RESULTS OF MULTIPURPOSE WATER MANAGEMENT STUDIES ON MARSHES ADJACENT TO THE GREAT SALT LAKE, UTAH[1]

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INTRODUCTION. Along the eastern shores of the Great Salt Lake is a strip of land varying from 2 to 18 miles in width and about 55 miles in length encompassing approximately 510 square miles. As late as 1872 this entire area was inundated by the water of the Great Salt Lake. Where usable water is available, this land is being developed primarily as marsh for wildlife and as pasture for livestock. Approximately 56 square miles of ground adjacent to this strip and slightly higher in elevation are irrigated to produce salt-tolerant forage and grain crops.

Approximately 70 percent of the human population of the state live between this strip of lake shore land and the abrupt front of the Wasatch Mountains. The population of this area has increased 17 percent during the past five years. As a result of this rapid increase in the population, greater attention has been directed towards the ownership and use of this lake shore land and water.

Some current water management practices along the lake shore are responsible for the production of pest and potential disease-transmitting mosquitoes, gnats, horse flies, deer flies and other noxious insects. The development of some waterfowl marshes has increased the production of mosquitoes and other noxious insects which could largely have been prevented had abatement measures been included in the development plans. Prolonged and/or careless irrigation of pasture and other crops has created prolific mosquito production, and in some instances, with detrimental effects to the intended crop. It is recognized that there is a need for more information on the relationship between the production of mosquitoes and other noxious insects and planned multipurpose water use. This information should include the necessary requirements for wild-

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life, agricultural crops, recreation, public health and other beneficial uses of the land and water.

A cooperative study was initiated in September, 1961, and continued through August, 1965, in which an attempt was made to develop and field-test physical facilities, techniques and water management practices for multipurpose use of this reusable water which would provide the greatest mutual benefits to all concerned. The history of the development of this cooperative study was published in *Mosquito News* (Rees 1965). The present paper is a summary of the results of this study.

RESULTS. It was determined that the soils on the old lake bed are alluvial clay, silt, loam and sand in texture with a high water content and heavily impregnated with salts including alkali salts. The soils at the higher elevations are of better quality but are still of limited use without adequate drainage.

The quantity of water entering into the study areas varies considerably both seasonally and yearly. The Surplus Canal, one of the major water sources for the study areas, varied from 0 to 1070 cubic feet per second during the four-year study. The seasonal and yearly variation of water quantity on the marshes resulted in a seasonal and yearly fluctuation of water levels and depth. The general pattern of this fluctuation was high water levels in the spring and early summer, a decrease during the summer, higher levels again in the fall and lower levels in the winter. Much of this water has a salt content as high as 0.4 percent and contains bacteria, detergents, silt and other pollutants in varying amounts, depending on the source. It is generally of low quality for agricultural use and is a potential public health hazard.

The construction of dikes to retain the usable water on the barren mudflats bordering the Great Salt Lake has been very successful in producing some 66,626 acres of marshes. The natural marsh vegetation develops rapidly when water is dispersed or retained on the flats. *Salicornia (Salicornia rubra A. Nels.),* salt grass (*Distichlis stricta* Torr. Rydb.), and alkali bulrush (*Scirpus paludosus* A. Nels.) appear during the first year and sago pondweed (*Potamogeton pectinatus* L.) has appeared in the first year in the deeper, more permanent, waters. Chara (*Chara* sp.), widgeon grass (*Ruppia maritima* L.), hardstem and olney's bulrushes (*Scirpus acutus* Muhl. and *Scirpus olneyi* A. Gray), cattails (*Typha* sp.) and a wide variety of other aquatic or semi-aquatic vegetation gradually infiltrate the developing marsh. All of these native plants become fairly abundant in such a marsh with proper water management.

