Wing Beats

of the Florida Mosquito Control Association

Salt Lake City residents out for a leisurely drive 1920s

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About the Cover: At one time the mosquito abundance in the Great Salt Lake Valley was so burdensome, that even in the summer residents had to be covered from head to toe. The Salt Lake City Mosquito Abatement District became operational in 1924, paving the way for residents to enjoy the great outdoors without the need of headnets thereafter. **Photo** provided by **Ary Faraji**, AMCA President and Executive Director of the Salt Lake City Mosquito Abatement District.

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Utah: The Greatest Snow on Earth

by Ary Faraji

Welcome to Utah!

A state in the high desert with magnificent mountains and The Greatest Snow on Earth. The third highest state in the union, with a mean elevation of 6,100 feet above sea level, and the lowest point slightly above 2,000 feet. In fact, the base elevation in the capital City of Salt Lake is over 4,200 feet. Utah has a mainly dry, semi-arid, and desert climate with virtually no humidity during the active mosquito season.

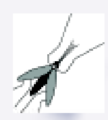
So, you may ask yourself, do we even have mosquitoes here? The short answer is: boy oh boy, do we ever.

We don't have the species diversity that other states may experience, but we certainly have an abundance that is on par with, or superior to, most other states. And the reason why is actually quite simple. Most of the populated areas of Utah are along the Wasatch Front, which stretches 120 miles from about the city of Provo in Utah County to the city of Logan in Cache County. This land is home to about 2.6 million people, with another 500,000 scattered throughout the rest of the state. The vast majority of people live in the base and the lowlands of the Wasatch Mountains where an average of about 600 inches of snow may accumulate during the winter months. In the spring, the snowmelt starts to make its way down the canyons and towards the Great Salt Lake. However, the water never quite makes it out there, as the vast majority of it is used by private landowners, farmers, environmental groups, and an intricate network of private duck clubs for waterfowl management. The constant flooding, dry down, reflooding, creates thousands of acres of prime mosquito habitat where floodwater species such as *Aedes dorsalis* and *Culex tarsalis* abound in astronomical numbers.

The overabundance of the above two species is what led to the creation of mosquito abatement districts in Utah. In fact, Utah was the third state to pass legislation for the creation of mosquito abatement laws and districts in 1923. This led to the formation of the Salt Lake City Mosquito Abatement District in 1924. We follow only New Jersey (1912) and California (1915) in those regards. I can hear the Floridians saying, "What about us?" The truth is that although the Florida Anti-Mosquito Association was created in 1922, the state did not pass laws for the creation of mosquito control districts until 1925! So, the fact that a high desert and mostly dry state beat Florida should be a testament to how bad the mosquito problem is in Utah!

Nonetheless, Utah has been involved in all aspects of our profession for nearly a century now, conducting mosquito surveillance, abatement and research. This special issue of *Wing Beats* is being dedicated to the men and women that have led the mosquito movement in our great state over the last century. Their stories are told in the numerous articles that will grace these pages. Their stories are indeed your stories, as their contributions have advanced our field and we stand proudly on their shoulders. Names such as Don Rees, Jay Graham, Lew Nielsen, Glen Collett, Lewis Fronk and Sam Dickson will live forever in distinction and we will continue to honor their great work and traditions. I am also grateful for the contributions of the current slate of mosquito abaters, who continue down the great road laid before them and have made significant contributions to Utah mosquito control and this issue in particular. These include Gary Hatch, Brian Hougaard, Eric Gardner, Tyson Packard, Randy Sessions, Greg White, Andrew Dewsnup, Brad Sorensen, Ryan Lusty, Scott Bradshaw, Sean Amodt, Dan Miller, Eldon Rowley, Keith Hill and Ryan Arkoudas, amongst many others. I am also grateful to the unofficial historian of mosquito control, Dr Gordon Patterson, for his article – and also his willingness to moderate and speak at a special symposium during the annual AMCA meetings in March of 2021 to honor the rich history and key players within Utah.

And speaking of the AMCA annual conference, no one is more disappointed than me in the cancellation of the in-person component of that meeting because of the ongoing COVID-19 pandemic. The Utah Mosquito Abatement Association had planned for a series of special events during this meeting, and we are extremely disappointed that we will not be able to serve as your hosts during 2021. We are hopeful the meetings can be brought back here in a few years, perhaps for an official 100-year celebration! But in the meantime, enjoy this issue and get ready for the first virtual AMCA meeting during 1-5 March 2021. We may not see you in person, but we'll see you virtually!



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The Genesis of Mosquito Control in New Zion

by Gordon Patterson

WESTWARD-HO

Organized, anti-mosquito work in Utah did not begin until the early 1920s. Mosquitoes and mosquito-borne diseases, however, played a critical, if unacknowledged, role in the mid-nineteenth century migration of tens of thousands of disciples of the Church of Jesus Christ of Latter-day Saints to the Great Salt Lake Valley. In 1839, Joseph Smith purchased 123.4 acres of land adjacent to Commerce, Illinois, to provide a refuge for his fellow Latter-day Saints fleeing persecution in Missouri. Shortly after arriving in Illinois, Smith penned a sobering perspective on the purchase. He observed:

"The land was mostly covered with trees and bushes, and much of it so wet it was with utmost difficulty a footman could get through, and totally impossible for teams. Commerce was so unhealthful, very few people could live there; but believing it might become a healthful place by the blessing of heaven to the Saints, and no more eligible place presenting itself, I considered it wisdom to make an attempt to build up a city" (Rollins et al 2006).

A year later, Smith rechristened the town as Nauvoo, which meant "beautiful" in Hebrew. The town's name, however, was belied by the region's swamplands and festering malarial marshes. In the summer of 1840, many of the 2,900 Saints suffered recurrent bouts of fever and chills. The then widely held miasma theory identified the origin of ague, as malaria was sometimes called, to tiny, poisonous particles (miasmata) released from decomposing matter that rose in poisonous vapors from the fetid soil in marshes (Hempelmann & Krafts 2013).

To rectify this noxious setting, Smith ordered an extensive drainage effort. This initiative inadvertently led to a significant reduction in the anopheline mosquito population. By 1841, Nauvoo's bi-monthly newspaper *Times and Seasons* reported that "the healthiness of the place during the past year had greatly improved by the digging of wells and draining off stagnant waters, and there was now but little or no sickness among the inhabitants" (Rollins et al 2006). By the mid-1840s, Nauvoo's population had grown to nearly 10,000 healthy, malaria-free residents.

Dissension within the ranks of the Saints, fueled by criticism of the Prophet Joseph Smith, surfaced in 1844. The insurgents set up a printing press and published a series of anti-Smith diatribes. Smith, Nauvoo's mayor, and the city council outlawed the newspaper, passing an ordinance identifying the dissenter's newspaper a "public nuisance." Rioting broke out when Smith's allies seized the paper and destroyed the printing press. Illinois Governor Thomas Ford ordered the state militia

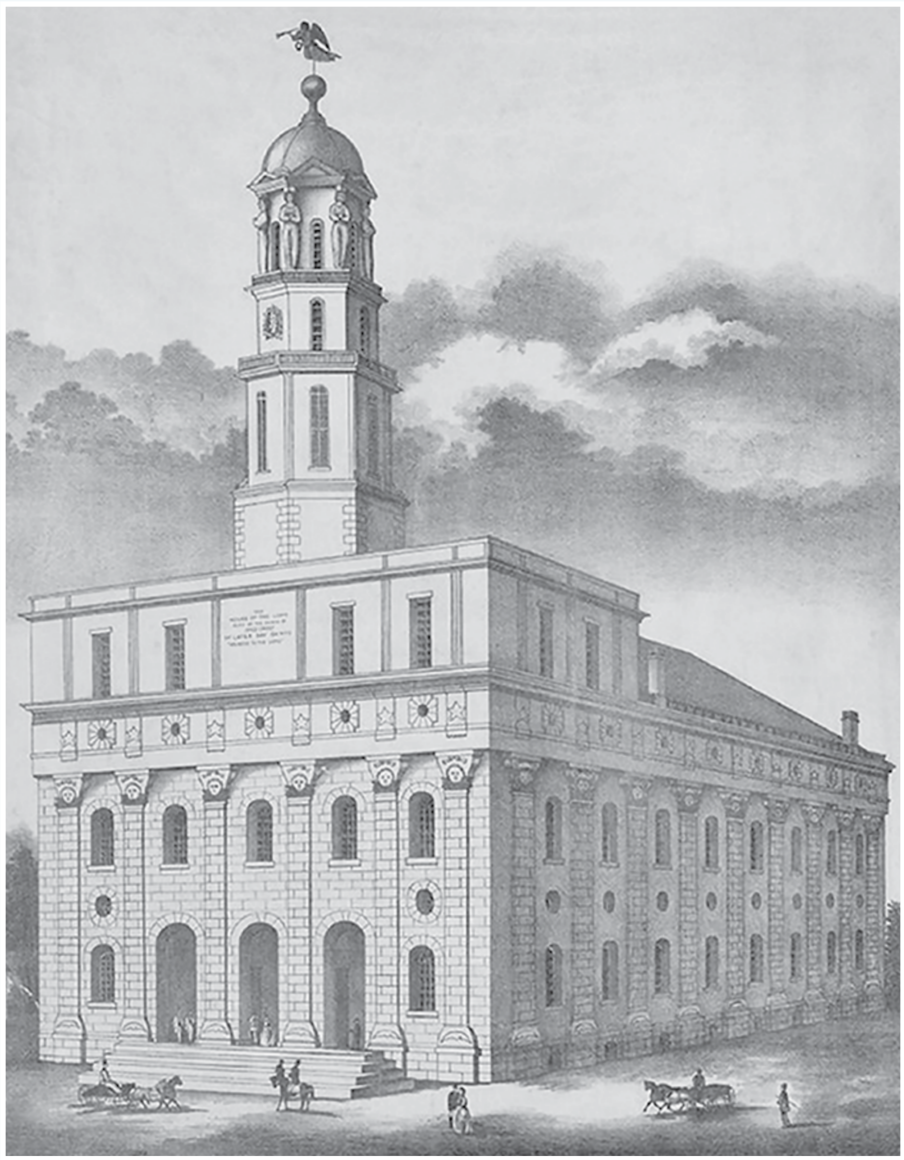

Figure 1: Joseph Smith's original temple, Nauvoo, Illinois, circa 1846.

to Nauvoo to restore order. On June 24, Ford's representatives arrested Smith. Three days later, vigilantes broke into Nauvoo jail, murdering Joseph Smith and his brother, Hyrum Smith.

Under the leadership of Brigham Young and the Quorum of Twelve Apostles, the Nauvoo Latter-day Saints struggled to remain in Nauvoo. The hostility of non-believing residents came to a head in September 1845, when Colonel Levi Williams, who was under indictment for murdering Smith, organized a raid against the Latter-day Saint settlement, burning homes and laying waste to the harvest. Five months later, in February 1846, Brigham Young and his fellow Latter-day Saints began their westward migration to the Great Salt Lake Valley.

EARLY ACCOUNTS OF MOSQUITOES ALONG THE WASATCH FRONT

Complaints about mosquitoes increased when the Saints arrived in Utah. The broods of mosquitoes were considered acts of nature like droughts, floods, crickets, and grasshoppers. Newspapers like the *Deseret News*, *Daily Ogden*, *Salt Lake Tribune*, *The Ephraim Enterprise*, and *Ogden Standard* published numerous stories about the broods of mosquitoes that tormented man and beast.

In 1879, a reporter for the *Ogden Standard* observed that "if Noah had foreseen the future, [and] killed the mosquitoes which took refuge in the ark, he would have rendered some of the strongest words in the English language unnecessary" (Noah 1878). Utah's mosquitoes were as numerous as the "sands upon the seashore" and as large as "sandhill cranes" (Wood River mosquito 1881). In the 1890s, a brood of mosquitoes disrupted work near the City of Bountiful in the Granada Valley. Heavy rains in June had "left behind a host of pests in the shape of clouds of mosquitoes, which make putting up of hay a serious task.

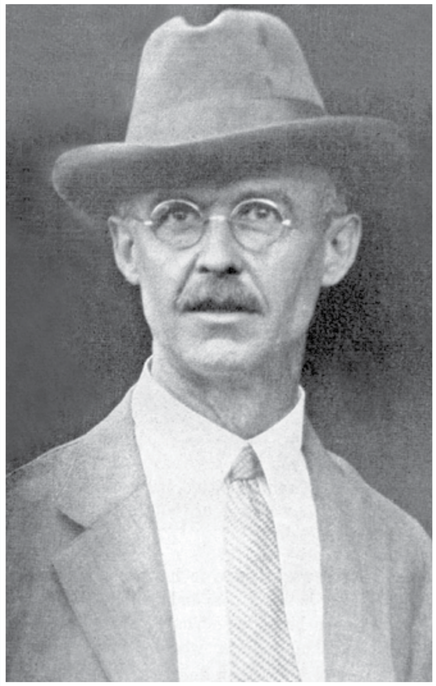

Figure 2: Joseph A LePrince.

In many places, fires have been kindled in the evening in order to protect stock which was almost wild with pain from the bites." (Granada 1894)

LAUNCHING ORGANIZED MOSQUITO CONTROL

In 1919, Utahans launched the state's campaign to reduce the mosquito menace. Theodore Beatty, the state health commissioner, wrote to Rupert Blue, the US Surgeon General, requesting federal assistance in addressing what Beatty characterized as Utah's "perplexing" mosquito problem. Blue dispatched Dr Ralph Tarbett, an MIT educated sanitary engineer and a captain in the US Public Health Service (USPHS), to Salt Lake City. Tarbett, who had led USPHS anti-mosquito work in Little Rock, Arkansas, spent two weeks surveying the situation in Salt Lake City and along the Weber River near Ogden (Sanitary engineer 1919).

