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The Origin of Mosquito Producing Waters in the Vicinity of Salt Lake City, Utah

(Diptera Culicidae)

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During the course of this investigation, from 1929 to 1937, of the mosquitoes in the vicinity of Salt Lake City, some interesting data have been collected on the origin of waters that produce mosquitoes. These data are now sufficient to justify certain pertinent conclusions.

As all mosquito larvae and pupae are confined to an aquatic habitat, it is important in studying the origin of mosquitoes to consider the source of mosquito producing waters. This is especially true in a semi-arid region such as Salt Lake City. Most of the mosquito breeding waters in this region are of a temporary or semi-permanent nature. It has been found that in permanent bodies of water the natural enemies of mosquito larvae prevent them from developing in excessive numbers.

Precipitation directly or indirectly constitutes the source of all surface water. Salt Lake City has an average yearly precipitation of about 16 inches. In the high mountain regions adjacent to the City precipitation is considerably higher and may average from 30 to 40 inches, while in certain sections of the desert west of the city, precipitation is less than 10 inches a year. The effect of this moisture upon the production of mosquitoes depends on the season of the year in which it falls, the amount falling in a limited time, the area in which it occurs, whether it is snow or rain, the movement and distribution through streams, springs, artesian wells, and the use of this water by man. The origin of mosquito producing waters will be considered as follows: 1. Pools from melting snow, 2. rainwater pools, 3. flood-water from streams, 4. irrigation water, 5. impounded water, and 6. springs and artesian wells. This classification of mosquito producing waters is more or less arbitrary but useful for present consideration. Certain species of mosquitoes are found developing in all types of water when other conditions are favorable, while others are restricted largely to breeding waters of a particular source.

SNOW WATER

As the snow melts in the spring of the year, numerous temporary pools of varying size are formed in all depressions. These pools in addition are often fed by early vernal rains. The pools are shallow, contain suitable food, and are free from natural enemies of mosquito larvae. This water constitutes excellent breeding places for several species of Aedes inhabiting the region in the vicinity of Salt Lake City. Eggs that were laid the previous season hatch in these waters and enormous spring broods of mosquitoes annually emerge from these pools. *Aedes dorsalis* produce their first brood of the season in these snow water pools and following broods during the summer in water from other sources. Other species in the region such as *Aedes niphadopsis* and *idahoensis* produce only one generation a year, and this brood develops almost entirely in snow water pools, sometimes increased by early rains.

RAIN WATER POOLS

Rain water pools in this locality are generally not as important directly as other sources of mosquito producing waters. However, under abnormal climatic conditions such as prevailed during the summer months of 1936, rainwater pools may constitute an important source of mosquito production. Normally in this area precipitation occurs in the winter months principally as snow, and the moisture that falls as rain is usually distributed during the season in such small amounts that it sinks readily into the ground, or evaporates from the small pools where it accumulates, before a brood of mosquitoes can complete development. However, during the spring, rains frequently extend or maintain the snow water pools for longer periods of time, thus enabling the early broods of mosquitoes to develop in these pools. During certain seasons, especially in May and August, abnormally high precipitation in a limited period of time occasionally creates rain-water pools over extensive areas on the flats west of Salt Lake City, from which large broods of *Aedes dorsalis* emerge.

FLOOD WATERS

Flood waters important in mosquito production occur when streams over-flow their natural channels. The water exceeding the bounds of the natural channel of the stream accumulates in all depressions along the margins and in this flood water mosquitoes are generally produced. Flood water occurs annually during the spring along the margins of all mountain streams in the vicinity of Salt Lake City. This flooding is the result of the rapid run-off from melting snow that has accumulated in the mountains during the winter or from heavy rains. Flooding occurring in the spring of the year does not continue after about June 20th. As the water recedes the temporary pools thus formed provide excellent mosquito producing water, and are sometimes very extensive and produce the principal breeding places of the largest seasonal brood of pest mosquitoes in the vicinity of the City. The species found developing in these flood waters is principally *Aedes vexans*, which is the dominating species in this situation. *Aedes dorsalis*, *Aedes campestris*, and *Culex tarsalis* also develop in these waters under certain conditions.

In addition to the flood waters from early spring freshets, what is known locally as "cloud-bursts" occasionally occur, wherein considerable rain falls in a very short period of time and causes streams to overflow their banks. This type of flooding occurring during the summer months is generally localized, but the flood water pools thus formed along the margin of the stream frequently produce broods of mosquitoes of the above named species.