These marshlands provide a habitat for about 140 species of birds, 29 species of mammals, 7 species of fish and numerous reptiles, amphibians and invertebrate animals. They also provide recreation for man in the form of hunting, fishing, boating, picnicking, photography and nature studies and produce commercial crops such as carp, muskrat pelts, forage for domestic animals, salt grass as a packing material and bedding for livestock and on private property the sale of hunting privileges. Agricultural crops produced on some of the higher ground adjacent to the strip of marshland provide grazing for domestic animals on native and improved pastures, salt grass crops, forage and grain crops and food and cover for wildlife.

Nine species of mosquitoes were collected in the study areas. *Aedes dorsalis* (Meigen), *Culiseta inornata* (Will.), *Culex tarsalis* Coq., *Culex erythrothorax* Dyar and *Culex pipiens* Linn. were collected in both the adult and larval stages. *Aedes fitchii* (Felt & Young) was collected only in the larval stages and *Aedes nigromaculis* (Ludlow), *Aedes vexans* (Meigen) and *Anopheles freeborni* Aitken were collected only in the adult stage. In addition, deer flies *Chrysops discalis* Williston and *Chrysops aestuans* Van der Wulp, the horse fly *Tabanus punctifer* Osten-Sacken, a biting gnat *Leptoconops kerteszi* Kieffer are prevalent and at times extremely annoying. Numerous species of other arthropods of lesser importance were present in variable numbers.

Discussion. Figure 1 portrays a profile of a composite waterfowl marsh in the study area. The marsh is divided into the following zones according to vegetation type: (A) upland, (B) moist soil, (C) emergent, (D) submergent and (E) floating aquatic vegetation. It is evident from this profile that not all parts of the marsh are mosquito producing and not all areas which produce mosquitoes are equal in productivity. Vegetated areas from which water is repeatedly removed and reflooded are highest in mosquito production especially for *A. dorsalis* a floodwater mosquito which is a vicious feeder on man and other animals and migrates into Salt Lake City and adjacent communities. Shallowly flooded vegetation areas are highly productive of *Culex* and *Culiseta* species if the water remains for 2 weeks or more when climatic conditions and other requirements are favorable. These fluctuating and shallow water areas are generally characterized by salt grass, a moist soil vegetation. Waterfowl nesting in this zone of moist soil vegetation is good if it is not flooded during the nesting season. Under these conditions there is no mosquito production. The fluctuating water which produces *Aedes* mosquitoes presents a hazardous environment for waterfowl nests.

Mosquito production in the emergent vegetation zone varies with the vegetation type and density, water depth and the season but is generally lower than in flooded salt grass. In general, the denser the vegetation the higher the mosquito production, and the deeper the water the lower the mosquito production. No larvae were found in these areas in water depths greater than 12 inches. Mosquito production in general declined below 4 inches and above 8 inches.

The waterfowl nesting in the emergent marsh zone was high in areas where the vegetation was fairly dense and the water of suitable depth. It may seem that mosquito control and waterfowl management practices are incompatible in the emergent marsh areas since the waterfowl are favored by dense vegetation and shallower water, the same conditions which favor mosquito production. However, the nesting season for waterfowl is in the spring and early summer while the peak mosquito season in the emergent marsh areas is in the mid and late summer. The water in this zone can be managed for waterfowl during the nesting season and for mosquito control during the remainder of the season without significant curtailment to either program.

No mosquito production was found in the submergent vegetation zone. This zone produces excellent waterfowl food and serves as an area for loafing activities.

When the floating vegetation formed a continuous mat on the water surface, no larvae were found. When the mats were broken some mosquito production was observed.

Table 1 presents the type of water management practiced, the effects on mosquito production and the waterfowl habitat in selected sampling stations that are representative of stations used in this study.