During the next three years, Beatty rallied support for mosquito control. In May 1922, Beatty used a trip to Washington, DC, to meet with Hugh Cumming, Rupert Blue's successor as Surgeon General. Upon his return, Beatty told a reporter for the *Salt Lake Tribune* that while in Washington, he briefed Cumming on his "plans to start mosquito control in the Bear River Valley, where public sentiment was aroused to the extent that cooperation was assured." At the end of their meeting the Surgeon General promised "to send one of the best men in the service to Utah."

The mosquito problem in Salt Lake had significantly worsened during Beatty's absence. "In Salt Lake I found the mosquito plague so bad," Beatty explained, that he felt impelled to send a telegram to Cumming declaring, "Hurry up your mosquito expert; badly needed in Salt Lake" (Hurry-up call 1922).

FROM PANAMA TO SALT LAKE: JOSEPH LEPRINCE

A week later, Major Joseph LePrince arrived in Salt Lake City. LePrince, who served as William Gorgas' chief sanitary inspector for fourteen years during the construction of the Panama Canal, was renowned for his anti-mosquito initiatives. Stories about LePrince's prowess as a mosquito warrior abounded. A single episode reveals LePrince's penchant for close observation. When he and Gorgas arrived in Panama, LePrince sought an explanation for the French canal builders' failure. He learned that the nurses in the French hospital treating workers suffering minor complaints brought bunches of wild roses and other flowers to the hospital wards. LePrince determined that *Aedes aegypti* mosquito larvae developed in the vases. The mosquitoes infected the patients with dengue and yellow fever. The nurse's effort to brighten the hospital had caused considerable mischief. With the stroke of a pen, LePrince banned flower arrangements, saving countless lives.

In 1914, LePrince returned to the continental United States and received a commission as a sanitary engineer with the recently formed USPHS (1912).

LePrince's fame grew during World War I. Army officials gave LePrince responsibility for developing mosquito control (anti-malaria work) around military facilities. After the war, he became an advocate of expanding mosquito control across the nation.

In early June, Beatty and LePrince formulated a strategy. LePrince would begin his survey in Salt Lake and move on to the Bear River Valley, "where the mosquito has[d] become such an increasing nuisance as to make life intolerable in some sections for man or beast and to prove a great economic detriment to the region" (US expert 1922).

By mid-June, LePrince had completed his survey of Salt Lake City. The situation was serious. "Indeed," LePrince told a reporter, "it will become more serious from year to year unless something is done. Your silting rivers and your long-continued irrigation without proper drainage have raised the water table to an extent…form[ing] ideal mosquito breeding places." Legislation authorizing the formation of abatement districts was needed. Most important of all, advocates of mosquito control must win the public's support (Eversoll 1922).

LePrince left Utah impressed with Beatty's commitment to fighting the mosquito menace. In February 1923, he reported to the members of the New Jersey Mosquito Extermination Association news of the stirring events that were taking place on the west side of the Wasatch Front. In his report on the *"General Plan for Mosquito Work in the Southern States and its Apparent Results,"* LePrince called attention to Utah:

"To arouse public interest in mosquito elimination the state health officer of Utah writes his messages to people about mosquitoes with mosquitoes. The words are made with the mucilage and mosquitoes are poured on. All his messages are read. And the cartoons referring to mosquitoes are rich and enjoyed" (LePrince, 1923).

Figure 3: Ralph V Chamberlin.

SALT LAKE CITY: THE FIRST ABATEMENT DISTRICT

Beatty's persistence paid off. In 1923, Governor Charles Mabey signed into law a bill sanctioning the formation of mosquito abatement districts, earning Utah the distinction of being the third state after New Jersey (1912) and California (1915) to authorize anti-mosquito work. One year later, the state's first mosquito abatement district formed in Salt Lake City.

The newly formed Salt Lake City Mosquito Abatement District's (SLCMAD) trustees met for the first time on May 19, 1924. The Commission wrestled with the question "what temporary measures" might be taken so late in the season. A week later, the trustees authorized hiring a "competent man" – competency meant owning a car – and paying him $100 a month until the beginning of October. The district, however, lacked the funds needed to begin the work.

Money proved a perennial problem for the district. In 1925 and 1926, the Utah Taxpayer's Association and the Salt Lake county attorney blocked the abatement district's effort to borrow money. By January 1926, the trustees had become "discouraged" (Bright future 1926). The District's chairman, Edward Rosenbaum, acknowledged there was "little chance for any work in [the] abatement of pests this year" (Pest control 1926). Real work did not begin until 1927.

In 1922, LePrince had vowed to return to Salt Lake to review the district's progress once work began. In October 1928, he honored his promise. During his visit, LePrince warned the trustees that it was essential that they fund an entomological survey of the district. He explained that "all of the successful work done in the coastal counties of New Jersey was based on a similar survey and, as you know, more progress has consequently been made in that state in mosquito control than in all the other states combined" (SLCMAD 1928).

Successful anti-mosquito work must be based on science. Accordingly, LePrince, met with the University of Utah's biology department. He hoped to find an entomologist to direct the mosquito survey. The department's head suggested LePrince talk to Ralph Chamberlin, an arachnid specialist, who had considerable field experience and a coterie of talented graduate students.

Before departing, LePrince warned the trustees that "if this study is ignored, then sooner or later your committee may be severely and justly criticized for working blindly and wasting funds because of lack of knowledge of local entomological data" (SLCMAD 1928). The trustees accepted LePrince's recommendation and Chamberlin agreed to undertake the assignment. LePrince promised to dispatch one of his assistants, WE Komp, a Rutgers graduate, to advise Chamberlin. Chamberlin, on his part, assigned a young graduate student named Don Rees to supervise the field work.

DONALD MERRITT REES

Don Rees was the catalyst for mosquito abatement in Utah. Born in 1901, Rees earned his BS (1926) and Masters (1929) degrees in zoology from the University of Utah and eight years later his PhD from Stanford in entomology. Rees' interest in mosquitoes grew out of his work on the survey. Rees based his master's thesis, *"An Investigation on the Mosquitoes of Salt Lake County,"* on the data he compiled during the survey. In 1942, Rees based The Mosquitoes of Utah on the research he began in his graduate studies.

In 1930, after completing his degree, the SLCMAD trustees hired Rees to lead the district's anti-mosquito campaign. Rees held this post until 1937, when he accepted a position as an assistant professor in the University of Utah's biology and zoology department. When Ralph Chamberlin resigned from the SLCMAD's board in 1938, the trustees asked Rees to fill the vacancy. He remained on the district's board for thirty-nine years, until his death in 1979.

THE GREAT DEPRESSION

The 1930s presented tremendous challenges to the mosquito control movement. The Great Depression left millions unemployed, forcing draconian cutbacks in municipal and state appropriations for sanitation. State and local authorities slashed funding for mosquito control. The situation worsened in the fall of 1933. In November 1933, President Franklin Roosevelt authorized the USDA to supervise an exciting initiative in which the federal government would directly employ tens of thousands of workers to do anti-mosquito work through the newly formed Civilian Works Administration (CWA). The CWA and later the Federal Emergency Relief Administration (FERA), and the Works Progress Administration (WPA) employed millions of men to work on mosquito control projects.

The problem was that in many areas, there was no supervision for the work. Engineers designed drainage projects without entomological guidance. Workers dug drainage ditches, but no money was earmarked for maintenance. Worse, some projects damaged sensitive wildlife habitats. Mosquito control's opponents in the United States Biological Survey – later, the US Fish and Wildlife Service) – and citizen groups, such as the National Audubon Society, demanded an accounting. Their objections led to a debate at the Third North American Wildlife Conference in Baltimore in March 1938, on the topic of *"What's Wrong with Mosquito Control."* Fred Bishopp, chief entomologist for the United States Department of Agriculture, and Louis Williams, Jr from the USPHS defended mosquito control. Clarence Cottam, from the Biological Survey, and William Vogt, from the Audubon Society, led the attack.

A NATIONAL DEBATE

Cottam, who hailed from St George, Utah, and had earned his BS and MS degrees from Brigham Young University before completing his PhD at George Washington University, spoke first. "A large percentage of mosquito-control projects," Cottam declared pointing to the CWA, FERA and WPA, "hitherto conducted in this country has been unnecessarily destructive of wildlife" (Cottam et al 1938). The use of oil as a larvicide had caused needless harm. Bishopp and Williams discounted Cottam's charges. "No intelligent person can logically contend," Bishopp declared in his rebuttal, "[that] mosquito control as such is undesirable" (Cottam et al 1938). The debate at the Third North American Wildlife Conference revealed the growing rift between advocates of mosquito control and groups such as the Audubon Society.

Utah escaped much of the fury in large part because of Chamberlin and Rees's work. During the 1929 entomological survey, Rees concluded that the fourteen duck clubs along the east side of the Great Salt Lake were a primary source of pest and nuisance mosquitoes. Ever practical, Rees sought to overcome the antipathy of the gun clubs through careful study and persuasion. In November 1933, the CWA assigned 1000 men to mosquito work.

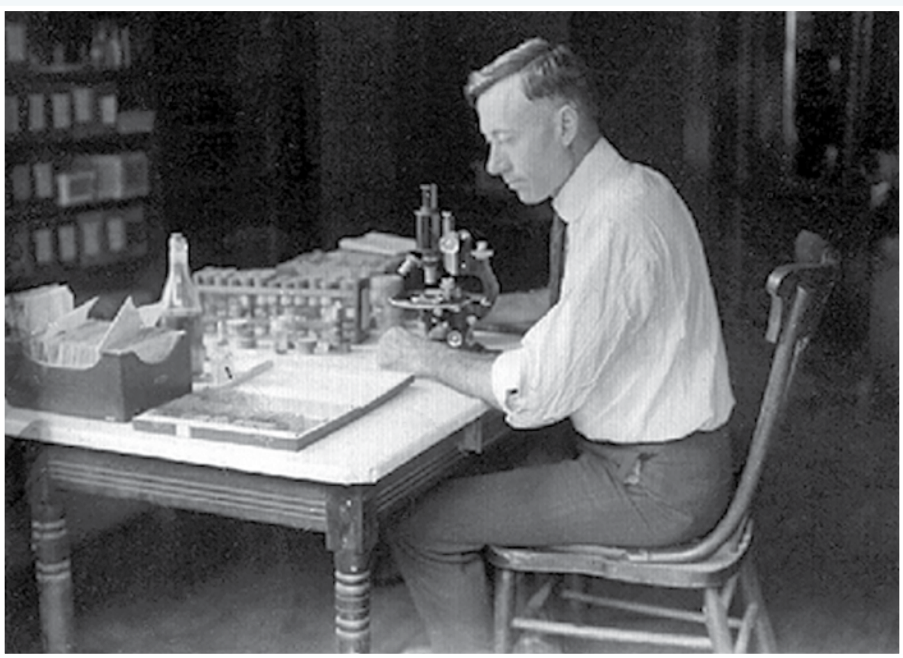

Figure 4: Fred C Bishopp, Chief of Division of Insects Affecting Man and Animals, US Department of Agriculture, 1926-1941.

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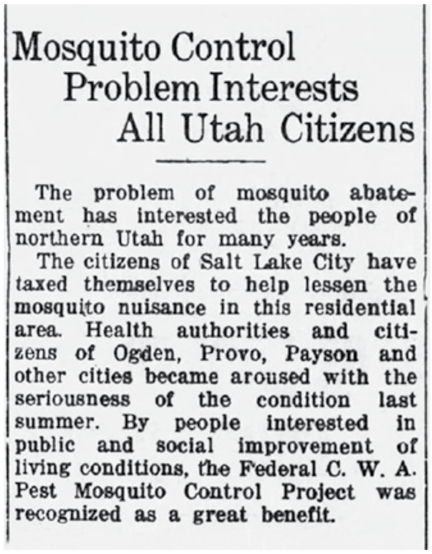

Mosquito Control Problem Interests All Utah Citizens

The problem of mosquito abatement has interested the people of northern Utah for many years.

The citizens of Salt Lake City have taxed themselves to help lessen the mosquito nuisance in this residential area. Health authorities and citizens of Ogden, Provo, Payson and other cities became aroused with the seriousness of the condition last summer. By people interested in public and social improvement of living conditions, the Federal C. W. A. Pest Mosquito Control Project was recognized as a great benefit.

Figure 5: *Box Elder News-Journal* article, January 30, 1934.

Don Rees supervised the work of nearly fifty percent of the CWA workers, making sure that they acted in an environmentally responsible way.

Decades before the concept of integrated pest management (IPM) came into practice, Rees developed a program combining biological, cultural, physical and chemical components. The use of *Gambusia affinis* was a key element in Salt Lake City. In 1927, 50,000 mosquitofish were shipped from California to Utah. The fish, however, perished during the first winter. In 1929, Joseph LePrince sent a second shipment of fish from West Virginia to Utah. These fish died in transit. Two years later, Rees asked LePrince to try once again. In May 1931, LePrince dispatched LM Fischer to Salt Lake. Twelve *Gambusia* survived. Rees placed the fish in an aquarium in the biology department at the University of Utah. The fish thrived. By 1938, when the debate at the Third North American Wildlife Conference took place, LePrince and Rees' fish had become a mainstay in the District's biological control program (Rees 1945).

A year after the Baltimore debate, Rees hammered out a "cooperative plan for mosquito control on the gun club properties west of Salt Lake City [that] has tentatively been accepted by all parties concerned" (Rees 1939). Rees, a life-long hunter and fisherman, possessed a deep sensitivity to wildlife issues and a long-standing relationship with the leaders of Utah's hunting and fishing community. Without federal funds, Rees estimated that it might have taken as much as twenty years to finish the work. "The launching of the Federal plans for [the] employment of large numbers of men," Ralph Chamberlin explained, "made possible the essential completion of this program and its extension in some respects" (Chamberlin & Rees 1935).

