THE RATIONALE FOR ATTEMPTING TO DEFINE SALT MARSH MOSQUITO-BREEDING AREAS IN GALVESTON COUNTY BY REMOTE SENSING THE ASSOCIATED VEGETATION

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ABSTRACT

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This presentation is concerned with the rationale for attempting to define salt marsh mosquito breeding areas in Galveston County. It includes a botanical survey of the marsh plant communities, their relationship to flooding, and their exposure to salt water. Particular emphasis is given to *Distichlis spicata*, a widespread marsh grass. Evidence suggests that breeding areas of *Aedes sollicitans* are associated with *Distichlis* and that both species respond to similar ecological conditions in the salt marsh. Aspects of the remote sensing of the *Distichlis* are considered.

INTRODUCTION

Salt marsh mosquitoes *(Aedes sollicitans)* are prevalent in large numbers along the Atlantic and Gulf coasts of the United States. The species is a strong flier and a savage biter; the mosquito is a great nuisance and a potential transmitter of disease in populated coastal areas (ref. 1). Wherever *Aedes sollicitans* is a problem, effective mosquito control has been difficult because the species breeds in coastal salt marshes and then flies into populated areas (refs. 1, 2, 3).

The salt marsh biome provides one of the richest natural habitats in nature and one of the most important food resources for man. For example, 28 percent of the total fish catch in the United States comes from the Gulf of Mexico. Of these 28 percent, not less than 97.5 percent is composed of estuarine species, oysters, and crustaceans which spend some portion of their lives in estuaries and bays associated with the coastal salt marshes (ref. 4). Any imbalance by insecticide poisoning or habitat destruction for mosquito control may ruin the salt marsh as a food source for the associated fish and could devastate the American fish industry.

Researchers and mosquito control personnel have frequently noted that an association exists between the distribution of certain salt marsh grasses, *Distichlis spicata* and *Spartina patens*, and the breeding areas of *Aedes sollicitans* (refs. 3, 5, 6, 7, 8, 9, and 10).

A project for developing remote sensing techniques to support local or regional mosquito control efforts was initiated in the Galveston area in late 1973 and continues. A test site was selected by personnel from the Galveston County Mosquito Control District and the Department of Preventive Medicine and Community Health University of Texas Medical Branch, Galveston in a salt marsh near the town of

Hitchcock in south Galveston County to analyze salt marsh plant composition, to define the sources of local salt marsh mosquitoes, and to attempt the use of remote sensing for effectively delimiting the specific areas of mosquito production for efficient mosquito control without damaging the important associated salt marsh.

The project was developed for the Health Applications Office of the National Aeronautics and Space Administration (NASA) led by Dr. Charles W. Barnes, Chief, and directed by Dr. F. T. Satalowich, Deputy Manager. Analyses of mosquito/breeding areas are being conducted by Dr. Warren F. Pippin, whereas the author is concerned with the composition of the marsh vegetation. Uses of various remote sensing techniques for determining the distribution of the plants is in progress and will be reported later. In this communication, we will concern ourselves with the rationale for attempting to define mosquito breeding areas in South Galveston County and we will analyze the basic composition of the salt marsh vegetation for use in remote sensing the associated salt marsh mosquito breeding areas.

METHODS

To develop an understanding of the marsh itself, background reference material was studied at length (refs. 11, 12, 13). Plants were identified by using standard botanical keys (refs. 14 and 15). Extensive botanical surveys were conducted on the ground and from boats to define the extent and identity of all important marsh components of the test site. Aerial surveys were completed with aid of several NASA and Galveston County helicopter missions. Aerial photographs were made by the author by using a Nikon 35-mm camera at various altitudes from 0.91 m (3 ft.) to 3,048 m (10,000 ft.). Film types included color and color IR film. Other data were obtained by two NASA overflights on November 21, 1973, and April 2, 1974, which included the use of black-and white infrared film and 24-band multispectral scanners. Additional data were provided by the Earth Resources Technology Satellite when possible.

RESULTS AND DISCUSSION

Relationship of Mosquitoes to Salt Marsh Plants

Precise mosquito-breeding areas must be defined for an efficient mosquito control program. Mosquitoes themselves are much too small and ephemeral to be censused directly, but the vegetation growing in their breeding areas is a permanent and recognizable entity. Because the mapping of mosquito-breeding areas is done indirectly, it is necessary to justify the validity of this approach to understand why mosquito-breeding areas can be mapped by the remote sensing of the associated vegetation.