IRRIGATION WATER

Irrigation water is the most important single factor in the production of mosquitoes throughout the season in this region. As all cities and communities in Utah, except a few mining towns, are largely surrounded by irrigated farms, this factor is unquestionably of primary importance in the production of mosquitoes in the vicinity of practically all communities throughout the state. The irrigation problem is undoubtedly of equal importance in all states of the intermountain west where irrigation is practiced as it is in Utah.

Irrigation is carried on extensively in the vicinity of Salt Lake City throughout the mosquito breeding season. The methods of irrigation are of two types: first, the water is carried over the ground in small furrows; second, the ground is flooded with water to a depth of several inches and the water allowed to remain until it sinks into the ground or evaporates. The first method of irrigation is the usual practice for all cultivated farm crops. The second method of flooding is used principally in the production of meadow grasses for pasturage and forage, and in some sections for the production of timothy and alfalfa. Both methods, under certain conditions, create extensive mosquito producing water. In addition, seepage from irrigation canals, and water remaining in the bottom of canals, drains, and ditches from which irrigation streams are periodically removed, create numerous prolific mosquito producing situations. The importance of this source of mosquito breeding water is due to the following conditions: 1. the extent of irrigation, 2. the periodic recurrence of these waters after each irrigation, 3. the continuance of these pools by irrigation throughout the mosquito breeding season, and 4. the creation of these pools in the immediate vicinity of communities. All of these factors combined tend to make irrigation water the most important source of mosquito producing water in the vicinity of Salt Lake City, and throughout the state.

Irrigation water is used from the first part of May until the last of September. This corresponds to the mosquito season in this region. When the first type of irrigation is used and water is carried over the land in small furrows, the water that reaches the end of the furrows is generally allowed to flood into depressions as waste water, forming surface ponds and pools of varying extent. In other localities this waste water is diverted onto meadows or pastures where it is frequently permitted to flood over many acres. These shallow temporary waste water pools, free from natural enemies, bring forth enormous broods of larvae; and, in most instances, the water remains long enough for them to complete development and emerge as adults. A new brood generally appears from this waste water after each successive flooding, and irrigation water is used periodically about every ten days until the crop is harvested. Each flooding corresponds to about the length of time necessary for a brood to complete development, thus creating an ideal situation for the production of mosquitoes, especially *Aedes dorsalis.*

The second method of flooding, used principally on pastures and meadows, is continued throughout the season. The amount and extent of flooding usually depends on the excess water available from other farm crops. During part of the season, particularly in the spring, late summer, and fall, hundreds of acres are flooded and the water permitted to stand in the grass until it sinks in the ground or evaporates. Many irrigation streams during certain periods are permitted to run continuously on some areas, and in such cases the water may stand for weeks at a time, insuring the production of mosquitoes.

The predominant species produced from irrigation water in this vicinity is *Aedes dorsalis*, the most important pest species in the region. Seven successive broods have been taken during the season from the same pools that were periodically flooded by irrigation water. Samples taken from these pools show *Aedes dorsalis* larvae to be frequently present on an average of 100 to a pint of water, and this condition to extend over many acres. *Aedes vexans* are frequently produced in similar numbers in certain localities from irrigation waters, generally in the spring or early summer. *Theobaldia inornata, Culex tarsalis,* and *Anopheles maculipennis* are also found developing in irrigation water in smaller pools and fewer numbers.

During the past eight years from 1930 to 1937 inclusive, the Salt Lake City Mosquito Abatement District has kept an accurate record of all pools inspected and treated for mosquito larvae, and the origin of the water, when possible, has been determined. For comparison the source of the water has been classified as follows: 1. *Precipitation,* which includes rain-fall or water from melting snow, 2. *Irrigation,* which includes flooding waste water, seepage from irrigation canals, and standing water in the bottom of irrigation canals and drains, 3. *Artesian Wells* and *Springs.*

It is possible from the records of the district to compare with considerable accuracy three important factors influencing the production of mosquitoes from water of different sources. *First*, the number of different localities where larvae were treated with larvicide gives the distribution of mosquito breeding areas in the district. *Second*, the number of places treated with larvicide is an index to the seasonal prevalence of the breedng areas. *Third*, the number of gallons of larvicide used indicates the surface area or extent of the breeding waters. The accuracy of this method of measuring the extent of the breeding water was established by measuring, on several occasions, a definite area and determining the number of gallons of larvicide used in treating this surface. It was found that some areas, especially those filled with vegetation, required more larvicide for treatment than open pools, and also that the amount of larvicide used varied somewhat with the method of application. However, as these chances for error are about equally probable for breeding waters of all sources, this method of determining the relative size of breeding areas, if carried over a number of seasons, should be fairly acceptable.