WORLD WAR II

World War II profoundly changed the anti-mosquito movement. Concerns about wildlife issues faded as war clouds gathered in the Pacific and Europe. Two months after Pearl Harbor, US Surgeon General Thomas Parran assigned Louis Williams, Jr and Stan Freeborn the task of organizing the program to protect military personnel and war workers from the malaria menace. In April, Parran officially changed the organization's name to Malaria Control in War Areas (MCWA).

MCWA's goal was to protect service members from contracting malaria while stationed in areas where the disease was endemic. In 1942, Don Rees noted that there was evidence that malaria was being introduced into Utah by returning veterans hospitalized in Brigham City at the Bushnell General Hospital. Rees feared that mosquito-borne diseases might spread beyond the hospital's wards to near-by communities. *Anopheles maculipennis freeborni*, a competent disease vector, was commonly found in Box Elder County (Rees 1944).

By 1944, the potential for the introduction of malaria into Utah's civilian population had heightened. Near Ogden, several large military reservations served as internment camps for prisoners of war. There was a real possibility that malaria might spread to the local population. Rees argued the challenges facing mosquito control required close cooperation between civilian and military authorities.

When Utah senator Elbert Thomas learned of the outbreak of malaria in Brigham City, he rallied congressional support for what became Public Law 410. Thomas told his colleagues that the law was needed because "there are coming back to our country from all parts of the world men afflicted with malaria and other sicknesses" (Humphreys 2001).

Utah's MCWA workers played a critical role in alerting the nation to the threat posed to civilian populations from returning military personnel. Public Law 410 represented a 180-degree shift in the goal of MCWA (Mountin 1944). In 1945, the USPHS launched the Extended Malaria Control Program (EMCP). The first step was to establish a "group of mobile units" strategically placed to respond to malaria outbreaks near military reservations or hospitals (Freeborn 1944). On July 1, 1946, the Surgeon General transferred responsibility for the EMCP to the newly created Communicable Disease Center (CDC) based in Atlanta, Georgia.

A NATIONAL ANTI-MOSQUITO ORGANIZATION

The World War led to the recognition of the need for a national anti-mosquito organization. In December 1942, the editors of the Eastern Association of Mosquito Control Workers (EAMCW) journal, *Mosquito News*, met to consider the journal's future. Ostensibly, the topic was what should be the journal's format. On December 12, 1942, Robert Glasgow, New York's state entomologist, wrote a letter to Tommy Mulhern, who was a leader of the New Jersey Mosquito Extermination Association. Glasgow wanted to know what Mulhern thought of the idea of forming a national anti-mosquito organization (Glasgow 1942).

Figure 6: Lewis Nielsen.

The challenge was finding a way to bridge the gap between the eastern, midwestern, southern and western members of the anti-mosquito movement. Utah supplied the link. In the 1930s, Ralph Chamberlin and Rees were regular participants in the NJMEA annual meetings. Simultaneously, Rees had cultivated a close working relationship with mosquito workers in California. Rees' temperament, scientific acuity, sensitivity to environmental questions, and contacts proved indispensable in the formation of the AMCA. Rees was a member of the AMCA's Executive Committee in 1947-48 and chairman of the association's Interim National Board in 1949. In Utah, Rees' talent as an institution builder led to the formation of abatement districts in Box Elder County (1945), Magna County (1946) and Weber County (1947). In 1948, Rees was instrumental in the formation of the Utah Mosquito Abatement Association (UMAA). He served for two terms as the association's president. Don Rees' contribution to the national mosquito control movement was recognized when he was elected president of AMCA in 1952.

THE LEGACY OF DON REES

Don Rees' most significant achievement, however, was as a teacher. In his four decades at the University of Utah, Rees taught a cohort of students who would make significant contributions to the development of mosquito control. Four of Rees' students would later serve as president of the AMCA: Jay E Graham, (1966-67), Glen C Collett (1972-73), David Bruce Francey (1976-77) and Lewis T Nielsen (1977-78).

Lewis (Lew) Nielsen and Glen Collett exemplify the scholarly and professional sides of Rees' multifaceted career. Rees guided both men's undergraduate and graduate studies. Nielsen, who was born in 1920, graduated from the University of Utah in 1942 and served during World War II as an officer in the Army Medical Service Corps. After the war, he returned to Utah, where he earned his PhD in zoology. In 1955, Nielsen joined Don Rees as a member of the biology faculty, where he served as a professor until retiring in 1989. During his thirty-four years as a professor, Nielsen published more than 90 scientific articles, founded and edited *Mosquito Systematics*, and served as the doctoral advisor of a host of graduate students. After his retirement, Nielsen remained active in Utah mosquito affairs and continued his work as a taxonomist, publishing *An Identification Guide to the Mosquitoes of Utah* with Robert Brand and Glen Collett in 2001 and *The Mosquitoes of New Mexico* with Thomas Wolf in 2007.

Glen Collett, who was born in 1926, and Lew Nielsen met in the late 1940s, when they shared an office at the University of Utah working as Rees' assistants. During his undergraduate and graduate studies, Rees arranged for Collett to work as a seasonal employee at the SLCMAD. In 1951, Rees secured Collett a post in California as the entomologist for the Tulare Mosquito Abatement District. Between 1952 and 1954, Collett served in the US Army as a medical entomologist in Korea. After

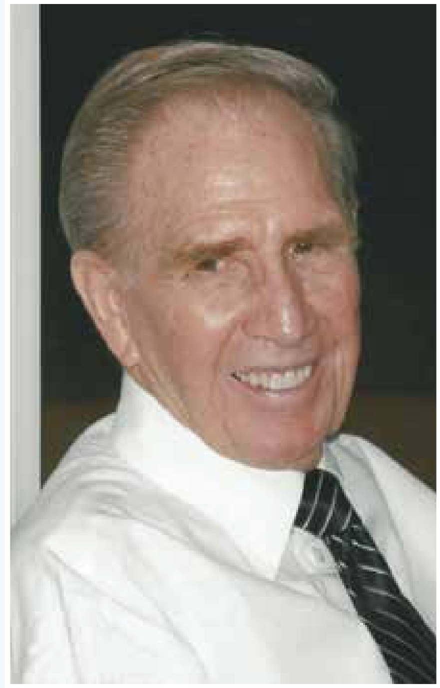

Figure 6: Glen Collett.

his discharge, he returned to Utah and served as a field supervisor for the SLCMAD. A year later, Collett assumed responsibility for the district. After his retirement in 1987, Glen Collett served for eighteen years as the executive director of the UMAA.

MOSQUITO CONTROL IN THE TWENTY-FIRST CENTURY

The history of the Beehive State's war against the mosquito menace is rich and varied. From the malarial swamps in Nauvoo to the salt marshes of the Great Salt Lake, mosquitoes have played an important role in Utah's development. In 2023, Utah will celebrate the centenary of the passage of legislation allowing the formation of mosquito abatement districts. Substantial challenges face mosquito control in the 21st century. The threats posed by invasive species, emerging pathogens, increased urbanization, and declining revenues make clear that the road ahead will not be easy. The quality that defines the organized mosquito control movement in Utah is collegiality. For one hundred years, men and women have worked in Utah to protect the public from pest and disease-bearing mosquitoes. Their commitment has made a substantial contribution to innumerable lives.

In 1922, Dr Joseph Porter, the first president of the Florida Anti-Mosquito Association and state's first health officer, told one hundred and fifty men and women gathered in Daytona, Florida, that waging war on the mosquito menace required commitment. To succeed mosquito warriors must "Keep everlastingly at it" (MacDonell 1932). Joseph LePrince, Theodore Beatty, Ralph Chamberlin, Don Rees, Lew Nielsen and Glen Collett established a sound foundation for mosquito control in Utah. The future of mosquito control in the Beehive State depends on their successors' commitment to science, sensitivity to the environment, and determination to "Keep everlastingly at it."

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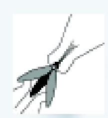

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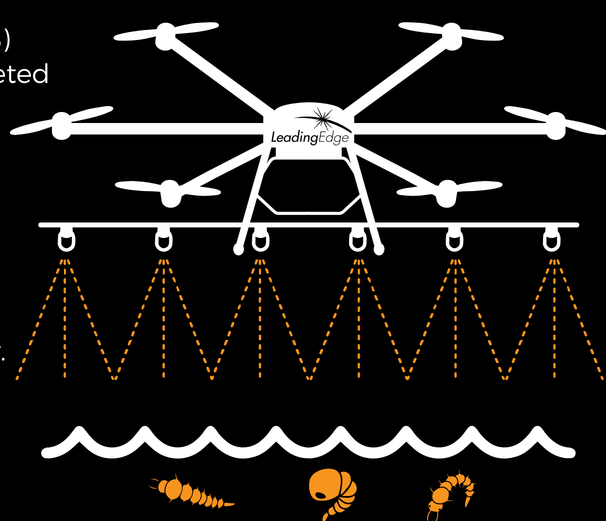

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Utah is the Place Where the Ties Bind: UMAA + AMCA

by Sammie Lee Dickson

The 2021 Annual Meeting of the American Mosquito Control Association (AMCA) is scheduled to be held virtually in Salt Lake City, Utah. As with all states that host an Annual AMCA Meeting, the Utah Mosquito Abatement Association (UMAA) is excited to share some of its long history. When the New Jersey Mosquito Control Association hosted the annual meeting in 2013, they were able to celebrate 100 years of organized mosquito control, and highlight the individuals, commissions, and state association that has been a leader in the mosquito control industry for the past century. Utah was the third state to pass legislation allowing for organized mosquito control in 1923, thus the 2021 Annual Meeting of the AMCA is a chance to highlight almost 100 years of organized mosquito control in Utah. UMAA members have had vital rolls in the formation and success of the AMCA for many decades. Likewise, the AMCA has played an enormous role in the success of mosquito control in Utah and the UMAA.

As a smaller organization located away from either coast, in a state with a modest current population of 3.28 million and vast deserted open spaces, it would seem that Utah is an unlikely candidate to have contributed to, and received so much from, the AMCA. The key to the ties between the two organizations begins before the AMCA (1935/1944) and UMAA (1948) were established.

DON MERRILL REES

In 1930, the University of Utah hired a young instructor for the Zoology Department. This man, who would later be known as the 'Father of Mosquito Abatement in Utah,' was Dr Don Merrill Rees. Don Rees began his interest in mosquitoes in the 1920s while earning

Figure 1: Don Merrill Rees.

his bachelor's and master's degrees at the University of Utah. While working as an instructor at the University, Rees also served as the supervisor of the Salt Lake City Mosquito Abatement District from 1930 through 1937. During those years, he was able to combine his love for the study of mosquitoes with their abatement. It was also during this time that he was concurrently working towards his doctorate degree, which he received from Stanford University in 1937.

The Salt Lake City Mosquito Abatement District (SLCMAD) was formed in 1923 as a way to protect the citizens of Salt Lake City from the hoards of mosquitoes that emerge from the freshwater marshes that occur just a few miles west of the Utah Capitol building. Dr Rees, as was the case with so many other mosquito workers in the 1930s, was frustrated with the lack of 'tools' to abate the mosquitoes. Rees began attending the annual meetings of the New Jersey Mosquito Extermination Association to share his experiences in Utah and learn new techniques for mosquito control. The Eastern Association of Mosquito Control Workers (EAMCW) was organized in 1935. Rees became an early member of that association and became a guiding force when, in 1944, the EAMCW was renamed the American Mosquito Control Association. Rees served on the AMCA's Executive Committee during 1947-48, and as the Chairman of the Interim National Board during the organization of the constitution and

Figure 2: Don Rees (*second from left*) with AMCA Presidents, circa 1963.

Figure 3: Jay E Graham.

bylaws in 1949. In 1952, Dr Rees became the first of six UMAA members that have served as President of the AMCA. In 1973, he received AMCA's highest honor, the Medal of Honor, along with his good friend Thomas Mulhern, who many folks regard as the founder of modern mosquito control. Sadly, Rees passed away in 1976. JD Gillett presented the first AMCA Memorial Lecture in 1979 to honor Dr Don Merrill Rees, entitled, *"Out for Blood: Flight Orientation Upwind & in the Absence of Visual Clues"* (Gillett 1979).

JAY E GRAHAM

The second Utahan to serve as AMCA President was Jay E Graham, in 1966. Graham began his interest in mosquito control while attending the University of Utah. He received a master's degree in entomology under the direction of Dr Rees, and was manager of the South Salt Lake County Mosquito Abatement District from 1953 to 1987. Graham took over thirty overseas consultant trips with the World Health Organization (WHO) and was a member of the Expert Committee of Filariasis for the WHO between 1973 and 1983. He was able to share much of his international experiences and knowledge with the AMCA through some 90 publications, many of which were published in *Mosquito News*. He was awarded the AMCA Medal of Honor in 1986. One of Graham's publications, in the June 1964 issue of *Mosquito News*, *"Surveillance for Western Equine Encephalitis,"* (Graham & Collett 1964) was co-authored by the next Utahan to serve as AMCA President, Glen C Collett.