Breeding patterns of the salt marsh mosquito are governed by the occurrence of intermittent flooding after a long, dry period of days, weeks, or months. The mosquito eggs may be laid in almost any moist place in the marsh and its associated grassy areas. The species seems to be little affected by variations in water salinity. Broods arise in 5 to 30 days, depending on the temperature. The emergent adults mate, and the females lay most of their eggs in the debris at the base of the vegetation just above the receding waterline (refs. 2, 9, 10, 16, 17). There is no time for development in the duration of a single daily tidal action. The species must choose an area which holds water long enough for development (3 to 8 days), but not long enough to sustain predators (as in a permanent pool).

Several things are important here. First, the area cannot remain constantly flooded, or no eggs will be laid. Second, the area must be flooded long enough for a brood to complete development. Third, an area must be moist long enough for the eggs to be laid as the water recedes and dry long enough for the eggs to develop.

The salt marsh mosquito is not host specific to any species of plant, in the sense that it requires some plant species to help complete its development. This fact is borne out by the wide choice of reported breeding areas, from swimming pool and oil well effluents to salt marshes (refs. 18, 19, 20).

In the Galveston County salt marsh, the primary breeding areas lie above the weekly and daily high-tide zones. They include those regions that are flooded by heavy rains or storm tides and that retain the flood water for a few days, before the water drains away into the sea. Salt marshes frequently develop *Aedes* breeding grounds because the ground relief is very gradual, the soil is usually saturated, and the vegetation is dense enough to resist the flow of water, creating, in effect, a dam. As pointed out in reference 21, this dam retards the quick dispersal of flood waters that are otherwise unable to escape by draining into the saturated soil.

If the tidal action of an area, the height of the normal flood waters, and the topography are known, then the region of mosquito breeding can be theoretically and strictly defined. All of these predictable, measurable aspects are obtainable only on uniform beaches and marshes. In the natural marsh, anomalies abound, including the pocketing effect that inlets create, the dampering effect found on hidden or protected coves, and the dune patterning effect on tidal action. Additionally, the presence of variable vegetation types affects the rate and volume of tidal movement and flooding. The distribution of salt marsh vegetation critically reflects the soil and water conditions in a typical salt marsh. This same vegetation also reflects any anomalies in the marsh soil and water composition created by inlets, bayous, etc. (ref. 7). Further, the vegetation will respond in a predictable and appropriate manner to subsidence, dredging, road building, or grazing. The vegetation is a living record of marsh ecology, both past and present. Thus, a census of the vegetation provides a real picture of marsh conditions.

Based on the literature previously cited and on preliminary investigations by Dr. Pippin in the Galveston County mosquito test site, evidence suggests that *Aedes sollicitans* breeding occurs primarily in the *Distichlis spicata* association. Although there is no host specific correlation between the salt marsh mosquito and salt marsh plants, the tidal conditions that produce a stratification of vegetation may also serve to delineate mosquito-breeding areas. This is possible because the intermittent tidal-flooding situation conducive to production of *Aedes sollicitans* is also conducive to the establishment and growth of *Distichlis spicata*.

The vegetation is a more practical indicator of conditions in the marsh than is the measurement of environmental and physical parameters (ref. 7). Thus, the vegetation is a permanent, responsive, and recognizable indicator of mosquito breeding and other marsh conditions (refs. 22 and 23). In the author's opinion, vegetation is the easiest, most accurate factor to census and map large areas for mosquito control or to monitor marsh conditions.

SUMMARY OF MARSH VEGETATION

The salt marsh is a very harsh habitat for plants, primarily because of the constant presence of salt water. Marsh species must tolerate salt spray, saline wet soil, and occasional immersion by fresh and/or salt water. Because few plant species have any tolerance to these conditions, diversity of species is very restricted. Among those species which are tolerant to these conditions, the degree of tolerance to variations in salinity and flood patterns is different (ref. 11). Consequently, in a marsh there is a separation of plant species into essentially pure growths of single species in response to the variations in salinity and flood patterns.