The following data are compiled from the records of the district. The area under control was 110 square miles in 1930, but was extended by 1936 to cover about 150 square miles. The data show that the extension of the boundaries of the district increased the number of pools treated, but the simultaneous extension of the drainage system and the planting of fish, *Gambusia*, substantially reduced the amount of larvicide used as many large areas were drained and smaller pools stocked with fish. Data collected are compiled in the following tables:

Table No. 1 gives the number of localities where mosquito producing water was found and treated with larvicide during the different seasons, the source of the water, total for all seasons, and per cent of all pools created from water of different sources. The different localities given in one season are frequently counted again in the following seasons, thus the same locality may be enumerated each year.

Table No. 2 gives the number of places treated with larvicide each season and the source of the water treated. As some breeding water in the same locality may be treated several times during the season, the number of places treated exceeds the number of localities given in Table No. 1. The source of the water in the same locality frequently changes. The same area may be flooded by precipitation, irrigation, artesian wells or springs during a single season. Breeding waters that were eliminated during the season by drainage, filling, evaporation, stocking with fish or other means, have not been considered in this table. Only the places treated with a larvicide have been used to arrive at a basis for comparison.

TABLE No. 3 gives the number of gallons of the larvicide used during the seasons on breeding waters of different origin. The total gallons of larvicide used and the relative per cent on the breeding waters of different sources indicates the extent of the surface area. The extent of the breeding surface is more important in determining the relative number of mosquitoes produced from water of various sources than the number of pools, as the size of the pools varies from a few square feet to many acres.

TABLE No. 4 gives a summary by amounts and relative per cents for comparison of irrigation water with the other important sources of mosquito producing water in the vicinity of Salt Lake City.

TABLE NO. 1

Number of Localities Where Larvae Were Found Developing and Were Treated with Larvicide in the Salt Lake City Mosquito Abatement District.

Cause	*Year*							
	1930	1931	1932	1933	1934	1935	1936	Per Cent
Irrigation	124	180	330	312	304	348	439	51%
Precipitation	103	154	389	341	135	298	162	40%
Wells and Springs	14	18	58	52	67	95	64	9%

TABLE NO. 2

Number of Treatments Made With Larvicide in The Salt Lake City Mosquito Abatement District.

Cause	*Year*							
	1930	1931	1932	1933	1934	1935	1936	Per Cent
Irrigation	370	612	854	1000	997	1019	1496	57%
Precipitation	274	376	873	714	172	536	666	32%
Wells and Springs	58	53	130	156	224	295	340	11%

TABLE NO. 3

Gallons of Larvicide Used in The Salt Lake City Mosquito Abatement District.