GLEN C COLLETT

Glen C Collett, a lifelong native of Utah, was known by many in the AMCA as a 'gentleman's gentleman.' Glen would have shied away from such praise, but yet I heard him use that term when describing his good friend Paul Hunt from Florida. As a member of AMCA for over 50 years, there were not many AMCA members that he did not know. When Glen attended annual AMCA meetings, he visited with everyone, remembering their names, details about their families, and offering positive words of wisdom. While I never heard Glen share how he became interested in mosquito control, a good guess would be that as another student under the tutelage of Dr Rees, earning a bachelor's (1949) and master's (1951) degrees, it would be hard not to become a convert to mosquito control and research. Glen was an ambassador for both the UMAA and the AMCA. As the manager of the SLCMAD from

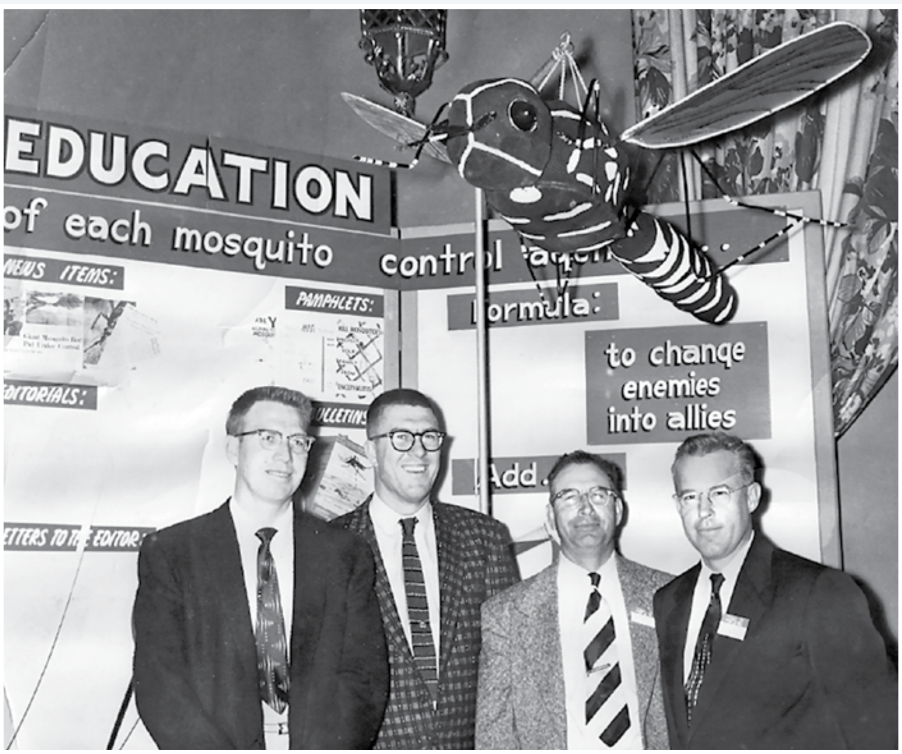

Figure 4: Glen Collett and Jay Graham (*on left*), circa 1965.

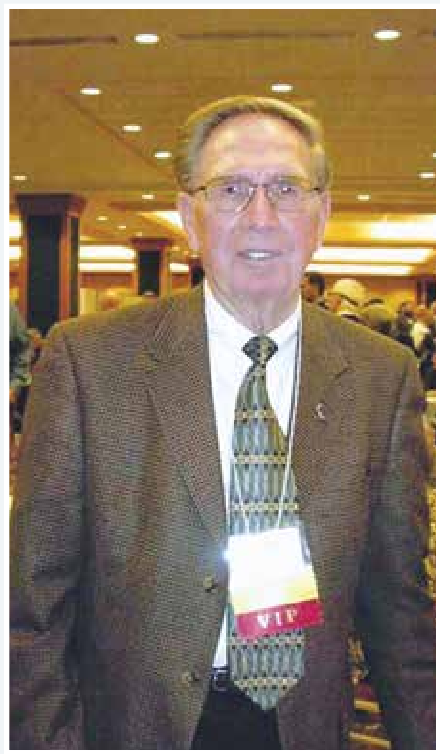

Figure 5: Glen Collett.

Figure 6: Lewis Nielsen (*left*) and Glen Collett on a collecting trip at the southern tip of the Great Salt Lake, circa 1950.

Figure 7: Lewis Nielsen, 1990.

1955 until 1987, Glen never missed an annual meeting of either the Mosquito and Vector Control Association of California or the AMCA. Glen also never missed an opportunity to invite other mosquito workers to attend the UMAA Annual Meeting and was a fantastic ambassador for the UMAA during his entire career. In 1972, Glen served as President of the AMCA. In 1990, he was recognized by the AMCA for his many contributions by being awarded the Medal of Honor. In 1998, AMCA made two of its long-standing members, Gene Gerberg and Glen Collett, Honorary Members of AMCA. Glen retired from his full-time job as manager of the SLCMAD in 1987, but remained active for 20 years following as the UMAA Executive Director.

LEWIS T NIELSEN

The fourth Utahan to be President of AMCA was Dr Lewis T Nielsen in 1977. Lew, like Glen Collett, was also a lifelong native of Utah. Dr Nielsen's lifelong love for the study of mosquito biology and systematics evolved serendipitously. After failing a junior high school algebra class, he was kept after school writing equations on a blackboard. At about this time a teacher by the name of Mr Archibald took an interest in him and urged him to think seriously about his future, and to continue his education. It was at this early age that Nielsen began developing an interest in natural history. While earning a nearly straight-A average in high school, he took botany and zoology classes, which further fueled his interest in natural history. After graduating high school at the age of 17, he entered the University of Utah in the fall of 1937, which began a lifelong association with the "U." While working his way through his undergraduate degree, he was assigned a position in the Zoology Department pinning mosquitoes for Dr Don M Rees. That led to a summer job at the SLCMAD and ultimately his life's work with mosquitoes. His three degrees in Biology included a BS (1941), MA (1947) *"On the Biology of* Aedes dorsalis," and PhD (1955) on *"The Taxonomy, Biology, and Control of the Rocky Mountain* Aedes *Mosquito Species."* As a professor of biology, Nielsen had 23 students who received their doctorates, and 17 who received their master's degrees under his guidance. Nielsen seldom had a student that he did not send to Glen Collett to apply for a summer job as a field technician at the SLCMAD. Dr Nielsen believed that all of his students that did research under him should get practical experience in mosquito control. Lew made sure that his students attended and presented talks at the UMAA and AMCA Annual Meetings.

Lew's favorite mosquitoes were the dark-legged *Aedes* snow pool species. If anyone in Utah had a question about the identification of any mosquito, Lew was the one to go to. Thus, it was no surprise when, in 1979, Lew took over as editor for *Mosquito Systematics*. For those who don't remember, *Mosquito Systematics* was an AMCA publication from 1969 until 1995, an academic journal for the serious mosquito systematist and taxonomist. Lew remained the sole editor through 1992, when Dr Ralph Harbach joined him as co-editor. Lew received a number of awards from the AMCA, including the Medal of Honor (1988), Honorary Member (1994), Belkin Award 2000, and presentation of the Memorial Lecture in 1997 to honor Stanley J Carpenter (Nielsen 1998).

SAMMIE LEE DICKSON

Sammie Lee Dickson was the fifth person in Utah to become President of the AMCA, in 2001. However, unlike the first four he was not a native to Utah. He grew up in Colorado, completing his BS in Biology at Colorado State University – Pueblo in 1976. Fortunately for him, Professor Jay Linam took an interest in him and

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Figure 8: Ary Faraji (*left*) and Sammie Dickson, 2015.

suggested he pursue a master's degree in entomology. He went to Missouri State University (Springfield) where his major professor Dr Steven Jensen, a mayfly expert, assigned him the master's project on the biosystematics of the mosquitoes of Green County, MO. This was quite a surprise to Sam, as he knew absolutely nothing about mosquitoes, but was relieved not to have to work on those boring mayflies. Sam completed his MS in Biology in 1978 and was set to return to Colorado to work in the local steel mill in Pueblo. Dr Jensen suggested that he instead should go study under Dr Nielsen at the University of Utah. At this time, Sam had no idea both Jensen and Linam had received their doctorates at the University of Utah, and that Linam's major professor had been Dr Lewis T Nielsen. In 1983, Sam received his doctorate for his work on a Great Basin mosquito, *Aedes niphadopsis*. The eggs of this single-brooded mosquito species hatch in January, with the adults emerging in April. This was a huge benefit to Sam as he was able to do his field research in the winter and spring, and work for Glen Collett at the SLCMAD during the summer and fall mosquito season.

After graduation from the University of Utah, Sam was hired by Glen Collett as Assistant Manager of the SLCMAD. Sam took over as the Manager of the SLCMAD in 1987 when Glen Collett retired, and he remained in that position until his retirement in 2016. Sam served as the West Central Regional Director of AMCA from 1999 until 2001, stepping down to run for election as the AMCA President. Sam ran for president three times, the first time losing to Dr Robert Novak and the second time to Dr Gary Clark. As a side note, Dr Novak was in the same high school graduating class as Sam's sister. Additionally, he had received his MS in 1971 under Dr Lewis Nielsen, his major professor at the University of Utah. Sam received several awards from AMCA: Presidential Citation (1996), Medal of Honor (2012) and Honorary Member (2017). For the 2021 AMCA Annual Meeting, Sam will be co-authoring the Memorial Lecture with Dr Mark Blackmore honoring Dr Lewis T Nielsen, the second Utahan to be honored with the AMCA Memorial Lecture.

ARY FARAJI

This year's AMCA President, Dr Ary Faraji, is also not a native Utahan, but feels completely at home in his adopted state. Ary was born in Iran and spent the bulk of his young life in California. He was interested in natural history from a young age and was hoping to become a wildlife biologist studying bighorn sheep and mountain lions in California. However, after one of his undergrad professors, Dr Bob Neher, who was also a Trustee for the San Gabriel Valley Mosquito and Vector Control District in southern California, suggested he apply for a seasonal position with them, he was hooked. He received his BS as a double major in Biology and Theology, and then went on to Rutgers University to obtain his master's degree under the tutelage of Dr Wayne Crans. He acquired a position as the Superintendent of Mercer County Mosquito Control prior to finishing his master's – and began his PhD on a part-time basis under Dr Randy Gaugler, while working full-time. While at Mercer County, he played an active role with the New Jersey Mosquito Control Association. Dr Dickson had met Ary while he was a master's candidate and was so impressed with him that he followed his career in hopes of recruiting him eventually to the SLCMAD. Ary remembers it differently, as his love for the outdoors and family ties in the area through his wife made him the actual pursuer of the job in Salt Lake. Nevertheless, Ary became the Assistant Manager of the SLCMAD in 2014 and took over as Manager of the SLCMAD

Figure 9: Gary Hatch (*left*) and Ary Faraji (*right*) presenting Sammie Dickson with West Central Mosquito & Vector Control Association award, 2016. Photo by Peter Connelly

Figure 10: *Left to right* - Lewis Fronk, George Knowlton, Glen Collett, Jay Linam and Jay Graham, circa 1965.

in 2016 upon the retirement of Dr Dickson. As the sixth AMCA President from Utah, Ary is still building on those "ties that bind" and is fully converted as a native Utahan now.

GARY HATCH

Gary Hatch served on the AMCA Finance Committee from 1996 through 2002 and then as its chairman from 2009 through 2010. In 2011, he took over as the AMCA Treasurer from Allan Inman and has remained in that position to the current time. Gary started his mosquito career with the Box Elder Mosquito Abatement District (MAD) as a field technician from 1977 through 1982, and later worked as a field technician for the SLCMAD (1983-1986) while attending the University of Utah. Gary became the Assistant Manager of the SLCMAD in 1987 and held that position until 1992, when he became the Manager of the Mosquito Abatement District-Davis. He remains in that position today. Gary served on the AMCA Board of Directors as the West Central Regional Director from 2002 through 2008. Dr Dickson and Gary were the key UMAA people when the AMCA Annual Meeting was held in Salt Lake City in 1997. This was a time right after an Executive Director of AMCA had nearly bankrupted the association, and the management of the association was in flux. Gary and Sam spent many hours recruiting vendors and contributors for the annual meeting. Many of the membership may not know that the bulk of AMCA's income came from the annual meeting. The fate of the association literally depended on the 1997 Annual Meeting being a financial success. Thanks to Gary's hard work and the generosity of our many members in industry, the meeting was a financial success. While Gary has not yet served as an AMCA President, it is only a matter of time before that happens.

LEWIS E FRONK

Another notable Utahan who played a key role in tying the two organizations together was Lewis E Fronk (1925-2000). Fronk served as the Manager of the Weber MAD in northern Utah. He received both the Meritorious Service Award (1975) and the Presidential Citation (1980) from AMCA.

2021 AND BEYOND

The UMAA has hosted the AMCA Annual Meeting four times – 1952, 1959, 1980 and 1997 – and is scheduled to host the virtual 2021 Annual Meeting in Salt Lake City as well. Anyone who has ever hosted an AMCA Annual Meeting, and especially those who have worked to host a meeting prior to the AMCA having a professional management team, knows that it takes an army of locals to make the meeting a success. It is impossible to know and list all of the UMAA volunteers through the years that have helped tie UMAA and AMCA. However, we are grateful for the ties that have bound our two associations over the last century, and we look forward to the next 100 years!

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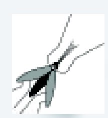

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When World War II Found Brigham City: The Creation of the Box Elder Mosquito Abatement District

by Tyson Packer

Shortly after the United States entered the World War II arena, federal agents began scouting the Intermountain region of the western states for a suitable location of a military hospital. The requirements of the federal government were many in terms of the needs of this future facility, and several cities were examined that had the potential to meet those criteria. The primary focus was finding a location that would serve injured soldiers from the western states of Idaho, Montana, Utah, Nevada and Arizona, allowing a close proximity for families to visit those who were recovering.