Permanent withdrawal of water from an area entirely eliminated mosquito production and created safe nesting sites for upland nesting waterfowl. If the water was withdrawn from the entire marsh area it would completely eliminate the aquatic

A_1—Upland vegetation (greasewood)
A_2—Upland vegetation (pickleweed)
B—Moist soil vegetation (salt grass)
C_1—Shallow emergent vegetation
C_2—Deep emergent vegetation } (alkali, Olney's, & hardstem bulrush, cattails)
D—Submergent vegetation (chara, widgeon, grass, sago pondweed)
E—Floating aquatic vegetation (duckweed)

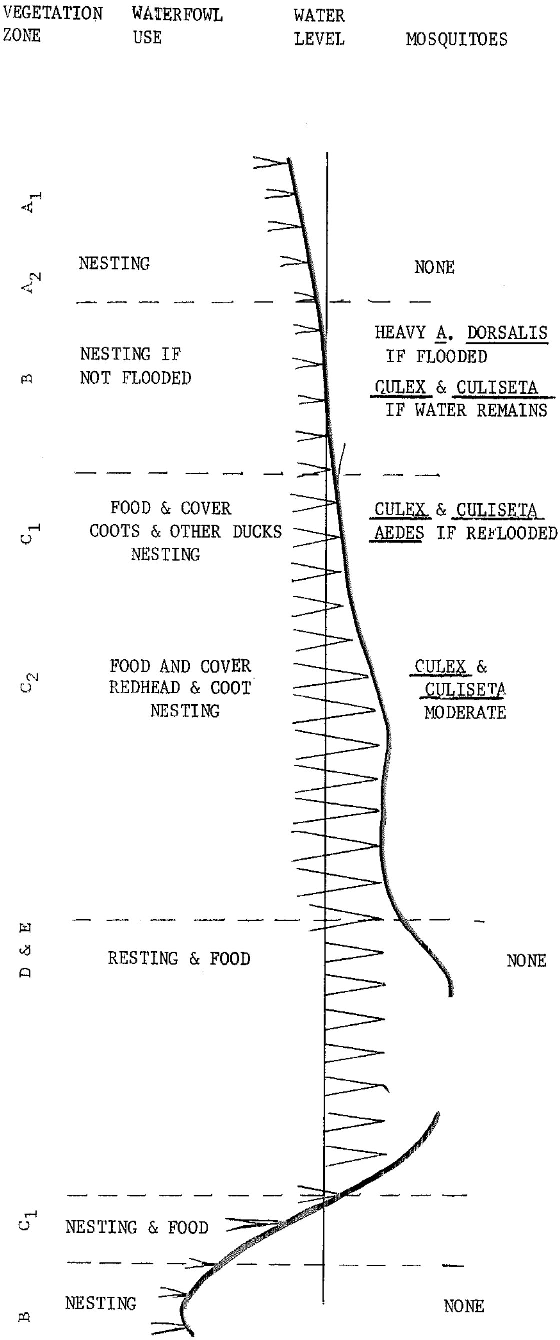

Fig. 1.—Waterfowl marsh profile.

TABLE 1.—Summary of selected sampling stations.

Sampling station		Principal vegetation type	Water management practiced		Mosquito production ave. no./dip				1965 wildlife productivity successful waterfowl nests/acre	
					1962	1963	1964	1965		
Wheeler	8	Salt grass	Permanent flooding		....	0.56	0.53	0.01	Feeding and loafing No nesting	
Wheeler	3	Salt grass	Permanent withdrawal		....	0.18	0.14	0.00	None—agricultural land	
Farmington Bay	8	Mixed salt grass and bulrush	Rapid seasonal drawdown	1	2.48	2.09	0.50	1.31	Duck Coot	0.72 0.36
Lake Front Gun Club	8	Mixed bulrushes	Gradual seasonal drawdown	2	0.40	0.11	0.07	0.54	Duck Coot	5.7 1.9
Farmington Bay	7	Mixed salt grass and alkali bulrush	Flood irrigation	2	0.91	0.20	0.03	0.46	Duck Coot	5.55 0.93

[1] This area was reflooded in August, 1965, and the brood of *Aedes dorsalis* produced increased the mosquito production.
[2] In 1965, the water left on these areas for a longer period of time resulted in higher mosquito production.

habitat. It is recommended that permanent withdrawal be applied only on the moist soil vegetation zone (salt grass complex) in specifically defined areas during the mosquito season.