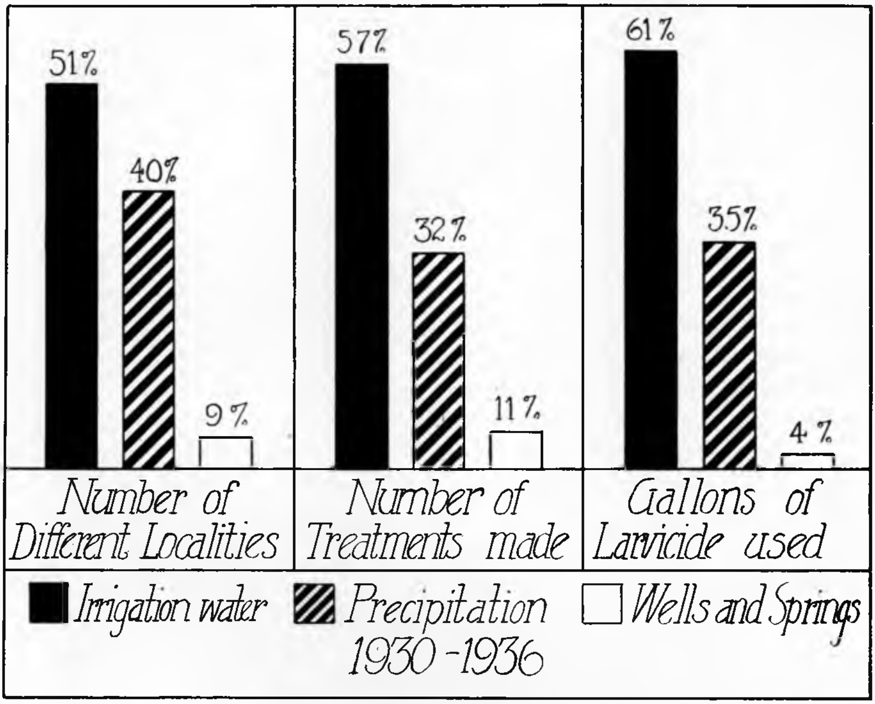
Cause	*Year*							
	1930	1931	1932	1933	1934	1935	1926	Per Cent
Irrigation	36,122	29,682	27,534	28,493	20,568	13,774	23,426	61.5%
Precipitation	15,610	14,398	27,387	22,892	5,067	7,850	7,573	34.5%
Wells and Springs	1,982	667	1,403	1,197	1,920	2,213	2,341	4.0%
Total	53,714	44,747	56,324	52,582	27,555	23,837	33,340	100.0%

TABLE NO. 4

Summary of Tables 1-2-3

Cause	*Irrigation Water*		*Precipitation*		*Wells & Springs*	
Number of Localities	2,042	51%	1,582	40%	368	09%
Number of Treatments Made	6,348	57%	3,584	32%	1,256	11%
Gallons of Larvicide Used	179,569	61%	100,777	35%	11,723	04%

Graph Summary of Table No. 4



From the above tables and graph it can readily be seen that irrigation water is the principal source of mosquito producing water in the vicinity of Salt Lake City, producing 51% of the different breeding localities, 57% of the number of pools treated and 61% of the total breeding area treated with larvicide. These percentages may vary considerably during a single season as other factors, such as abnormal precipitation, high temperatures, etc., may alter conditions.

Other factors that cannot be determined from the tables that may influence mosquito production should be considered. The depth of the water as well as the surface area determines the volume of mosquito producing waters. This factor is of minor importance as all mosquito breeding water is relatively shallow and of fairly uniform depth regardless of its source. The species of mosquitoes found developing in different kinds of water is an important factor in determining production, as some species of mosquito larvae are rarely as numerous in an equal volumn of water as other species. However, *Aedes dorsalis* is the most common species found developing in irrigation water, and is also the most serious pest mosquito of this region. The larvae of this species are usually exceedingly abundant, thus adding further importance to irrigation water in the production of pest mosquitoes in this area.

IMPOUNDED WATER

Large permanent bodies of water that are impounded for various industrial or irrigation purposes are generally found to be comparatively free of developing mosquito larvae. Natural enemies are usually present in sufficient numbers to prevent mosquito development in these waters. However, in temporary or semi-permanent bodies of impounded water, very prolific mosquito production occurs.

In Utah, as in all semi-arid states, water is impounded during certain seasons when available, to be used at other times during the season. Water is stored for various purposes in the district, but only water impounded for three purposes has been found during this investigation to be of any major importance in the production of mosquitoes. This water will be considered as *first,* water stored for irrigation purposes, *second,* water impounded for wild fowl, and *third,* water confined in small ornamental pools.

The water stored for irrigation is sometimes important locally in the production of large broods of mosquitoes, generally in the spring of the year. Irrigation water is stored in reservoirs of natural lakes during the winter and early spring months. When excess water is available the water is raised into the grass and vegetation around the margins, and in this shallow marginal water large broods of mosquitoes usually develop. This condition only exists in the spring of the year, as the water rapidly recedes from the margins early in the summer as it is drawn off for use in irrigation. Mosquito larvae are rarely found in the main bodies of water of reservoirs and lakes later in the season. The larvae found developing under these conditions are usually *Aedes dorsalis, Theobaldia inornata, Culex tarsalis,* and sometimes *Anopheles maculipennis.*

Water impounded for wild fowl is an important source of mosquito production during certain periods of the season. The impounding of water for wild fowl is a recent practice in the vicinity of Salt Lake City and is carried on extensively around the shores of the Great Salt Lake.