Table I illustrates the comparative positions of the important species associations found in normal portions of the test site in south Galveston County, and table II provides a simple key to each association. The position of each association is related to land elevation and water salinity. Land elevation alone creates the salinity gradient. Fresh water enters on the upslope and surface sides via rain, flooding, and percolation of water from inland out toward the sea. This water movement leaches the sea salts and soil nutrients down and toward the sea. Salt water enters from the seaside (lower side), and it too percolates through the soil. Tidal activity, winds, and storms push salt water onto land for varying periods of time and at varying depths throughout the marsh. A dynamic equilibrium results between fresh water and salt water and between flooded lands and higher lands. It is the distribution of this dynamic equilibrium which decides the distribution of salt marsh grasses. The grasses are tolerant to specific degrees of salinity and flooding and are thus confined to the particular marsh sites which they can tolerate.

Spartina alterniflora resides in those areas of the marsh that are frequently flooded by salt water and remain wet and very saline. This species resides along the muddy estuary margins and sits about 7.5 cm (3 in.) above the normal daily high-tide mark. The roots always remain in saline sodden mud, whereas the aerial portions and crown receive periodic inundation by salt water for periods of several weeks during each winter. During the summer, however, prevailing offshore winds allow for the drying necessary for growth.

Associated with *Spartina alterniflora* is *Batis maritima*. It grows in situations nearly identical to *Spartina alterniflora*, but is not as widely established in this particular marsh. As a zone, the *Spartina alterniflora* community may cover hundreds of square yards. Much of the area surrounding *Spartina alterniflora* and *Batis maritima* is devoid of all vegetation and consists only of flats.

On the higher, or uphill, side of the *Spartina alterniflora* and *Batis maritima* district, the *Distichlis spicata* association develops. It is also well adapted to highly saline water and long periods of inundation. However, it must reside in higher ground because of its shorter stature which does not allow it to compete with *Spartina alterniflora*. Associated with the widespread mat-forming *Distichlis spicata* is *Salicornia virginica*. This perennial *Salicornia* is fairly common and widely distributed among the *Distichlis*, but it is not evident most of the year because of the density of *Distichlis* stands. In the spring, however, the *Salicornia* does evidence itself for a few weeks. It is from this district that most *Aedes sollicitans* appear to be produced in Galveston County. This grassy community may cover hundreds of acres along the shoreline, and the association may mix with *Spartina patens*.

Spartina patens grows with and above *Distichlis spicata*. This *Spartina* can stand conditions similar to the *Distichlis*. Both species withstand flooding, prolonged inundation, and salinity, but *Spartina patens* seems less able to withstand the depths of water occasionally encountered by the *Distichlis*. *Spartina patens* therefore resides on higher ground. However, this apparent elevation may be due in part to the tussock type growth of *Spartina patens*. In the test site this grass forms only small mixed associations of a few square yards each. However, in other marshes, this grass is very important and is therefore treated as a separate association.

The salt flat community is found on muddy flats above those districts frequented by *Distichlis spicata* and *Spartina patens*. The flats are also found throughout the *Spartina spartinae* association and may actually form a subcommunity within the *Spartina spartinae* association. The salt flat association derives its name from the presence of expanses of unvegetated saline clay soil. Around the edges of these areas, mounds of *Salicornia utahensis* and *Monanthochloe littoralis* grow. The annual *Salicornia bigelovii* forms pure stands in the center of the mud flats during the spring of each year. Flooding soon kills out the *Salicornia bigelovii*, again leaving only expanses of muddy salt flats. This association is seldom extensive and only occurs as a marginal fringe between the *Spartina spartinae* association and the *Distichlis spicata* association.

The *Spartina spartinae* association resides on high ground of at least 25. cm (10 in.) above highest tide where inundations occur only during storm tides rather than at the weekly or monthly intervals as found in the *Spartina alterniflora* and *Distichlis spicata* districts. *Spartina spartinae* has minimal tolerance to saline conditions, and inundation for extended periods is fatal to it. The ground, however, usually remains sodden because of poor drainage and frequent rains, which lower the salinity levels considerably and maintain them most of the year. In the upper portions of the *Spartina spartinae* district (over 91 cm, or 3 ft.), only tropical storm and hurricane-associated floods occur. The *Spartina spartinae* association is easily the most extensive vegetation type of the salt marsh. As much as 50 percent of the total marsh and nearly all of the higher portions of the marsh are dominated by this grass.

