ECOLOGIC FACTORS AFFECTING MOSQUITO CONTROL BY AIRCRAFT IN THE GREAT BASIN

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INTRODUCTION. The Great Basin, ecologically classified as a part of the desert biome covering much of the western United States (Behle 1969), occupies Northern Utah and Nevada along with parts of California, Idaho, and Wyoming. The Basin lies mostly above 4000 feet. Rainfall is fairly evenly distributed throughout the year and averages 5 to 16 inches. Much of the precipitation falls in the winter months in the form of snow. Summer temperatures are high, with a monthly mean of 76.4° F in July while the January mean is 28.2° F (Andersen 1966). Where rainfall averages 15 inches a year sagebrush communities predominate. Areas of lower rainfall (under 8 inches per year) tend to have alkaline soil with growths of shadscale and greasewood.

Mosquito problems in this area are geographically scattered; but where they occur, along riverbottoms, bordering lakes and reservoirs, and in irrigated farmlands, infestation can be intense. The Great Basin states have the lightest population densities in the continental United States. The number of communities large enough to support mosquito control programs is small and districts may be poorly staffed and budgeted (Rees 1968).

Salt Lake City with its environs is the major population center between Denver and San Francisco. It lies against the Wasatch mountain range and is bordered on the west by the Great Salt Lake and the Great Basin Desert. Contrary to popular impressions of the lake as an American "Dead Sea," the eastern shore of Great Salt Lake receives 2.5 million acre-feet of fresh water from the Jordan, Weber, and Bear rivers and numerous smaller mountain streams. This has resulted in a band of marshland 70 miles long and 2 to 18 miles wide that has been largely preserved and developed as habitat for the millions of waterfowl that use this segment of the Pacific Flyway.

Organized mosquito control in the Salt Lake area dates from 1924, following the passing of enabling legislation in 1923. Additional control districts have been organized until today six mosquito abatement districts protect the area from Brigham City to Provo where 80 percent of Utah's population resides. With better mosquito control has come recognition of the Salt Lake marshes as a great national wildlife resource to be preserved and developed. Utah today offers more open shooting to its citizens than any other state. This public is now an urban population that expects modern mosquito control along a 70-mile strip-city never more than 10 miles from the salt marshes.

Spray aircraft were first used in the Salt Lake City M.A.D. during 1948 to spray a total of 400 acres. In 1969 four leased aircraft sprayed over 40 percent of the Wasatch front acreage under protection. Previous to the 1969 season the aircraft contracted by the Utah districts were calibrated to a rate of 2.0 gallons per acre. Ethyl parathion in water emulsion applied at a dosage rate of 0.1 to 0.2 pound per acre was the pesticide of choice.

THE SALT MARSH ENVIRONMENT. The marsh areas that are the major targets of aerial applications for mosquito larvae in the Salt Lake districts are representative of the cold, temperate desert communities common to much of the Great Basin. Greasewood (*Sarcobatus vermicularis*) and shadscale (*Atriplex confertifolia*) predominate on the alkali salt flats. In the

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transitional areas between dry land and the marshes are found glasswort (*Salicornia rubra*), pickleweed (*Allenrolfea occidentalis*), and saltgrass (*Distichlis stricta*). In the marshes, now mainly managed for duck hunting, are three species of bulrush (*Scirpus paludosus, Scirpus olneyi,* and *Scirpus acutus*) and the broadleaf cattail (*Typha latifolia*). Submergents and floaters include sego pondweed (*Potamogeton pectinatus*), widgeon grass (*Ruppia maritima*), and duckweeds (*Lemna minor* and *Spirodela polyrhiza*). A few plantings of wild millet (*Echinochola crusgalli*) have been made on the marshes, but at present they are small and scattered.

Saltgrass is the major control problem on the marshes. It was described by Behle (1969) as "A tufted, perennial grass, the plants being mostly a foot high or less . . . occurs in dense stands, spreading from root stalk as well as seeds. In the former case the individual plants are arranged in a straight line."

The plant is desirable as nesting cover for ducks and the seeds are used as food. Saltgrass will survive and grow in shallow water and when submerged, in 2 to 6 inches of water, it provides excellent habitat for mosquito larvae. *Aedes* eggs will survive under this cover and produce multiple hatchings as the water level rises and recedes during the warm months.