Word spread quickly through the small Utah towns of Price, Cedar City, and Brigham City about their chances of being chosen. A 1,500-bed military hospital would certainly mean a massive boon for any local economy and a much-welcomed alternative to the previous decade of depression. Local leaders from Box Elder County, in which Brigham City is the county seat, and surrounding communities lobbied heavily for the bid, citing their location's ample water supply, electrical access, and highly able workforce. When the bid was awarded to Brigham City, the frustration from the losing cities was tremendous, with some even suggesting the seceding of their counties from the state of Utah! Ultimately, the new location for the hospital was inland, safe from the wartime vulnerabilities of the Pacific coast, adjacent to an especially important network of railroads, and central to the surrounding intermountain states.

Construction of the hospital began almost immediately in the spring of 1942. Laborers were brought in from different states and many were summoned from the local community. In six months, the nearly 250-acre site was transformed from orchards and farmland to a small city complete with 60 buildings, a fire station, a sewage treatment plant, a theater, bowling alley, swimming pool and many amenities to support the staff and patients. The most modern technology available was deployed throughout the entire location. The hospital was given the name of Bushnell, honoring the late Colonel George E Bushnell, a specialist in tuberculosis. Injured soldiers from the battlefronts in Europe and Asia immediately began to flood into Brigham City.

The Bushnell Hospital specialized in several areas of patient recovery, some of which bore tremendous impacts throughout the nation and the world. Soldiers arriving at the hospital with infections were given penicillin, a relatively new drug in the trial stages. The US government chose Bushnell as the first place to research its effectiveness on mild and extremely severe infections alike. The hospital also took in many military personnel who had lost arms or legs on the battlefront. The amputee recovery and rehab program not only helped those who had lost limbs to heal physically, it also focused on mental recovery and training for their return to civilian life and the workforce. Major advancements in prosthetics were pioneered at Bushnell during this period. The hospital also specialized in maxillofacial surgery, plastic surgery, neuro-psychiatric and neurosurgical cases, and training for doctors and nurses heading out to the battlefield.

Figure 1: US Soldiers who lost limbs during WWII were sent to Bushnell General Hospital, Brigham City, Utah for recovery and rehabilitation. Photo courtesy of US National Library of Medicine

There was one aspect of the hospital that was a catalyst for concern in the community. American soldiers were being sent from the Pacific Theater to Bushnell to recover from, and receive therapy for, tropical diseases, primarily malaria. Ward 26 was a location at the hospital designed specifically for quarantining soldiers infected with tropical diseases. Being one of three hospitals in the United States that were experimenting with treatments for malaria, staff took extra precautions to prevent any spread of malaria through the hospital or into the community. Fortunately, by this time, the involvement of mosquitoes in the transmission of malaria had been deciphered through the pioneering works of Charles Laveran, Ronald Ross, and Giovanni Grassi, amongst others. It was no longer perceived that "*mala aria*" was simply "bad air." Patients lived and slept inside mosquito nets that separated them from potential contact with mosquitoes from the area. Aside from the quarantined servicemen, hometown soldiers would soon be returning from the warzone and could also be carriers of the malaria parasite. Even with the measures taken to contain the spread of malaria, savvy members of the community knew the potential for a catastrophic outbreak was not only feasible, but the geography and ecology of the area made it very much a reality.

Box Elder County lies at the northern end of the Wasatch mountains in Utah, butting up against the southern border of Idaho. The Great Salt Lake lies in the center of the massive county, with 60% of its body contained within Box Elder. The Bear River is one of the largest contributors to the Great Salt Lake, with its delta only a few miles west of Brigham City. Box Elder County is home to a staggering 550,000 acres of wetlands, most of which are fed as a direct result of the Bear River or the several hundred miles of canals it feeds. All water in the valley essentially flows into the Great Salt Lake, but not before it is captured for agriculture, flood irrigation, or filling lakes and impoundments for waterfowl management. Endlessly flooded saltgrass fields and wetlands filled with some of the greatest larval habitat in the country have borne staggering amounts of mosquitoes from all corners of the valley. Long before Bushnell Hospital came to Brigham City, the area struggled with the impacts of tremendous mosquito populations and was long overdue for a county-wide mosquito abatement program.

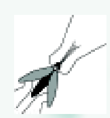
Box Elder County leaders were aware that the western malaria mosquito, *Anopheles freeborni*, was found plentifully from early March to late October. Making their winter homes in log piles, sheds, culverts, and about any other place with moderate shelter, they are early risers in the spring, looking for a bloodmeal right away. Their numbers ebb and flow through the summer, but host-seeking activity picks up just before the cold weather sets in. For the many residents of WWII-era Brigham City, having infected malaria patients in the city and a competent mosquito vector in abundance was a risk that they were not willing to take. They knew that although the warfront was thousands of miles away, a threat that was just as ominous had returned with their soldiers. Oftentimes throughout history, mosquitoes and disease have been responsible for more deaths than battle itself. The reality of that fact wasn't just across two oceans anymore; it had found Brigham City.

County leaders began a campaign to encourage the creation of a mosquito abatement district to not only control the *Anopheles* species, but all other potential vector and nuisance mosquitoes. They enlisted the help of legal experts and entomologists in preparation for necessary steps for setting up an abatement district. Both Dr Don M Rees and Dr George F Edmunds, Jr offered their support and expertise in the establishment the new district. Edmunds, a renowned expert on mayflies and a professor at the University of Utah, proposed several benefits of mosquito control in Box Elder, but focused on the malaria concern. He stated *"In the Brigham area,* Anopheles freeborni *is abundant. This mosquito is known to be a first-class carrier of malaria. Under such conditions the locality is potentially malarious and may only need the introduction of human carriers who are exposed to anopheline mosquitoes. Post-war conditions in Europe have repeatedly produced such new foci of infections."*

Rees, known as the "Father of Mosquito Abatement in Utah," was a major force in establishing numerous mosquito abatement programs throughout Utah, offering support, knowledge and assistance to many in the mosquito control field. Dr Rees was also a professor of entomology at the University of Utah, and his impact is still felt in the Utah Mosquito Abatement Association, an organization he created. He stated in a letter to the citizens of Box Elder, *"This is a public service that all progressive citizens are going to demand in the future just as they insist upon proper sewage disposal, pure water, food and other sanitary and health measures."*

On May 17, 1944 the county commission ordered that because of public necessity and welfare, a mosquito abatement district be created using the boundaries of Box Elder County. It became only the second mosquito abatement district in Utah, after Salt Lake City Mosquito Abatement District. With help and oversight from Rees and others, a new manager was hired and trained to run the massive district. Records show that right from the start, there was a concern for environmental impact and use of integrated pest management to lessen the risk of mosquito-borne illness and improve the quality of life for the citizens of Box Elder.

The Bushnell hospital closed immediately following the war, but the impact it had on the community is still present. Nearly 76 years later, the Box Elder Mosquito Abatement District has carried on the tradition of providing safety to its citizens through the most effective and science-based methods of mosquito control. Although they are now just memories of the past, World War II and Bushnell Hospital were the catalysts that allowed for the residents of Brigham City and Box Elder County to have an improved quality of life and a better community in which to live for generations after.



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Discovery of Cache Valley Virus in Utah

by Greg White

Not long after the end of World War II, the United States set its sights on improving life for all American citizens. The scourge of malaria had been identified as a major health issue, and in 1946 the Communicable Disease Center was created from its predecessor, the Malaria Control in War Areas program (CDC 2019). This small organization would later change its name to the Centers for Disease Control and Prevention (CDC), placing its headquarters in Atlanta. The reason for being located in Georgia, and not in Washington, DC like other federal institutions, was that Atlanta was in the heart of the malaria endemic region of the country (CDC 2018). The primary focus for employees at this new agency were entomology and engineering. Nearly 60% of the staff were involved in mosquito abatement and habitat management. By 1951 malaria was essentially eliminated from the US, but other vector-borne diseases continued to affect its citizens (CDC 2018). As more diseases and health issues were added to the charge of the CDC, mosquito-borne diseases and mosquito control remained a large part of its focus.

In the 1950s there were four branches of the CDC that were dedicated to vector-borne diseases, each with different areas of emphasis (CDC 1958). The Technology Branch had a mission stated as:

Conducts investigations on the natural history of communicable disease, including the ecology of hosts, vectors and etiologic agents. The Branch develops methods, materials, and equipment for the use in their control. It investigates the resistance of insects to insecticides. It studies the health hazards of the various pesticides and devises ways to preclude danger to humans. Technical assistance to States in the form of demonstration and consultation is provided to bridge the gap between development and disease control procedures and their practical application. Also, the Branch furnishes disaster and epidemic aid to States.

One field station of the Technology Branch was located in Logan, the home of Utah State University. Logan is in Cache Valley, which is the name of the area and the county. It is north of Salt Lake City and the county borders Idaho, but the valley itself extends into parts of southern Idaho, around the city of Preston. The Logan Field Station Technology Branch of the CDC carried out many studies in the mid-1950s, such as determining the blood feeding habits of mosquitoes; determining peak biting activity for *Culex tarsalis*; identifying hibernation sites for *Cx tarsalis* mosquitoes in areas without mines, caves, or cellars; developing and testing pesticide application equipment for dispersing granules to flooded fields; and determining residual pesticide longevity under field conditions. There were a number of test plots in Cache Valley used to study pesticides on mosquitoes (CDC 1958).

In the fall of 1955, a small outbreak of Western equine encephalitis virus (WEE) occurred in horses in Cache Valley. This led to a study in 1956 to investigate the mosquitoes in Cache Valley to determine what viruses they carried, mosquito infection rates, the percentage of horses and humans with antibodies to WEE and St Louis encephalitis virus (SLE), and additional studies to identify factors important to the spread of arboviruses. Dr Preston Holden and Dr Archie D Hess were the key investigators who tested the field collected mosquitoes for arboviruses. Hess was stationed at Logan as part of the Technology Branch. He would later go on to serve as the director of the CDC laboratory in Fort Collins, Colorado and would be elected as the first president of the West Central Mosquito and Vector Control Association. Holden was from the Greeley Colorado Field Station, which was part of the Epidemiology Branch of the CDC. The mission of the Epidemiology Branch at this time was:

Renders assistance in emergencies and conducts investigations relative to the occurrence of communicable diseases throughout the nation. Through this Branch the CDC maintains national

Figure 1: An aerial view of the Cache Valley region shows the Wellsville Mountains in the background.

surveillance of these diseases, analyzing morbidity and mortality statistics as a guide to operations. Recruitment and training of professional personnel as epidemiologists contributes materially to public health programs in general, as well as to the CDC program. Field epidemiologic and epizootiologic investigations lead to development of new and improved disease control techniques. Upon request from State Health Departments, epidemiologic assistance is provided in local outbreaks of communicable diseases.

Mosquitoes were trapped, sorted and grouped into pools for virus testing. As was common at the time, mosquitoes were tested for arboviruses using weanling mice. The procedure involved grinding mosquitoes in a saline serum diluent containing antibiotics and inoculating young mice via the intracerebral route. One pool of 50 *Culiseta inornata* mosquitoes collected from under a bridge near the town of Wellsville, on the south end of Cache Valley, showed signs of causing encephalitis in mice tested. Further passages and tests performed showed that although it had usual characteristics of a virus, it seemed different compared to WEE and SLE, which were common in the area.

The virus was sent to the Rockefeller Foundation Virus Laboratories in New York where Dr Jordi Casals and Dr Loring Whitman found that serologically it belonged to their newly designated "Bunyamwera" group. The results of the finding of this new virus were published in a 1959 article in *Science* (Holden & Hess 1959). Casals and Whitman realized that the distribution of this virus was not confined to Utah, as they determined that the virus was identical, or very similar, to unidentified virus specimens from *Aedes scapularis* mosquitoes collected near Belem, Brazil and from Trinidad, West Indies. This work, and additional discoveries about viruses in their newly described Bunyamwera serogroup of the genus *Orthobunyavirus*, was published the following year.

Figure 2: Virologist Jordi Casals.

Cache Valley virus (CVV) has since been found to have a wide distribution throughout all of North and Central America, as well as many parts of South America (Grimstad 2001). CVV is similar to other viruses, and there have been some changes to understanding its phylogeny over the years. Some of the original isolates from Brazil and Trinidad are now classified as a closely related virus called Maguari virus. CVV isolates have been identified in USA, Canada, Mexico, and Colombia, with CVV subtypes found in Ecuador (Playas virus) and Mexico (Talactopan virus) (Armstrong et al 2015).

Since its initial discovery in *Cs inornata*, isolates of CVV have been found in over 40 mosquito species (Waddell et al 2019). The most common mosquitoes from which CVV has been detected are *Anopheles quadrimaculatus*, *An punctipennis*, *Coquillettidia perturbans*, and *Cs inornata*. It is likely there are a number of mosquito species capable of transmitting CVV, but not necessarily all the species from which it has been isolated to date. The virus is most commonly detected in mosquitoes during late summer and early fall (Armstrong et al 2015, Grimstad 2001). Laboratory studies investigating vector competence have shown that *An punctipennis*, *An quadrimaculatus*, *Cq perturbans*, *Cs inornata*, *Ae scapularis*, *Ae japonicus*, *Ae sollicitans*, *Ae taeniorhynchus* and *Ae vexans* can all transmit CVV, but some at much lower levels compared to others (Waddell et al 2019).

Fortunately, there has not been widespread illness associated with CVV. Despite being discovered in the 1950s, the first disease outbreaks of CVV occurred in the 1980s in sheep (Edwards et al 1989). Small ruminants seem to be most susceptible to CVV infections, especially sheep and goats. Five outbreaks in sheep populations have been reported (Uehlinger et al 2018). A number of animal laboratory studies have been undertaken to help understand CVV infection risks. Disease is most prevalent in fetal and newborn lambs, with major harmful outcomes being stillbirth, spontaneous abortions, congenital defects, and death. These outbreaks occur during the winter months from December to February, which is when lambing occurs. It is thought that white-tailed deer may also play a role as a reservoir host for CVV (Blackmore & Grimstad 1998).