AERIAL CHARACTERISTICS OF *DISTICHLIS* AND *SPARTINA PATENS*

To remotely sense *Distichlis spicata* and *Spartina patens*, the grasses most commonly associated with *Aedes sollicitans* breeding, it is necessary to identify them at various altitudes.

In the Galveston test site, *Distichlis* forms essentially pure stands of grass which resembles a lawn from a distance. Each grass plant is composed of a stem 7.5 to 45. cm (3 to 18 in.) tall with two ranks of leaves, each 7.5 cm (3 in.) long, slender, and slightly curved. *Distichlis* forms extensive mats of almost pure grass and with only an occasional *Salicornia virginica* mixed among the grass. Typically, the mat is very dense. The lawn-like appearance is very diagnostic and is recognizable at altitudes in excess of 305. m (1,000 ft.). Therefore, identification of *Distichlis* should be possible from any low-flying aircraft or imagery taken over a salt marsh. Diagnostic characteristics of this association include the short, fine-leaved stature, the occurrence on mud flats, the lawn-like uniformity, the vast pure populations, the gray-green summer color and straw-yellow winter color, and the ability to be flooded for weeks each winter without dying out.

The second important association is a rather small one composed solely of *Spartina patens*. The community is common in Louisiana and to the east and north of Galveston County, but is not common in the immediate Galveston mosquito test site.

Spartina patens is best characterized by its medium-green long, narrow foliage which gives a silky hair-like effect when viewed in context with the other marsh land communities. The grass stands 38 to 6[illegible] (15 to 24 in.) tall, forms clumps, and frequently occurs near *Distichlis spicata*. The two grasses are easily separated because the lawn-like *Distichlis* differs markedly from the soft and hair-like *Spartina patens*. Additionally, color or black-and-white infrared photographs of the marsh separate *Spartina patens* from all other grasses in the marsh.

CONCLUSIONS

Careful analysis of appropriate literature reveals that the occurrence of salt marsh mosquitoes (Aedes sollunctions) may be tied to particular vegetation types; i.e., *Distichlis spicata* and *Spartina patens*. Analysis of the Galveston salt marsh community, reveals five major plant associations ranging from sea level to 91 cm (3 ft.) in elevation. The associations are *Spartina alterniflora*, *Distichlis spicata*, *Spartina patens*, salt flats, and *Spartina spartinae*. From aircraft overflights at various altitudes, characteristics that identify *Distichlis spicata* and *Spartina patens* were defined. These characteristics may be used in identifying the associated mosquito-breeding areas either visually or by remote sensing.

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TABLE I. – SUMMARY OF THE PLANT COMMUNITIES AND ASSOCIATED GROUND ELEVATION IN THE GALVESTON MOSQUITO TEST SITE

Ground elevation		Plant communities in the Galveston mosquito test site	Environmental notes
Cm.	In.		
121.9	48	Trees	
60.9 - 182.8	24 - 72	Shrubs, grasses	Hurricane and tropical storm tide zone
60.9 - 121.9	24 - 48	Mixed grasses	
25.4 - 91.4	10 - 36	*Spartina spartinae*	Occasional flooding
25.4 - 60.9	10 - 24	*Salicornia/Monanthochloe* + void	Occasional flooding
20.3 - 39.4	8 - 12	*Spartina patens*	Monthly high tide and seasonal wind
15.2 - 25.4	6 - 10	*Distichlis spicata*	Monthly high tide and seasonal wind
7.6 - 20.3	3 - 8	*Batis* + void	Tide zone
7.6 - 15.2	3 - 6	*Spartina alterniflora* + void	Tide zone
0	0		Mean high tide on a calm day

TABLE II. – REFERENCE KEY TO THE SALT MARSH ASSOCIATION

Vegetation	Association
Barren areas boarded by small shrubby mounds	Salt flats
Vast lawn-like expanses of green to gray-green grass	*Distichlis spicata*
Circles or expanses of reedy coarse grass	*Spartina alterniflora*
Circles or expanses of low uniform shrubs with light-green leaves and often conspicuous stems (not a grass)	*Batis maritima*, component of the *spartina alterniflora*
Clumps or tufts of stiff, coarse wire-like grass	*Spartina spartinae*
Clumps or tufts of soft, silky green hair-like grass	*Spartina patens*