SALT MARSH PRODUCTIVITY AS AFFECTED BY THE SELECTIVE DITCHING TECHNIQUE, OPEN MARSH WATER MANAGEMENT[1]

J. K. SHISLER

Mosquito Research and Control, New Jersey Agricultural Experiment Station

AND

D. M. JOBBINS

Dept. of Entomology and Economic Zoology, Rutgers—The State University, News Brunswick, N.J. 08903

ABSTRACT: To evaluate the effect of selective ditching for mosquito control on productivity, unditched and ditched sections of short form *Spartina alterniflora* Loisel, marsh were sampled in New Jersey. Standing vegetational biomasses, densities of fiddler crabs (*Uca pugnax*), isopods (*Philoscia vittata*) and salt marsh snails (*Melampus bidentatus*) were sampled 3 and 4 years after the marsh was ditched.

Significantly higher total (live and dead) vegetational biomasses were found in the mosquito ditched marsh (1462.3 dry g/m^2) compared to that of the unditched marsh (852.5 dry g/m^2). This difference was probably the result of the increase in tidal circulation and possible nitrogen fixation in the ditched marsh. The mosquito ditched marsh seemed to be progressing towards a more productive-low marsh community as evidenced by: 1) significant increases in fiddler crab holes and isopod densities; 2) decreases in salt marsh snail densities; and 3) increases in individual *S. alterniflora* stem biomasses.

INTRODUCTION

The manipulation of water levels can be an important and ecologically sound method for mosquito control. Smith (1907) in New Jersey first advocated filling in *Aedes sollicitans* breeding depressions and later suggested ditching into such depressions to enhance tidal circulation and to allow entry of predaceous fish into these breeding areas. The method was altered after Smith's death to a simpler parallel ditch system and these ditches may be seen today in large sections of many East Coast marshes. Smith's major premise was to alter only those areas of the marsh that bred mosquitoes. Recently, New Jersey has been trying to apply Smith's water management methods utilizing modern equipment. One method that has been developed is termed Open Marsh Water Management (OMWM) (Ferrigno and Jobbins 1968, Ferrigno et al. 1975). OMWM is directed at larval control by the elimination of actual mosquito breeding depressions while increasing estuarine food web components. OMWM incorporates the utilization of tidal ditches, ponds and pond radials which are comparable to the major features of the salt marsh, tidal creeks and salt marsh ponds (Ferrigno et al. 1975). Tidal ditching in OMWM increases the circulation of the tidal water through the marsh (Shisler and Jobbins 1977), which is important in the movement of organic seston, water-borne chemicals, and associated flora and fauna.

Increased productivity associated with nitrogen fertilization indicates that the growth of short form *Spartina alterniflora* is nitrogen-limited (Sullivan and Daiber 1974, Gallagher 1975, Broome et al. 1975, Valiela et al. 1973). Electrophoretic analyses of total soluble protein and isozymes of the tall and short form *S. alterniflora* and reciprocal transplants of the 2

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers—The State University, New Brunswick, N. J.

forms by Shea et al. (1975) have shown that the short and tall forms are ecophenes, rather than ecotypes. Valiela et al. (1973) state that uncontaminated salt marshes probably obtain the bulk of their nitrogen from flooding tidal waters. Therefore, the increased tidal circulation resulting from water management for mosquito control (Shisler and Jobbins 1977) should increase the availability of nitrogen and increase the productivity of short form *S. alterniflora*. The objective of this study was to measure the effect of increased tidal circulation caused by water management on the productivity of *S. alterniflora* and the associated invertebrates of the high marsh.

MATERIALS AND METHODS

The marsh studied was located in Tuckerton, New Jersey. The study area comprised approximately 20 ha of salt marsh where OMWM procedures (Ferrigno and Jobbins 1968) were utilized on one-half of the area in the fall of 1970. Tidal ditches (0.5 m wide and 1.0 m deep) were constructed with a backhoe mounted on a John Deere tractor and spoil was mashed down to the marsh surface.

Marsh vegetation in the study area consisted mainly of short *S. alterniflora* (> 30 cm) and *S. patens* as shown in a 1971 survey of the area by the New Jersey Department of Environmental Protection (Map Sheet #259–2088). The area was divided into ditched and unditched areas and three 10 x 10 m plots of typical short *S. alterniflora* were selected and sampled in each marsh area during the fall of 1973 and 1974. The three plots within each marsh area would account for variability within each marsh area (treatment effect) and yearly samples within each plot accounted for any yearly variations. Fall standing crop biomasses were determined by harvesting the above ground biomass of *S. alterniflora* with hand clippers in 5 randomly tossed 0.04 m² quadrats (Busch 1975) within each of the plots. The plots were located between ditches at least 10 m from a ditch to eliminate the ditch edge effect. Biomass samples were separated into live and dead components and oven dried at 100°C for 24 hr before weighing. Density of *S. alternilfora* stems and the numbers of fiddler crab (*Uca pugnax*) holes, salt marsh snails (*Melampus bidentatus*) and isopods (*Philoscia vittata*) found in the quadrats in the field and during the separation of the vegetative samples were recorded for each sample. A partially hierarchic analysis of variance was performed to test for significance of differences in treatment (ditched or unditched) plots within treatments, sampling years and various interactions among these variables (Table 1). The Student-Newman-Kuels multiple range test (SKN) was used to compare differences in means (Zar 1974).

