikungunya.[168] Once an infected traveler arrives, the major threat comes in the form of one of the *Aedes* mosquitoes biting that person, and then transferring the illness to other human hosts. dengue and chikungunya have been reported at high rates in the last decade, and so the chances of the diseases being transported over the border rises.[169] Areas of California farther North from the US-Mexico border are considered threatened by the arrival of infected travelers from a wide variety of locations. The distribution of *Aedes* mosquitoes throughout the state allows for arriving diseases to be spread regardless of their point of origin. The modern availability of international transportation in the form of boats and planes allows for rapid transport of diseases. In many cases, travelers are not showing symptoms upon traveling to California, and the incredible speed at which one can reach international destinations minimizes the chance of recognizing the presence of zoonotic diseases during movement.[170] Increasingly advanced modes of travel being introduced globally compound the risk of importing illnesses because they could not only make the speed of travel faster, but also increase availability for people to travel between countries.

[168] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."
[169] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."
[170] Porse, "Public Health Response to *Aedes aegypti* and *Ae. albopictus* Mosquitoes Invading California, USA."

Climate Change

Rising temperatures would position more northern regions of California, the United States, and the Northern hemisphere as a whole as more suitable environments for mosquitoes to infest.[171] Referring back to points made about the role of climate change in the further spread of mosquito-based risk, Anna Wienhues explains:

> In practice, there are considerable regional differences that are in the process of transformation due to climate change, with not all regions and communities being equally affected by mosquito-borne diseases.[172]

Once again, the link between human and mosquito populations becomes highlighted. It is a complex web of connections in which humans facilitate the spread of mosquitoes, which enables the mosquito to feed on humans and spread disease, leading humans to enact control regimes. At the forefront of it all, climate change works to control where humans will be able to not only live comfortably, but simply survive in the face of extreme weather events and rising temperatures. The latter point reveals a worrisome consideration: as temperatures increase, the availability of habitats for mosquitoes will increase in tandem. Gradually the insects will be able to settle into new regions, as well as survive for longer in areas that previously had temperature constraints.[173] With these factors allowing mosquitoes more freedom to fly, feed, and breed, disease transmission becomes much more possible. Moreover, as certain areas become too difficult to live in, such as coastal areas or regions within arid or tropical

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[171] Morrison and Lemke. "AweWonderExcitement," 145.
[172] Wienhues, “The innocent mosquito?,” 206.
[173] Reiter, “Climate change and mosquito-borne disease,” 141-161.

biomes, human populations might move farther inland. Mass migration of humans opens yet another door through which the mosquitoes could fly to a more prolific period of population growth.

When considering the future in this context, one must also consider points previously made in this thesis. Follow me as I set a hypothetical scene: *Ae. albopictus* becomes more prevalent and reported throughout the United States as more habitats become available. Disease transmission is increased due to the removal of temperature constraints in some areas, and thus more people begin to contract diseases such as yellow fever, dengue, or chikungunya. Public health departments would likely address the issue in an effort to educate people on how to reduce the risk of being exposed and/or infected by these diseases, and in each of these addresses, a name appears: "The Asian tiger mosquito." At this point, how can officials plan to address the racialized connotations of the mosquito's common name? Possible options include releasing statements educating the public on the fact that it is the origin point of the species, and trying to control perceptions through awareness. Alternatively they could begin issuing disclaimers with every statement that explicitly tries to educate readers that the diseases spread by it are not "Asian diseases" or tied to Asia through anything but the origin point of the invasive species. Officials could also simply do nothing to address the cultural effects of having a racialized name on a massive public health threat. There's practically no way to accurately predict how this might develop in the coming years. Of course, these assumptions and predictions are based mainly on models and existing fear introduced by scholars, and so even they could play out in entirely different ways. The reality exists, however, that as long as a disease vector is linked to a racial identity,

then there exists a risk that humans belonging to that racial identity as well will face prejudice and violence because of it.

In terms of the future of *Ae. albopictus'* common name, I argue that, seeing as how the species is already established not just here in the United States, but also globally in numerous countries such as Europe and Brazil, then there simply is not a need for it to be directly attributed to wherever it first departed from. Regardless of where the mosquito came from originally, in terms of the insect's lifespan, that was some hundreds of generations ago. At this point in time, the common name including "Asian" does nothing other than link it and any of its harmful actions to an Asian identity.

Conclusion

For copious reasons, the mosquito exists as a champion within environments when it comes to disease transfer and adaptability. The insect is profoundly capable of instilling change within ecosystems, and in the relationship between human and non-human populations. Indigenous mosquitoes within America have proven to be resilient in the face of pointed eradication techniques, and invasive species have been able to gain footholds simultaneously. Not only has there been considerable risk associated with mosquitoes in North America, and California specifically up to this point, but so too have there been considerations of how the future of mosquito spread is a daunting obstacle of the future. Indisputable climatic changes offer a vessel in which mosquitoes can catch a ride to new habitats, new feeding grounds, and even populations of people which have survived without their interference for some time. Not to mention, of course, the ways in which these growing populations specifically put certain human demographics at risk through associations in nomenclature.

California's unique position as an agricultural center, and densely populated state that is already experiencing the establishment of invasive mosquito species places it in a spotlight of questions and concerns with regard to these species. Continued spread of vectors and their respective diseases within the state are already becoming a larger nexus of discourse, with state health organizations and vector control districts creating more instructional materials for the public to use. As the Golden State is morphed by climate change, this discourse is only likely to grow in frequency and magnitude. In the same way that sociocultural elements of human life are likely to be affected by *Ae.*

albopictus, the full dangers of mosquitoes in general are still not fully understood, and California is situated in a way where it will likely experience many of them, and will act as a template for maneuvering those unknowns.

Historically, mosquitoes have played a major role in public health analyses and their presence is noted far and wide within the United States. They're progression can be traced through medical reports and endemic disease outbreaks, and using that material it is possible to construct a more complete understanding of just how powerful the insect is in terms of adaptation and survival. Despite numerous eradication efforts aimed at removing the risk of malaria or yellow fever, populations have resurged. Additionally, in the face of engineering techniques designed to limit the habitation of mosquitoes, environmental change has facilitated the arrival of new areas that are ideal for the insects. In totality, the insect has a rich history of affecting humans, and they continue to do so today on a scale much larger and more complex due to human developments. Evolving agricultural techniques, human movement, and climate change are all incredibly potent catalysts for the mosquito to become a recognized source of concern.

The growth of invasive species in California shows how the role that pests play cannot be understated or underestimated when it comes to public health risks, or public safety as a whole. Moreover, the incredible capabilities of these species highlight them as particularly dangerous, and push them to the forefront of obstacles to tackle at present and in coming years. Efforts must be continued and expanded to distribute educational materials regarding the risks of mosquitoes, as well as mitigation methods for the general public.

Aedes albopictus, the Asian Tiger Mosquito, poses immense risks if it were to continue without a name change, as the possibilities surrounding disease outbreaks becoming associated with Asian populations could prove to be a catalyst for further anti-Asian racism in the United States.

While control methods are evolving at a rapid pace, and the threats posed by mosquito populations are extremely dynamic, it is impossible to tell exactly what the mosquito's role will be in the coming years. The only guarantee is that it will still be present, and it will be intertwined with humans in the same undeniable way that it has been for the entirety of US history.

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