Levees and dykes have been constructed by various gun clubs and groups of sportsmen at the mouth of the Jordan River and the Surplus Canal. These streams formerly discharged into the lake through a series of fresh water sloughs. The levees and dykes now divert the water from it natural channels and thousands of acres of level salt grass areas are flooded along the margins of the lake. The water in these newly flooded areas is shallow, filled with salt grass and other vegetation, and is of a more or less temporary nature. This affords an ideal breeding ground for several species of mosquitoes, particularly *Aedes dorsalis.* The most extensive flooding in these areas occurs in the spring and fall of the year, when water is available, and during these seasons literally billions of mosquitoes are produced from these impounded waters. At times during the summer months after heavy rains, the rain-water and released irrigation water is diverted by these levees over extensive tracts of ground previously dry; and large broods of *Aedes dorsalis* appear. Other species such as *Aedes campestris, Aedes vexans, Aedes niphadopsis, Culex tarsalis,* and *Theobaldia inornata* are found, during parts of the season under certain conditions, developing in considerable numbers in these waters.

The third type of impounded water, that found in ornamental pools and ponds, is not so important in the production of large broods of mosquitoes since such pools are relatively small in size. Most of these ornamental pools cover but a few feet in area and are usually very shallow. However, they are generally constructed in the immediate vicinity of homes in the residential sections. In Salt Lake City 928 of these ornamental pools have now been located, and mosquito larvae were found developing in all of these pools that were not stocked with fish or periodically drained. Larvae were also found in some pools that were stocked with gold fish where water vegetation was luxuriant. Prior to mosquito control activities in Salt Lake City, at least 73 per cent of these pools were producing mosquitoes. These small ornamental pools constitute an important source of mosquito breeding water for certain species of mosquitoes. The species generally found developing in these pools reproduce continuously throughout the season and the near proximity to houses insures a human victim for each female that emerges. This type of mosquito producing water is comparable to the "'rain-barrel" of other sections of the United States. The species of mosquitoes commonly found developing in these ornamental pools are *Theobaldia inornata, Theobaldia incidens, Culex tarsalis, Anopheles maculipennis,* and under certain conditions *Aedes vexans.*

SPRINGS AND ARTESIAN WELLS

Springs and artesian wells are considered jointly as the mosquito producing waters from these sources are generally similar in character. The water from larger springs and wells is ordinarily put to beneficial use, and very little mosquito breeding results from this source. However, numerous small springs, seeps and artesian wells are found scattered about in the vicinity of the city, and water from these sources is permitted to spread out near the outlets creating small pools and puddles in the tracks of domestic animals and in natural depressions. Water of this kind is constantly available for mosquito development and in certain localities may be fairly extensive. This water extended at times by precipitation or irrigation water, produces considerable numbers of mosquitoes. The most common speceis found in water of these sources are *Culex tarsalis*, *Anopheles maculipennis*, *Theobaldia inornata*, *Theobaldia incidens* (generally in deep springs) and at times *Aedes vexans* and *Aedes dorsalis*.

Summary and Conclusions

1. Mosquito producing waters in Utah can arbitrarily be classified according to their origin as follows: 1. snow water, 2. rain water, 3. flood water from streams, 4. irrigation water, 5. impounded water, and 6. springs and artesian wells.

2. Irrigation water wherever present is the most important single source of mosquito production in Utah. This, undoubtedly, is equally true in all neighboring states where irrigation is carried on as it is in Utah.

3. Water of a semi-permanent or temporary nature is the principal source of mosquitoes in this region. Permanent bodies of water maintaining a constant level, regardless of the source of the water, tend to support a sufficient number of natural enemies to greatly reduce or entirely prevent the development of mosquito larvae.

4. Temporary mosquito breeding waters occur in Utah principally in the spring of the year and are created largely by melting snow and vernal rains. From these temporary vernal waters issues the largest single brood of mosquitoes that occurs during the season.

5. Semi-permanent mosquito producing waters appear intermittently throughout the season in the same localities. These situations are usually maintained by irrigation water and certain types of impounded water, such as on gun clubs and in some ornamental pools. Mosquitoes that produce several generations during the season continue to reproduce in great abundance throughout the season in these semi-permanent waters, thus constituting the most continuous source of mosquito production.

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