Saltgrass is harvested in this area on a small scale, but usually it is left to provide nesting cover for the waterfowl. After a period of several years, the grass is laid-over and matted by birds, wave-action, ice and snow. Figure 1 shows a

Fig. 1.—Saltgrass (*Distichlis stricta*) overgrowing 4 inches of larvae-producing water.

175-pound man supported dry-shod over 4 inches of larvae infested water.

An investigation of local airspray records in the M.A.D.'s indicate that it is these mats of saltgrass that force, in May or early June, an increase of pesticide dosage from 0.1 to 0.2 pound per acre (ethyl parathion).

Mosquito species found in the Salt Lake City M.A.D. in order of abundance are *Aedes dorsalis, Culex tarsalis, Culiseta inornata, Culex pipiens, Aedes vexans* and *A. nigromaculus* (Collett 1968).

1969 INVESTIGATIONS. The Salt Lake City M.A.D. in 1968 contracted with their aerial applicator to investigate concentrated pesticide formulations that could be utilized at total aircraft spray rates of 1 gallon per acre or less. The Chemagro Corporation, Kansas City, Missouri cooperated in these studies. Table 1 is spraying at the 1.0 gallon per acre rate from April through September. The higher costs in April and May reflect the more scattered nature of the early season plots and the time required for the pilot to learn the area.

The aircraft used during the 1969 season was a Call-A9, 290 horsepower sprayplane fitted with dual standard and low volume application systems (Burgoyne and Akesson, 1966). To apply 1 gallon per acre 15 SS D6-46 nozzles were fitted to point 15 degrees back and operated at 25 psi. Fourteen SS D3-45 nozzles pointed 15 degrees foward at 40 psi delivered 1 quart per acre. The low volume system was 11 SS 80015 flat-fan nozzles aimed 15 degrees foward at 25 psi and delivered 5.2 fl. oz. per acre. Standard flight conditions were: airspeed 87 miles per hour at an altitude of 8–12 feet, swath 75 feet.

TABLE 1.—Summary of aerial application of insecticides: Salt Lake City M.A.D.* 1954–1968.

Year	Total acres treated	Total hours	Acres per hour	Total flights
1954	12,128	215	56.41	483
1955	13,314	216	61.64	520
1956	8,665	120	72.21	262
1957	6,893	110	62.67	233
1958	10,757	159	67.65	390
1959	10,170	122	83.36	289
1960	11,390	142	80.21	372
1961	6,078	74	82.13	191
1962	15,979	167	93.08	451
1963	15,645	151	103.61	410
1964	10,189	143	71.24	308
1965	12,187	134	90.95	349
1966	14,272	138	103.42	387
1967	20,970	225	92.25	410
1968	14,290	160	89.30	286

* Summary from the Thirty-Ninth Annual Report of the Salt Lake City Mosquito Abatement District, 1968.

a summary of the flight operations of the Salt Lake City M.A.D. from 1954 to 1968. These applications were all made at a total rate of 2 gallons per acre.

In 1968, air application cost per acre was $0.60. The 1969 cost was $0.50 per acre for the 1 gallon rate, $0.30 for a rate of 1 quart, and $0.19 for a low volume rate of 5.2 fluid ounces (fl. oz.) per acre (Graph II). Graph I illustrates the cost of

Using the method of Maksymiuk (1964) the mass mean diameter of the droplets was determined to be:

One gallon per acre rate	531 microns
One quart per acre rate	219 microns
5.2 fl. oz. per acre rate	172 microns

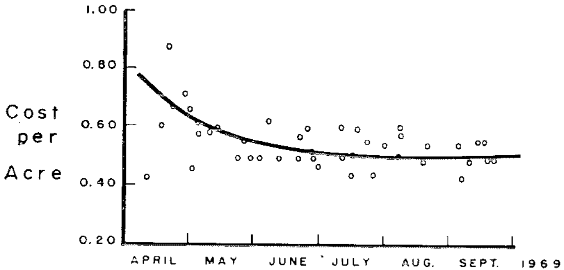
Saltgrass, common in the Salt Lake marshes, is a favorite habitat for *Aedes*

SALT LAKE CITY M.A.D.