Permanent flooding during the mosquito season eliminated the production of the floodwater mosquitoes but in some instances provided a better habitat for the more permanent water mosquitoes. In the permanently flooded areas, no mosquito larvae were found in water depths of 12 inches or more. This type of water management is recommended only when there is sufficient water the entire season to maintain a proper water depth and when a unit is designed for feeding and loafing activities of waterfowl rather than nesting.

Seasonal drawdown during the mosquito season is the most versatile management program for the prevailing condition of a plentiful water supply during the spring runoff, a steadily decreasing supply in the summer and an increase in late September and October as the agriculture irrigation season ends. The drawdown may be either rapid or gradual according to the local conditions and desired results. This drawdown should not begin until after the high water peak which is generally in June. A drawdown before this time may result in the reflooding of areas with subsequent production of broods of *Aedes* mosquitoes.

After the middle of June *C. inornata* appeared in increasingly greater numbers. These mosquitoes generally appeared in the shallowly flooded salt grass vegetation and rapid drawdown of the water from this area helped alleviate production of this species. If the *C. inornata* do not constitute a mosquito problem, a gradual drawdown may be a better management technique.

Around the middle of July the *C. tarsalis* increased rapidly, appearing in greater numbers first in the salt grass, if still flooded, and then in the bulrush and cattail areas. A gradual drawdown of the water, first in the moist soil vegetation and later from the emergent marsh vegetation, was effective in controlling *C. tarsalis.* This drawdown from the emergent marsh was applied after the waterfowl nesting season and did not affect those birds which prefer to nest over the water.

Periodic drying of certain parts of the marsh has the effect of retarding or setting back ecological succession and maintaining a given section of the marsh in a desirable successional stage. This drying is also useful or necessary for moving equipment into an area for construction of dikes or for mechanical removal or thinning of vegetation. The dried areas were reflooded in late September or early October just prior to the hunting season. The mosquitoes produced this late in the season were either destroyed by the cold weather or were largely restricted in their movements and did not constitute a problem except in the marsh area.

Seasonal drawdown with prevention of reflooding of dry areas also protected waterfowl nests from destruction by flooding. The submergent marsh areas should be permanently flooded throughout the summer. In some instances it was advantageous to deepen some marsh areas in order to concentrate the water during periods of low water supply. In these deeper areas more water can be stored with less surface area thereby reducing loss by evaporation. On the Lake Front Gun Club, deep borrow pits created by the removal of earth for dike construction served this purpose and at times contained the only water in an otherwise dry marsh.

Flood irrigation over an unimpounded area was used to bring in marsh vegetation onto previously barren soil. The alkali bulrush was generally the first to appear in this plant succession. Irrigation where the water was uniformly distributed and either penetrated the soil or continued to flow over a level surface did not create mosquito-producing situations, but where the water stagnated in small depressions the mosquitoes found a suitable habitat, especially when salt grass was present. Successful waterfowl and shore bird nesting was very high in these areas when the water depth remained 2 inches or less.

The birds generally used areas slightly raised out of the water for their nesting sites. Water must be carefully controlled in these areas to prevent flooding of the established nests.

The type of management employed on any marsh unit must be flexible and be adaptable to the particular situation or area. The management should also be dictated by the interests of all who are concerned with soil and water use in a given area.

CONCLUSIONS.

1. Limitations of multipurpose use of water to provide the greatest mutual benefits to fish and wildlife, recreation, agriculture, public health and related programs:

a. The present quality of the soil and water in the marsh land restricts the use of this land and water to its continuance as a marsh; however, there is a need and a great potential for improving conditions in certain areas in the marsh in order to provide greater beneficial use for all programs concerned. Further deterioration of the water quality could prevent its use for agricultural and wildlife development and increase its potential as a health hazard.

b. The quality of the soil on some of the ground at higher elevations and some of the water of better quality make it possible to produce pasture and satisfactory yields of selected agricultural forage and grain crops; however, at present the expense involved in preparing the land and acquiring and applying the water for agricultural crops makes the cost involved prohibitive for most land owners.