There have been just 6 clinical human cases of CVV reported (Waddell et al 2019). The virus presents itself as a neuroinvasive disease ranging from self-limited meningitis to fatal meningoencephalitis with multiorgan failure (Wilson et al 2017). The first case was reported in 1995 in a 28-year-old North Carolina man (Sexton et al 1997). The illness began, like many other viral infections, with flu-like symptoms, but eventually caused a prolonged coma, multiple organ failure, and necrosis. To try and save the victim, doctors amputated one of his legs, but he unfortunately succumbed from pulmonary complications. Dr Daniel Sexton, the lead author, was interviewed about this case by a local newspaper from Cache Valley, *The Herald Journal*, saying "I'd never seen anything like it in my life. It was a horrible illness" (Wright 2004).

What makes this illness so hard to diagnose is the rarity of infections seen in people, and because of this, few diagnostic tools are readily available for physicians to detect CVV in patients. There have been two reported cases from people in Australia, where CVV is not found. One victim was infected while traveling abroad, and the virus was only identified after metagenomic next-generation sequencing was performed. The patient underwent many months of progressive neurologic declines including memory loss, slowing of speech, mood alteration and intermittent tremors. As months progressed the patient could no longer walk, eventually stopped eating, went into a coma, and ultimately died 42 months after symptoms first appeared (Wilson et al 2017).

In this instance, and in at least one other case, the patients were known to be immunodeficient. It is likely most people don't need to worry about infections from CVV, despite the widespread nature of the virus, because of the high prevalence of antibodies in people, ranging from 3% to 50% (Waddell et al 2019), making clinical human infections extremely rare. In Cache Valley, where the virus was first discovered, researchers analyzed serum in people able to neutralize the virus, indicating a past infection, and although they did not detect it in people, they did in horses in the area where mosquitoes were collected (Holden & Hess 1959).

The discovery of CVV highlights the importance of investigating arbovirus outbreaks to protect public health. New diagnostic tools are needed to help determine the cause of infections when other pathogens have been ruled out. New arboviruses will likely continue to be discovered and old ones will keep inflicting harm on people, so it is important for mosquito control personnel to continue on in the early mission of the CDC: studing pathogen transmission, mosquito biology and mosquito control methods to protect the public from harm by arthropod-borne disease. The discovery of CVV in Utah is yet another contribution that our small state has made to the larger field of medical entomology and mosquito control.

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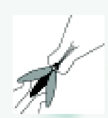

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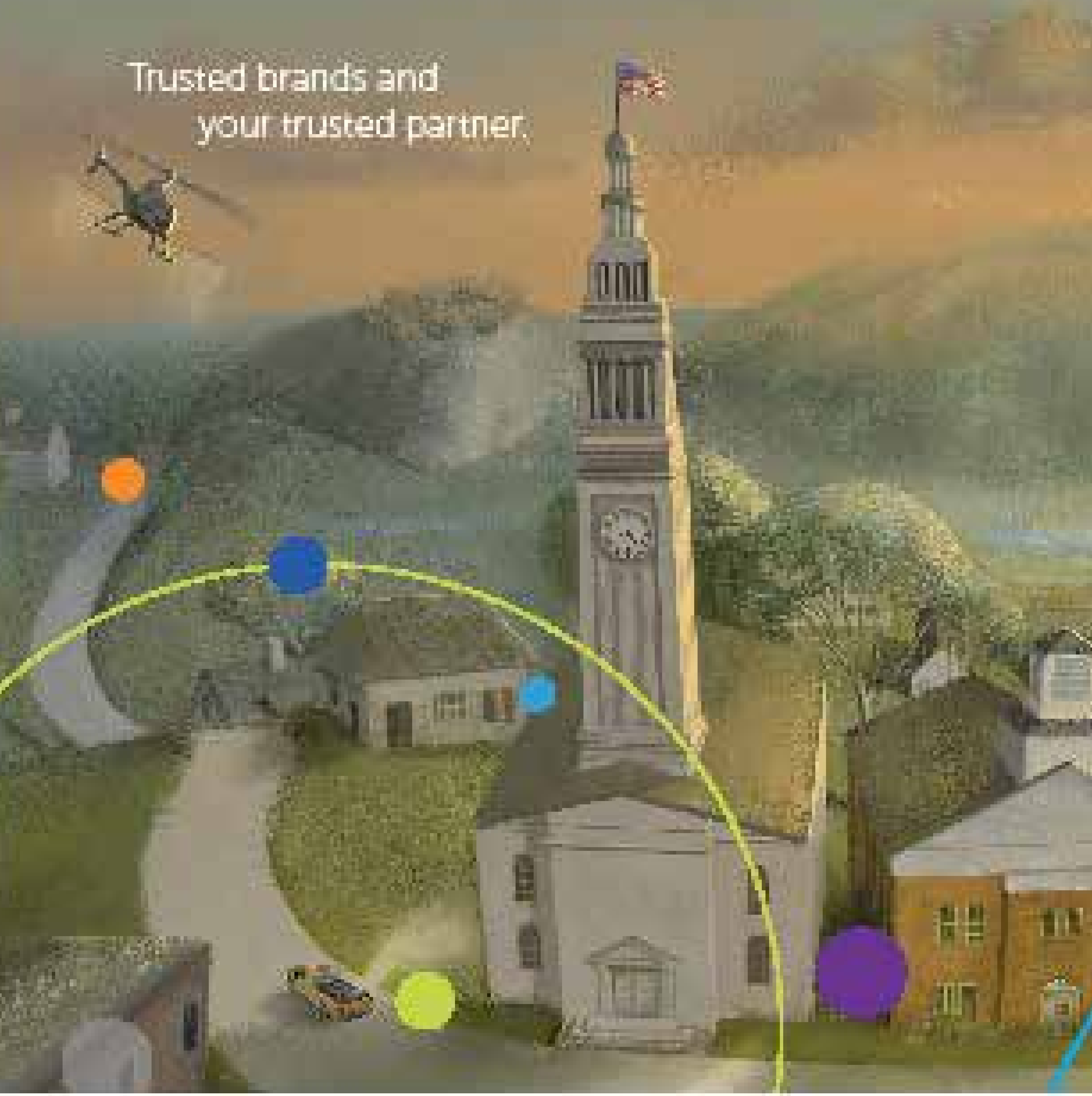

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WNV, WEE and SLE: Arboviruses in Utah

by Gary Hatch

Utah has a long history of vector borne diseases. Prior to West Nile virus (WNV) entering Utah there have been sporadic outbreaks of primarily Western equine encephalitis (WEE). The first recorded WEE outbreak in Utah occurred in 1933, involving 3,958 horses. The outbreak was centered along the Wasatch Front in Utah and extended north to Franklin County, Idaho. Equine cases were reported every year from 1935 until 1951, with the highest during this period occurring in 1941 involving 837 horses (Brookman 1955). The number of human cases prior to 1957 is not known because WEE cases were not separated from other forms of encephalitis. In 1957, two human cases were reported. The largest WEE outbreak occurred the following year with 48 human cases, including one fatality, and 244 equine infections (Graham & Collett 1964). Only two human cases of WEE have been reported since 1958, one in 1963 and one in 1966 (Graham & Collett 1969, Wagstaff et al 1986). WEE was relatively quiet until 1978, when 60 horses in the Uintah Basin were diagnosed (Romney et al 1980).

ENCEPHALITIS SURVEILLANCE

Utah has conducted various forms of vector-borne encephalitis surveillance for many years. During the 1958 WEE outbreak the US Center for Disease Control (CDC) tested 34 samples of *Culex tarsalis* mosquito pools, of which six were positive. Limited mosquito pool testing was conducted from 1969 through 1982. Early mosquito pool testing was time consuming, with results slow in coming. It proved to be an inefficient early warning of virus outbreaks.

The US Army Proving Grounds at Dugway conducted extensive WEE surveillance from 1965 through 1976, using horses placed in single trailer-sized enclosures. Their research focused on testing many animal species to determine the overwintering mechanism for WEE. Due to the remote location in the west Utah desert and limited populations of *Cx tarsalis*, their research had limited value to the mosquito districts.

Positive Surveillance Chicken (WEE & SLE) and Equine Cases				
Year	WEE	SLE	Equine	District/County
1983	3			South Salt Lake MAD: 1 WEE Utah County: 2 WEE
1984				
1985				
1986	5	5		Uintah County MAD: 2 WEE + 3 SLE Duchesne County MAD: 3 WEE Emery County: 2 SLE
1987	5			Uintah County MAD: 5 WEE
1988				
1989				
1990	3			Uintah County MAD: 3 WEE Duchesne County MAD: 3 SLE
1991	4	2		Uintah County MAD: 4 WEE Uintah County MAD: 1 SLE Box Elder County MAD: 1 SLE
1992	8		2	Uintah County MAD: 4 WEE Duchesne County MAD: 4 WEE + 2 equine
1993	7		3	Uintah County MAD: 3 WEE + 1 equine Duchesne County MAD: 2 WEE Moab MAD: 2 WEE + 2 equine
1994	2			Utah County: 1 WEE Carbon County: 1 WEE
1995				
1996				
1997				
1998		1		Moab MAD: 1 SLE
1999				
2000				

Table 1: Encephalitis activity in chickens and horses in Utah, 1983 - 2000.

In 1982 the CDC recommended the use of sentinel chickens for surveillance of WEE and St Louis encephalitis (SLE), and state surveillance programs ran consistently from 1983 until 2001. Detection of these two viruses has been sporadic over the years, with most activity occurring in eastern Utah, in the Uintah Basin, which consists of Uinta, Duchesne and Daggett Counties and the Uintah and Ouray Indian Reservations of the Northern Ute Tribe. During this period the Uintah Basin accounted for 75% and 90% of WEE and SLE positive chickens, respectively, and 90% of the equine cases. The number of chicken flocks used in each county was very limited, with most mosquito districts only running one or two flocks. The state started with 11 flocks of 10 birds each, increasing to 21 flocks in 1985.

Figure 1: Gary Hatch (*left*) and Sammie Dickson bleed sentinel chickens, 1992.

WEST NILE VIRUS SURVEILLANCE

With the introduction of WNV in 2003, the number increased to 28 flocks, and districts reduced their flocks to 5 birds each to allow for better coverage within their respective boundaries. Sentinel surveillance continued for most districts until 2014, when CDC's Epidemiology and Laboratory Capacity (ELC) Grant to the state was greatly reduced. Without funds for the Utah State Veterinarian Lab to conduct chicken surveillance testing, districts would have to pay for those tests on their own, so many of the smaller districts stopped testing chickens and focused on mosquito pool testing only. Districts that decided to continue with chicken surveillance signed a contract with the State of California or the Sacramento-Yolo Mosquito & Vector Control District to run the tests. Due to budget constraints at that time, most mosquito districts discontinued their sentinel chicken surveillance programs, with only two districts continuing to run such programs today.

In Utah, as with many states, WNV ushered in a new era of surveillance and mosquito control. Surveillance programs began looking for WNV in 2001, and by 2003 full integration of WNV surveillance had been implemented in all mosquito control programs. Surveillance for WNV activity brought together a multitude of agencies due to its impacts on human, mosquito, wild bird, horse, and sentinel chicken populations. Local mosquito abatement districts performed the necessary trapping, sorting and identification for mosquito surveillance. They filled collection tubes with *Cx tarsalis* and *Cx pipiens* for testing by the Utah Public Health Laboratory (UPHL). Sentinel chicken flocks were purchased, maintained and bled by mosquito abatement personnel. Chicken blood samples were processed at the Utah Veterinary Diagnostic Laboratory (UVDL) in Nephi. Oral swabs from wild birds, both live and dead, were collected by Utah Division of Wildlife Resources officials and sent to UPHL for testing. Horse blood samples were collected and submitted by local veterinarians, with the Utah Department of Agriculture and Food coordinating testing efforts at the UVDL facility in Logan. Health care providers submitted human samples for testing by both UPHL and private concerns, such as Associated Regional and University Pathologists (ARUP) Laboratories. The three major blood banks servicing Utah – American Red Cross, ARUP and Mountain Star – coordinated screening of donated blood for identification of viremic donors. All local health departments in Utah were involved primarily with disseminating, investigating and responding to positive human cases, and working with their local mosquito districts to conduct increased mosquito surveillance and control in areas where positive human test results occurred. Mosquito pool testing for WNV started in 2002, though not detected until 2003, and WNV has been detected every year in the state since then. For the first decade of surveillance, 2006 and 2007 had the highest incidence of WNV activity, while 2017 was the most active year in the second decade of WNV testing.

Though WEE and SLE detection was sporadic in the 20 years prior to the introduction of WNV, testing for all three viruses continues. Even with expanded surveillance since 2003, very little WEE has been detected. Washington County in southern Utah has accounted for the majority of WEE activity, with some mosquito pools testing positive early, at the beginning of the

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Human	1	11	52	158	70	27	2	2	3
Horse	35	5	68	59	18	8	6	3	1
Wild Bird	2	8	22	75	19	3	0	0	*
Sentinel Chicken	9	32	79	107	74	16	1	1	0
Mosquito Pools	3	181	80	466	225	140	284	33	25
Counties with detections	9	11	17	19	19	14	12	5	6

*Wild bird testing was not part of Utah's active surveillance in 2011

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Human	5	7	2	8	13	62	11	21	1
Horse	3	7	4	4	7	35	6	9**	0
Wild Bird	-	40*	2	-	-	3	4	-	-
Sentinel Chicken	1	2	1	4	-	-	-	-	-
Mosquito Pools	21	69	167	281	244	443	180	272	21
Counties with detections	8	9	9	8	8	17	16	5	6

*testing of eared grebes and bald eagles
** UPHD started grouping horse, chickens and wild birds to reporting as all animals

Table 2: Seasonal comparisons of WNV activity in Utah, 2003 - 2020.

mosquito testing program. SLE has not been detected in mosquito pools or chickens since 1993. We recorded our first human SLE case in 2018 but did not detect SLE in mosquito pools collected from the area or in the state during the summer.