Flight Operations 1969: Cost per Acre

CALL A-9, 290 hp

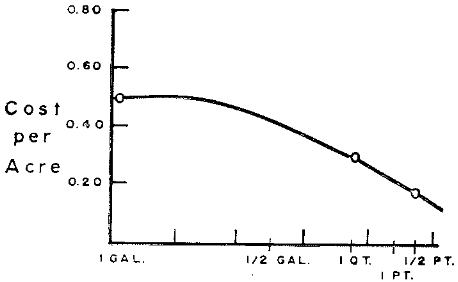
GRAPH I



TOTAL MIX: 1 gal./acre, normal application rate

90 missions, 1.8 acres/minute, 15,000 acres (3)

GRAPH II



Total Rate per Acre:
1 gallon/A (1)
1 quart/A (2)
5.6 fl. oz./A (2)

(1) NORMAL APPLICATION RATE

(2) EXPERIMENTAL RATES

(3) MECHANICAL ABORTS AND FLIGHTS FROM AIRPORTS OTHER THAN HOME BASE NOT INCLUDED IN DATA

dorsalis and often affords a solid protective "roof" over the developing larvae. Cattail, bulrush, tamarack, and shallow water present only minor obstacles to the penetration of the airspray. Table 2 is a cross section of incident light readings made at 3-foot intervals across a stand of saltgrass cover that had reported a control failure at the 1 gallon per acre rate, 0.1 pound per acre ethyl parathion. Light penetration is measured on an arbitrary scale of 0 to 1000. Although the authors recognize that small droplets under 70 microns may "zig-zag" through overlaying plant surfaces, larger droplets follow a straight-line trajectory and impact within the matted saltgrass. As our mmd for the 1 gallon rate was 531 microns, much of our chemical may never contact the larvae.

TABLE 2.—Incident light readings * across an area of saltgrass (*Distichlis stricta*). Salt Lake City M.A.D. June 1969.

#	Cover	Reading	Percent light transmission	Observations
0	open	550	100%	
1	open water	550	100	
2	" "	550	100	
3	standing saltgrass	500	95	very light cover
4	" "	500	95	" " "
5	" "	500	95	" " "
6	laid-over saltgrass	85	15	
7	standing saltgrass	250	45	
8	laid-over saltgrass	85	15	
9	" "	85	15	
10	open (shaded)	400	73	muskrat run
11	laid-over saltgrass	65	12	
12	standing saltgrass	200	37	
13	open water	550	100	pool
14	" "	550	100	open water, end of plant growth

Time: 0800 MST, sky clear.
Measurements taken every nine feet.
* Leicameter with incident light insert, calibrated to a scale of 0 to 1000.
Saltgrass 8 to 12 inches.

In an effort to determine the amounts of chemical that impacted in the saltgrass, a series of grids were placed in an area of heavy cover (Figure 2). Nine stakes, 3 feet apart, arranged in a square were placed under the path of flight. A calibrated aluminum weighing pan and a 2 by 4 inch Kromkote drop-sizing card were laid under the plant cover at the base of the stakes and also affixed to the top of each stake. After a normal application, comparisons were made between recoveries from pans in the open and pans under cover for the amounts of chemical recovered as determined by gas chromatograph analysis. The cards, placed with the pans, were analyzed as to (a) numbers of droplets recovered, and (b) the mass median diameters of the droplets. Table 3 illustrates the pesticide recoveries above and below the saltgrass cover.

The pesticide recoveries in the open suggest that 40 to 89 percent of the chemical may be lost from the swath. However, drift studies (Akesson and Yates 1967) indicate that although the total loss from drift may be substantial, the majority of the material will settle into swaths near the target. Of more significance to the local penetration problem is the "open vs. under cover" recoveries. No pesticide recovery from below the plant cover was higher than 20 percent and the average was below 10 percent (four tests in saltgrass, four flights each test, 18 replica-

TABLE 3.—Pesticide and droplet recoveries in saltgrass 1969.

Run	Pass		Pesticide recovery open	Pesticide recovery in cover	Droplet recovery open vs. cover	Droplet size microns open	Droplet size microns in cover
I	1	(1)	17.0%	9.0%	29.0%	391	181
IV	1	(1)	50.0	18.0	......	...	...
IV	3	(2)	37.0	9.4	......	...	...
V	4	(1)	60.0	2.0	......	...	...
V	1	(2)	27.0	1.75	......	...	...
VI	1	(1)	25.0	1.3	23.4	...	...
VI *	3	(2)	11.0	0.6	7.3	187	85

Nine replicates each pass.
(1) One gallon per acre rate.
(2) One quart per acre rate.
* Dursban (4 pound) at 0.05 lb. per acre in water emulsion.
Other treatments: Ethyl parathion at 0.2 lb. per acre.