2. Effects of water management practices on mosquito production and waterfowl habitat on the study areas.

a. Impoundment of water to flood a marsh almost invariably creates mosquito-producing situations that may also detract from the marsh as a waterfowl and wildlife habitat unless adequate water control structures are installed and suitable water management techniques and practices are applied.

b. Water management practices applied and conclusions derived:

(1) *Permanent withdrawal* of waters from moist soil vegetation (salt grass complex) eliminated mosquito production and created safe sites for upland nesting waterfowl.

(2) *Permanent flooding* during the mosquito season eliminated the production of *Aedes,* the floodwater mosquitoes, but provided more permanent water required for the production of *Culex* and *Culiseta* mosquitoes. Stabilizing the water at 12 inches or more in depth virtually eliminated all types of mosquito production at this depth. Stabilizing the water level also prevented the flooding of established waterfowl nests and influenced the change in vegetation from a moist soil to a more desirable emergent or submergent type.

(3) *Seasonal drawdown* during the mosquito season was the most versatile management practice for the existing water conditions and was successful in reducing both floodwater and permanent water mosquitoes. The drawdown may be either rapid or gradual but dry areas should not be reflooded before the end of the mosquito season. Seasonal withdrawal protects waterfowl nests from destruction by flooding. Periodic drying of certain types often has the effect of retarding or setting back ecological succession and may be effective in maintaining a given section of marsh in a desirable successional stage.

(4) *Flood irrigation* where the water

was uniformly distributed and either penetrated the soil or continued to flow over a level surface did not create mosquito-producing situations. Such irrigation is useful in introducing marsh vegetation into previously barren soil. Successful nesting in these areas was very high when water depth remained 2 inches or less.

(5) Water management techniques and practices used in this study that were effective in mosquito abatement often improved the marshes for waterfowl and other wildlife.

(6) Areas where water management for mosquito control was not practiced were in general highly productive of mosquitoes and other noxious insects and were of lesser value as wildlife habitats.

c. The development and improvement of multipurpose water management programs on the marshes and adjacent agricultural ground can be accomplished for the mutual benefit of all concerned without a significant curtailment of the objectives of any of the current programs.

d. On parts of the three study areas used in this investigation these multipurpose water management methods and techniques are demonstrable and can be used for this purpose.

3. As a result of this study the participants and others have become more fully aware and conscious of the objectives and requirements for multipurpose use of the water and the mutual benefits to be derived from such a program.

Recommendations.

1. The development and improvement of multipurpose water management programs on these marshes and adjacent agricultural ground can be accomplished by:

a. determining the objectives of the water use and the definite boundaries of the areas upon which it will be used;

b. determining the probable maximum and minimum flow of water available for each area and, as soon as possible, establish legal ownership and thus responsibility for its use;

c. providing a by-pass for excess water during maximum flow;

d. providing adequate structures for introducing, confining and removing the water and managing it on the selected area to obtain the desired objectives while it is in use and for its proper disposal after use.

2. Water Management Structures:

a. Use dikes to divide the marsh into units in which the water can be maintained and the level stabilized when the unit is in use.

b. The units should be small enough to be maintained during the periods of minimum water flow and sufficient in number for extending the water in the marsh when it is available and there is a need for additional flooded areas. As a guide in planning, the Utah State Department of Fish and Game calculates that each cubic foot per second flow of water entering a marsh can irrigate or flood one hundred acres of marsh ground.

c. Dikes should be constructed where necessary to confine the water on all sides within each unit.

d. Dikes should have a roadway adequate for automobile travel.

e. Inlets and outlets and channels leading to and from each unit should be adequate in size to accommodate the maximum flow entering each unit.

f. Spillways must be adequate in width and/or number to provide for the rapid outflow of any potential increase in the amount of water entering a unit.

g. The design, specifications and installation of the recommended units should be made in accordance with approved engineering principles and practices.

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