When the ELC Grant was cut further in 2016, requiring the UPHL to start charging for testing mosquito pools, many districts began mosquito testing in-house, employing RAMP® (Response Biomedical Corp, Vancouver, Canada), Vector Smart™ (Co-Diagnotics Inc, Salt Lake City, Utah) and RT-PCR (reverse transcriptase-polymerase chain reaction) tests. The UPHL has done a very good job in testing mosquito pools over the years, but there was a time lag in getting tests run and results back to the districts. In-house testing allows us to be more flexible in our trapping and testing and with quicker results, enabling us to be more proactive with control measures when positive mosquito pools are found. The UPHL has set up test panels that each district conducting RT-PCR must run at the beginning of each season to show good lab technique and testing proficiency. Once a district has shown proficiency in testing, their results are accepted and no additional testing and confirmation by UPHL is needed.

MIGRATORY BIRD MORTALITY

In 2013 a significant WNV event occurred involving eared grebes and bald eagles (Ip et al 2014). The Great Salt Lake and surrounding wetlands are a major resting point for migratory birds, especially waterfowl, on their annual route south for the winter.

EARED GREBES

Each year half of the entire North American eared grebe population gathers on the Great Salt Lake en route to the southern US and Mexico. At peak gathering an estimated 2 million eared grebes arrive to gorge themselves on brine shrimp in the lake, forming very large groups or rafts of thousands of birds. They feed so heavily that the birds will double their weight, building energy for their journey. By mid-December, the brine shrimp population has been greatly reduced, and the eared grebes begin to leave the Great Salt Lake to continue their migration south.

In late October 2013 wildlife biologists noted about 1,200 dead and dying eared grebes; by November 8th a large increase in mortality was observed (Hon et al 2014). Heavy mortality is not uncommon and has historically been due to avian cholera. Avian influenza and botulism have also caused severe mortality in grebes and other waterfowl in the Great Salt Lake Valley. An estimated 15,000 - 20,000 eared grebes died between November 1 and December 31. On November 21 and December 20, 5 birds were each collected from Davis County and Box Elder County, respectively, for testing.

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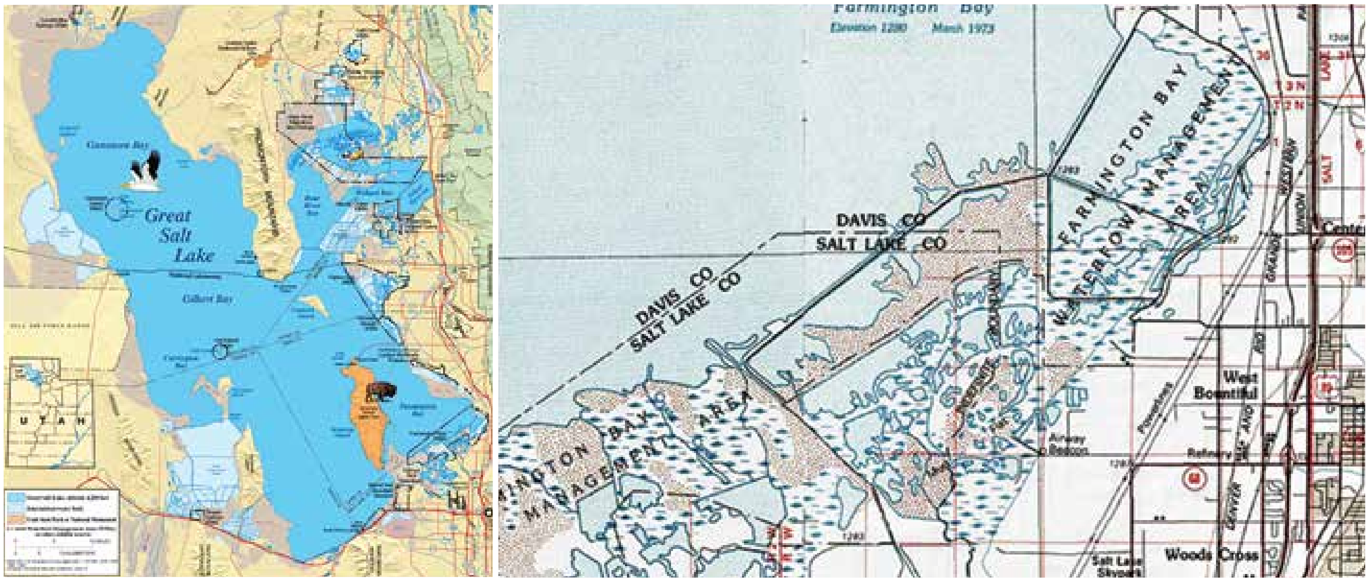

Figure 2: Map of Great Salt Lake (*left*) and Farmington Bay Waterfowl Management Area.

Avian cholera, caused by *Pasteurella multocida*, was suspected in all 10 birds based on gross examination, but no pathogenic bacteria were cultured from the grebes tested. All the birds tested negative for lead poisoning. Avian influenza RT-PCR tests were negative. All ten grebes tested positive for WNV and WNV was isolated from seven individual birds. WNV shedding was found on seven of the ten birds through cloacal and tracheal swabs.

It is unknown how or where the eared grebes were initially infected, but there was WNV activity in many of the counties around the Great Salt Lake when they migrated into the area in mid to late September. However, it is unusual occurrence to have late season transmission because *Cx tarsalis* and *Cx pipiens* prepare to enter diapause and mosquito biting activity is very minimal. Whether transmitted locally or brought in by infected grebes migrating into the area, WNV most likely spread from bird to bird through viral shedding due to their close proximity with each other. It is not known if all the 20,000 birds died from this disease, but if so, it would possibly be the single largest WNV-associated wild bird mortality event.

BALD EAGLES

Between 750 and 1200 bald eagles will move into Utah for the winter. The Great Salt Lake area is the wintering home for a large population, which begin arriving in the valley around November through mid-February. The Farmington Bay Waterfowl Management Area in Davis County hosts as many as 400 bald eagles that come to feed on carp in the shallow waters of the wetland.

In early December of 2013, bald eagles were found dead or showing signs of head tremors, lethargy and paralysis

Figure 3: An eared grebe, *Podiceps nigricollis* (*left*) and roosting bald eagles, *Haliaeetus leucocephalus.*

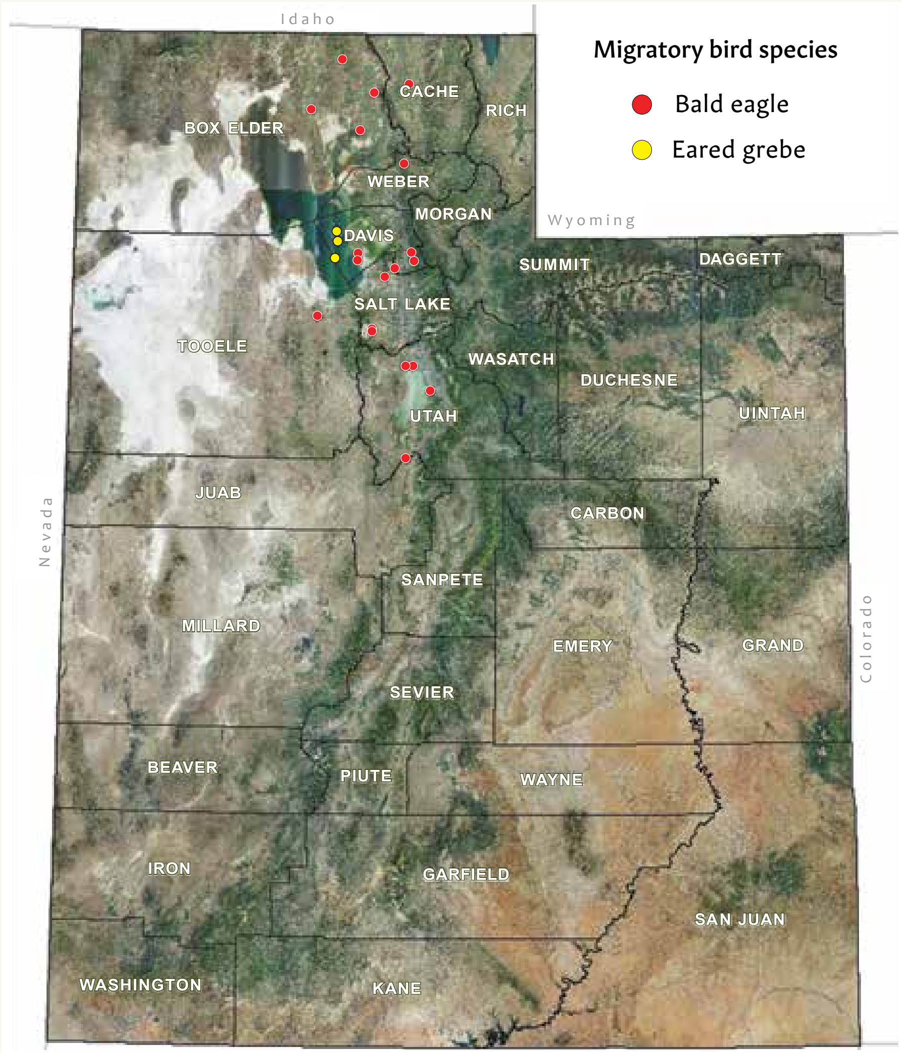

Figure 4: Utah map showing locations of migratory bird morbidity and mortality, October - December 2013.

of wings and legs, and by December 31st a total of 43 bald eagles from six counties (Box Elder, Davis, Salt Lake, Tooele, Utah and Weber) had died or were euthanized. Nine eagles were collected for testing, with 8 birds being submitted to the National Wildlife Health Center and 1 to the UVDL for postmortem examination.

Histological examination of 6 of the eagles showed meningoencephalitis and myocarditis. The eagles were tested for avian cholera, avian influenza, botulism, pesticide exposure and lead poisoning. No bacteria were isolated from the eagles, and results were negative for lead poisoning and organophosphate insecticide exposure. All birds tested positive for WNV by RT-PCR. WNV was isolated from the brains of 8 of the birds and from spleen/kidney pools from 3 of 4 birds.

With nightly temperatures dropping below 10° C by the time eagles were infected with WNV, the transmission of WNV from mosquitoes to the eagles was highly unlikely. A severe cold front had moved into the valley towards late November, freezing the shallow waters of the marshes, and causing the eagles to broaden their range in search of food. They most likely began scavenging on the dead and dying grebes on the Great Salt Lake and were thus infected with WNV. Some bird-to-bird transmission probably occurred in the bald eagle population, when they congregated in roost trees and shared roost branches. By the spring of 2014, 82 bald eagles had died of WNV and 4 infected birds had recovered in wildlife rehabilitation facilities.

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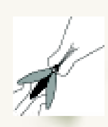

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Small Fish in Small Ponds: Challenges and Successes Using Fish for Biological Mosquito Control in Utah

by Eric Gardner and Brian Hougaard

The use of fish as a deliberate means of biological mosquito control has become an important component of integrated mosquito management in Utah. Though fish stocking may not be an appropriate control method for all situations, in some settings it can provide an alternative to chemical control that may remain effective through an entire mosquito season or longer. However, just as early pioneering human settlers experienced some severe hardships traveling to and settling in what is now Utah, establishment of fish stocking as a mosquito control tool in Utah did not begin, nor does it continue without challenges and setbacks.

Figure 1: Early mosquito abatement worker catching mosquitofish with a dip net. Photo courtesy of Salt Lake City Mosquito Abatement District

IF AT FIRST YOU DON'T SUCCEED

The first attempts to use the western mosquitofish, *Gambusia affinis* (Baird and Girard), for mosquito control in the state were overseen by Dr Don M Rees, then supervisor of the Salt Lake City Mosquito Abatement District (SLCMAD). In 1927 the District received around 50,000 fish from southern California; these fish were distributed to pools throughout Salt Lake City where they thrived for several months. However, none of the fish were observed the following spring, suggesting 100% mortality (Rees 1934) and leading some to question whether the harsh winter conditions in Salt Lake City could sustain populations of this fish species.

A second attempt to establish mosquitofish in Utah occurred in May 1929, when Colonel JA LePrince of the United States Public Health Service (USPHS) sent a small shipment of *Gambusia* from West Virginia to Utah. The journey across the plains proved too perilous for these pioneering poeciliids, as all perished en route (Rees 1934).

Two years later, Colonel LePrince again sent aid to Utah, this time in the form of LM Fisher, also of the USPHS, and 12 additional *Gambusia affinis*, these from Shelby County, Tennessee. Fortunately, fish and Fisher fared far more favorably than LePrince's earlier emissaries. Following a month in an indoor aquarium, the fish were introduced into an outdoor pond where they remained and multiplied until November of that year. Having enough sense to come in out of the snow, the majority of the progeny of the original 12 fish – now numbering around 246 – spent the winter in an indoor aquarium. Fifty or so fish that remained outdoors failed to survive the winter (Rees 1934).