FIG. 2.—Area of heavy saltgrass growth used as a penetration test area; Salt Lake City M.A.D. 1969.

tions). The percentage of the droplets recovered under the saltgrass was higher than the gross amounts of chemical recovered, but this parameter is affected by the larger numbers of small droplets that penetrate and are counted, as is indicated by the data indicating that mmd's of the droplets "under cover" are approximately half the mmd of the droplets recovered in the open.

Under plant cover the differences in pesticide recoveries between the 5.2 fl. oz. per acre rate and the 1 gallon per acre rate were not significant (5 percent vs. 8 percent). The 1 quart per acre rate, both in the open and under cover, resulted in recoveries of about one-half the 1 gallon per acre rate, Table 3. It must be determined if the operational savings of the 1 quart rate outweigh the loss of chemical.

Table 4 lists the percent light transmission beneath laid-over saltgrass, 12 inches long, measured across a grid of nine replicates similar in arrangement to those used for the pesticide analysis.

Table 4.—Light transmission through laid-over saltgrass 1969.

Station	Percent transmission *			
3.	15%	17%	15%	
2.	18%	13%	18%	
				$\bar{m} = 16\%$
1.	15%	17%	17%	
	A.	B.	C.	station

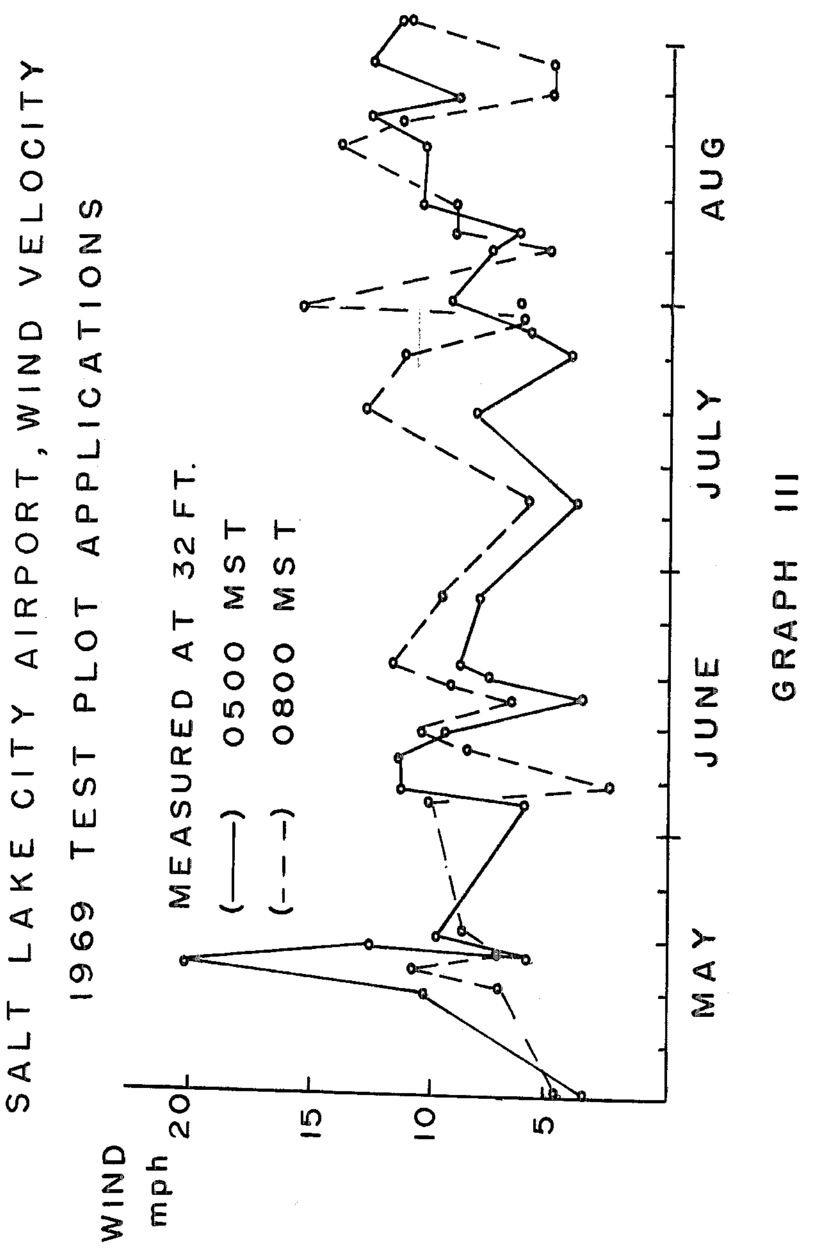
* Measured with a *Leicameter* equipped with incident light insert over cell.
100% light transmission = 450 units.