Upon the advent of Spring 1932, mosquitofish from the indoor aquarium were again transferred to outdoor pools throughout Salt Lake City, where they reproduced throughout the summer. As winter approached, some fish were taken indoors, others were placed in various water bodies throughout Salt Lake City, in an attempt to locate suitable outdoor winter habitat. Many of the fish left outdoors succumbed under ice and several feet of the greatest snow on earth during a particularly harsh winter. However, a few that were introduced into a pond fed by a warm spring survived the winter in good condition. This warm pond proved to be an excellent *Gambusia* habitat and provided thousands of fish for stocking in other pools for mosquito control in the summer of 1933. By 1934 this pond was supporting approximately 40,000 individuals, and fish survival in other locations was also observed following the winter as well (Rees 1934).

During the following decade, *Gambusia* from the established colony were introduced in other Utah counties as far as 65 miles from Salt Lake City. Fish from these transplanted populations became successfully established, especially in waters fed by warm springs, but in some cooler habitats as well (Rees 1945). Though the number of locations in which *Gambusia* survived through winter was limited, some persistent populations were established to provide stock from which mosquito abatement districts could draw to seasonally plant fish in larval mosquito habitat (Gaufin 1949).

Though *Gambusia* persist in wild habitats in Utah, factors such as urban development and unpredictable environmental conditions reduce the reliability of specific sources. Consequently, several mosquito abatement districts have installed housings to propagate mosquitofish within their facilities. Outdoor ponds of various construction, including designs with sides and bottom all of concrete, earthen bottom and concrete sides, and ponds lined with synthetic rubber have been installed and used with some success at three districts. Ponds with earthen bottom and stone and concrete sides installed at Mosquito Abatement District-Davis and patterned after ponds used at the Sacramento-Yolo Mosquito and Vector Control District in California have proven the most productive. Indoor tanks constructed of fiberglass are also currently employed by all Utah districts using mosquitofish. The controlled conditions of these systems allow mosquitofish to be held and propagated year-round, reducing reliance on outdoor systems more subject to fluctuating conditions.

Figure 2: Outdoor *Gambusia affinis* production pond at Mosquito Abatement District - Davis, Kaysville, UT.

THIS IS THE RIGHT PLACE

Early fish stocking efforts included the introduction of *Gambusia* to a variety of habitats, including lakes, drains, ponds, and streams. Several concerns eventually emerged that limited the use of *Gambusia* for mosquito control in large and natural waterways. In addition to high winter mortality, predatory birds hindered successful fish introductions. *Gambusia* population size and distribution within large bodies of water was at times inadequate to satisfactorily curtail mosquito production, especially in spring and early summer. Dense aquatic vegetation prevented fish from accessing all areas affording acceptable habitat for mosquito larvae, and *Gambusia* were implicated in range reduction of native fishes including the least chub, *Iotichthys phlegethontis* (Gaufin 1952, Young 1954, Rosenfeld 1989).

Early practitioners recognized the utility of using *Gambusia* to control mosquitoes in small ornamental ponds (Gaufin 1949, Young 1954). Despite the need to replant fish in many such ponds annually following loss to winter kill, and removal by children, cats, birds, and snakes (Gaufin 1949), stocking mosquitofish in ornamental ponds has persisted as a mosquito control practice to the present. Ornamental ponds were recognized as potential habitats for vectors of Western equine encephalitis during an outbreak of that disease in Utah in the 1950s (Fronk 1961), and more recently as a source of vectors for West Nile virus. Their capacity to harbor developing disease vectors in close proximity to human hosts makes ornamental ponds important targets for effective mosquito control, and the use of fish has become an important practice in those efforts.

LOVE THY NEIGHBOR

To address concerns about introduced species preying on non-target organisms, competing with or otherwise displacing native fish and contaminating impacted systems with aquatic pathogens, state agencies have regulated the collection, possession, propagation and distribution of aquatic animals, including mosquitofish (Bushman 2001). In Utah, a memorandum of agreement between the Utah Division of Wildlife Resources (UDWR), the Utah Department of Agriculture and Food, and Utah mosquito abatement districts provides authorization and guidance for the use of fish in mosquito control. Regulations regarding releasing *Gambusia* include a rule that mosquitofish must not be introduced into any waters having open connections to natural streams, springs, lakes

Figure 3: Indoor *Gambusia affinis* production tanks at South Salt Lake Valley Mosquito Abatement District, West Jordan, UT.

or ponds, unless approved by the UDWR. Additionally, fish collected from wild sources or reared from brood stock at mosquito abatement district facilities must be tested annually for aquatic pathogens and treated for Asian tapeworm, *Bothriocephalus acheilognathi*, before being distributed.

The SLCMAD, Mosquito Abatement District-Davis, and the South Salt Lake Valley Mosquito Abatement District partnered with the Utah Department of Natural Resources in 2008 and 2009 in a trial to evaluate the effectiveness of the least chub, a Utah native fish, as a biological mosquito control agent.

The least chub, is a small minnow with a maximum size of less than 2.5 inches. It primarily eats small aquatic invertebrates, including mosquito larvae, and algae. These fish are endemic to Utah and historically were widely distributed in rivers, streams, creeks, springs, ponds, marshes, and swamps throughout the Bonneville Basin (Bailey et al 2005). Population declines beginning by the 1940s, attributed largely to habitat degradation and increased predation and competition from non-native fish, including game species and mosquitofish, prompted listing the least chub as a threatened species under the Endangered Species Act in 1972 and 1979. Subsequent review of least chub status resulted in removing the species from the threatened list and its reclassification as a candidate species. Following establishment of a conservation agreement amended in 2014, the least chub was removed from the list of candidates for threatened or endangered status (Fish & Wildlife Service 2014).

The 2008-2009 trial involving mosquito abatement districts was designed to evaluate the efficacy of using the least chub to control mosquito larvae in ornamental ponds and compare the performance of the least chub to that of *Gambusia*. Results suggested that the least chub could successfully control mosquito larvae, though higher stocking rates than used with *Gambusia* were required to achieve comparable results (Dickson 2008). Participants also observed lower survival rates among the least chub than among *Gambusia* during transport and following stocking (Sharp & Bowlden 2009), and greater difficulty acclimating least chub to conditions in ornamental ponds. To this point, least chub have not replaced mosquitofish as biological mosquito control agents in Utah, though interest in ecologically responsible practices continues.

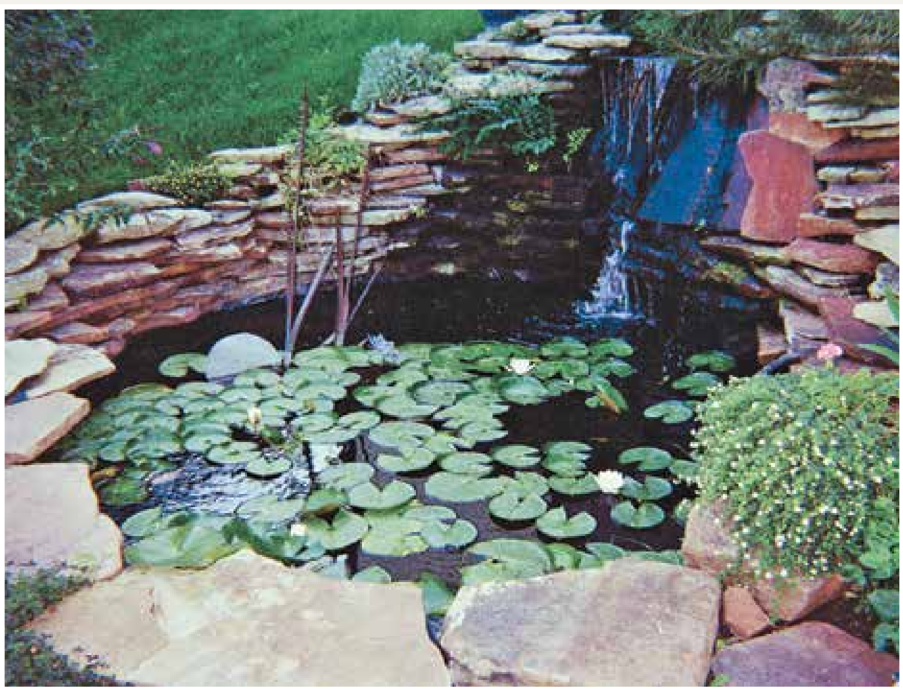

Figure 4: A candidate ornamental pond for fish stocking.

Figure 5: *Left* - Utah Department of Natural Resources deliver least chub to Salt Lake City Mosquito Abatement District. Photo courtesy of SLCMAD *Right* - Close-up of least chub in a net. Photo courtesy of Utah Division of Wildlife Resources

In conclusion, the use of fish as biological mosquito control agents has found a niche in Utah in mosquito habitats created primarily by confined bodies of water such as ornamental ponds. In 2020, four mosquito abatement districts in Utah deployed a total of nearly 31,000 fish to treat more than 3,200 ornamental ponds in urban and suburban parts of the state. As it has since its inception, the practice will undoubtedly continue to evolve as best practices are refined to continue toward safe, effective, and responsible mosquito control. Biological control utilizing *Gambusia* has proven to be an appreciated public relations tool and a valuable component of integrated mosquito management measures within Utah mosquito abatement districts.

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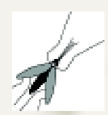

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From My Lookout: COVID-19 and Public Health Mosquito Control

by David Brown

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus. Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness without requiring special treatment. Older people and/or those with underlying medical conditions are more likely to develop serious illness. As this issue of *Wing Beats* goes to press, almost 2.2 million people have died from the disease worldwide (WHO 2020a). It has affected almost every aspect of our lives, including dining at favorite restaurants, closing of schools, mandating mask wearing, and staying six feet away from everyone in public places. Thanksgiving and Christmas were much smaller gatherings – although spikes of cases after these holidays demonstrated that not everyone followed the advice of experts knowledgeable in virus transmission.

The current COVID-19 pandemic and measures aimed at containing it put health systems worldwide under enormous pressure, according to a Global Vector Hub survey (Seelig et al 2020), and we certainly saw this in the United States. Challenges to mosquito control efforts here included not being able to procure personal protective equipment (PPE), N95 masks being the most prominent protective equipment unavailable. The diversion of personnel, laboratories and testing facilities having operations shifted to concentrate on COVID-19, has resulted in the delay, or simply absence, of tests related to mosquitoes or other vectors. In a meeting of the Vector Borne Disease Network, the US Centers for Disease Control and Prevention (CDC) mentioned that cases of tick and other non-mosquito vectored diseases were likely much higher than being reported, due to the transfer of personnel and resources to track them (Dykstra et al 2020).

The Global Vector Hub concluded from the results of their survey that a "combination of pandemic-induced absence of staff, lack of access to physical resources – such as field sites, laboratories, testing and rearing facilities – and lack of funding" would have deleterious effects on the control and research on arboviruses and other vector-borne diseases (VBDs).

Available resources can always be a problem. Even in those areas in the United States which have mosquito and vector control programs with historically strong dedicated funding may see their programs hampered in 2021. The long-term impact of the economic climate caused by COVID-19 may result in a loss of future revenues due to tax bases being affected by the shutdown orders and corresponding depression of the economy. The current high unemployment rate and the potential for a permanent loss of

jobs and/or businesses is especially concerning.

So, is it appropriate to compare a new pandemic with our professions' yearly occurring "endemics"?

Malaria is a life-threatening disease caused by parasites that are transmitted to people through the bites of infected female *Anopheles* mosquitoes. In 2019, there were an estimated 229 million cases of malaria worldwide. The estimated number of malaria deaths stood at 409,000 in 2019. Children aged under 5 years are the most vulnerable group affected by malaria; in 2019, they accounted for 274,000 of all malaria deaths worldwide. Total global funding for malaria control and elimination reached an estimated $3 billion in US dollars (WHO 2020b).

Dengue viruses are spread to people through the bite of infected *Aedes* mosquitoes. These mosquitoes also spread Zika, chikungunya and other viruses. Dengue is common in more than 100 countries around the world. Forty percent of the world's population, or about 3 billion people, live in areas with a risk of one of these viruses. Each year, up to 400 million people get infected with dengue. Approximately 100 million people get sick from infection, and 22,000 die (CDC 2019).

West Nile virus (WNV) is the leading cause of mosquito-borne disease in the continental United States. There are no vaccines to prevent or medications to treat WNV in people. While most people infected with WNV do not feel sick, 1 in 5 develop a fever and other symptoms. Of those, approximately 1 out of 150 people develop a serious, sometimes fatal, illness (CDC 2020).

See any issues with these numbers? I do. Transferring resources from programs that control endemic mosquito-borne diseases which result in significant morbidity and mortality is simply unacceptable. Clearly our public health infrastructure needs to be fortified. The United States Congress recognized the reality of this when they passed the Tick Act and the SMASH Act. Congress now needs to fund them to ensure we do not have further lapses in our public health umbrella.

Dedicated funding through these legislative bills will shore up testing and lab capacity for vector-borne diseases, will maintain research programs dedicated to vector-borne diseases at the Regional Centers of Excellence and bolster the personnel in the field who work to prevent vector-borne disease transmission from occurring. If you are reading this, contact your federal legislator to make this happen!

I have several talking points to share:

First, nobody anticipated a pandemic resulting in over 1.5 million deaths globally in 2020, but we DO know we will have close to 1 million deaths from vector-borne diseases, because they happen EVERY year. Second, new viruses like COVID-19 or emerging viruses and pathogens (remember Zika?) can – and are likely to – happen within the United States at any time. Third, while a vaccine for COVID-19 will likely be distributed as you are reading this, there are virtually NO vaccines for mosquito-transmitted diseases. Lastly, the transfer of resources from one public health program that addresses endemic conditions EVERY year is simply a very poor public health response. We can and should do better.

COVID-19 has demonstrated just how vulnerable our public health infrastructure is. Let's do what we can to make sure our essential programs are not compromised when the next illness hits our shores.

Stay safe and healthy, and let's make 2021 a year to celebrate.

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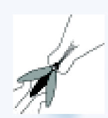

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