No attempt can be made to obtain an exact correlation between light transmission and pesticide recovery as light is exempt from the factors of wind, droplet size, and relative humidity that act on the chemical between plane and target; however this technique will continue to be investigated as an aid to help applicators make a calculated judgment on the amount of pesticide needed for successful control of larvae in an infested area. In general a successful treatment is a function of prevailing weather, droplet size, and vegetative cover rather than of application rate or chemical dosage.

Few mosquito-producing areas in the Great Basin are not bordered at least in part by mountains. Typical of this mountainous terrain in summer are mountain-valley winds in the early morning hours, variable to gusty winds to mid-day, resulting in convective build-up of cumulus clouds during the afternoon with possible thunderstorm activity in the late afternoon and early evening (U. S. Weather Bureau 1969). Graph III records the winds during applications to our 1969 test plots. As 6.0 miles per hour is the recommended maximum for air applications in Utah, it is evident that aircraft in the Great Basin operate under considerable handicaps from the uncertain weather, especially when applying water emulsions at low rates. Although located in a desert area, relative humidities in the marshes are not exceptionally low, usually ranging from 70–80 percent at dawn to 40–50 percent at noon.

Summary and Conclusions. Mosquito populations in the Great Basin area of the Mountain States are scattered and localized, but may reach levels that threaten the comfort and health of nearby communities. The majority of intermountain control programs are located along the eastern salt marshes of the Great Salt Lake between Provo and Brigham City, Utah. The major control problem in the marshes is the inability to penetrate with aerial sprays large stands of saltgrass (*Distichlis stricta*) that cover shallow mosquito breeding areas.

Recoveries of pesticide measured from under the saltgrass indicate that less than 20 percent of the chemical applied, and often as little as 2.0 percent, penetrates to the larval habitat. Droplet sizing in the same test plots indicates that the droplets that do penetrate are less than 100 microns in size. Efforts to correlate chemical penetration with incident light readings were not successful, but the procedure may hold promise as a guide to estimating required dosage in operational programs.


SALT LAKE CITY AIRPORT, WIND VELOCITY
1969 TEST PLOT APPLICATIONS
MEASURED AT 32 FT.
(——) 0500 MST
(– – –) 0800 MST
WIND mph
20
15
10
5
MAY
JUNE
JULY
AUG
GRAPH III

Airspray applications in the Great Basin are subject to the vagaries of mountain winds. More than two-thirds of a series of carefully planned test plots had to be applied in winds exceeding 4 miles per hour. Little difference was found in the penetrating abilities of sprays applied at 1 gallon, 1 quart, and 5.2 fl. oz. per acre. The authors suggest that, while more susceptible to drift, rates under one-half gallon per acre may be used in areas away from agriculture in order to treat more acreage in the limited periods of minimum wind conditions that are common to mountainous areas (Burgoyne and Akesson 1968).

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ANALYSIS OF CO_2 SUPPLEMENTED MOSQUITO ADULT LANDING RATE COUNTS

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The ability to accurately sample an adult mosquito population in the field has always been a problem for mosquito workers, both in research and control. Huffaker and Back (1943) covered this subject well when they stated "the many established methods of sampling have been severely and justifiably criticized on the grounds of the selectivity of the methods."

The aim of this study was to provide organized mosquito control districts with a surveillance method, not dissimilar to the methods in practice, but one which would more accurately sample the population over the entire day of inspection and with little regard for the variables produced by higher midday temperatures and greater light intensities.

The authors, Harden and Poolson (1969), in preparing a previous paper on seasonal distribution of mosquitoes in Southern Mississippi encountered these very problems even when using several methods (e. g. New Jersey light traps, CO_2 supplemented CDC miniature light traps, daytime landing rate counts, truck traps and larval sampling). There was

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