RESULTS

The 1974 ditched total *S. alterniflora* biomass mean was significantly higher than the 1973 mean yet there were no real differences between these years for the unditched marsh total vegetational biomass mean (Tables 1 & 2). This increase in total biomass in the ditched marsh was due to a significant increase in that year's live component (Tables 1 & 2). The coefficient of variation of 20.9% for the live component falls between that reported by Squires and Good (1974) 6.4% to 46.6% in New Jersey while below the observed 38% by Nixon and Oviatt (1973) in Rhode Island. Significantly higher dead *S. alterniflora* biomass means were observed in the ditched marsh than in the unditched marsh.

Shoot density was significantly less in the ditched marsh (Table 2). Dividing the 2-year live vegetative biomasses (ditched = 715.0 g/m², unditched = 482.5 g/m²) by the marsh type shoot densities (ditched = 397.5 shoots/m², unditched = 2647.5 shoots/m²) yields average shoot biomasses of 1.8 and 0.2 g/shoot, respectively. Since a significant year effect was observed in the ditched marsh live vegetational biomass data (Table 1), analysis of individual year shoot biomasses revealed a 1973 mean

Table 1. Summary analysis of variance results for sampled parameters in ditched and unditched marshes for 1973 and 1974.

		Total Veg.	Live Biomass	Dead Biomass	Shoot Density	*Uca*	Isopods	*Melampus*
	Df.	F. Values	F. Values	F. Values	F. Values	F. Values	F. Values	F. Values
Total	59							
Treatment	1	102.99[3]	49.91[3]	71.72[3]	321.66[3]	80.42[3]	29.48[3]	79.87[3]
Plots/T	4	NS	NS	NS	NS	NS	NS	NS
Years	1	NS	NS	NS	NS	NS	NS	23.36[3]
Y x T	1	5.18[1]	5.64[2]	NS	NS	NS	NS	27.68[3]
Y x P/T	4	NS	NS	NS	NS	NS	NS	NS
Samples (Y x P/T)	48							
Coefficient of Variation		20.2%	20.9%	31.3%	31.9%	81.2%	111.0%	71.0%

[1] $0.05 < P < 0.25$.
[2] $0.25 < P < 0.001$.
[3] $P < 0.001$.
NS = Not significant

value of 1.5 g/shoot and 1974 mean value 2.3 g/shoot.

The high variability in fauna densities (Table 1) could be associated with sampling methods and non-random distribution of the individuals. *Uca* burrow densities ranged from 0 to 140 active burrows/m^2 (Table 2) which is less than those reported by Lesser et al. (1976) in a ditched Misspillion marsh in Delaware. Ditched marsh isopod mean densities were approximately 10 times higher than the unditched means (Table 2). Significantly higher salt marsh snail densities were observed in 1974 than in 1973 in the unditched marsh (Table 2). The increase could be caused by changes in the behavior of the snail, which has a clumping tendency (Apley 1970).

DISCUSSION

The 1.4-fold increase in live standing crop of short form *S. alterniflora* and a 9-fold greater mean shoot biomass on the ditched marsh have presumably occurred in response to increased tidal circulation and the accompanying nitrogen resulting from OMWM procedures completed in 1970. Our data showing increases in standing crop are comparable to data of Gallagher 1975 and Shea et al. 1975. The increased tidal circulation in the ditched marsh should accelerate both the removal of detritus and the decomposition of the dead material causing a decrease in the dead vegetative biomass (Gallagher 1975). However, the opposite effect was observed in the ditched marsh where the ratio of live to dead biomass was less than that on the unditched marsh (Table 3). Odum and de la Cruz (1967) reported that 42.0% of the total dry weight of *S. alterniflora* on Georgia marshes was still present in the litter bags after 300 days. Squires and Good (1974) in New Jersey found almost half of the previous year's standing crop of short *S. alterniflora* present on the marsh at the beginning of the following summer. The increase in dead biomass on the ditched marsh may result from a greatly increased stem biomass, since Gooselink and Kirby (1974) showed an inverse relationship of

Table 2. Comparison of 1973 and 1974 0.04 m² quadrat data in ditched (D) and unditched (U) marshes. LSD = least significant differences at a 0.01 level.

Year	Plots	Total Veg. Biomass		Live Veg. Biomass		Dead Veg. Biomass		Shoot Density		*Uca* Holes		Isopods		*Melampus*	
		D	U	D	U	D	U	D	U	D	U	D	U	D	U
1973	1	61.0	33.5	27.4	18.5	33.6	15.0	21.8	123.4	3.0	0.2	10.4	0.0	5.6	8.4
	2	57.6	36.9	24.5	22.6	33.1	14.3	17.0	94.2	2.4	0.0	8.6	0.4	3.0	21.6
	3	44.5	35.9	28.8	21.1	15.7	14.7	16.4	89.4	3.7	0.2	6.6	1.8	3.8	20.2
	$\bar{X}_n = 15$	54.4	35.5	26.9	20.7	27.5	14.7	18.4	102.3	2.7	0.1	8.5	0.7	4.1	16.7
1974	1	65.9	30.6	28.8	16.0	37.1	14.6	13.6	98.8	2.8	0.0	3.2	2.2	2.0	54.0
	2	61.1	31.5	32.3	17.8	29.3	13.7	13.8	140.0	5.6	0.2	9.2	1.6	4.0	44.2
	3	60.5	35.6	29.6	20.1	30.9	15.5	12.4	90.0	2.8	0.0	13.4	0.4	2.0	55.8
	$\bar{X}_n = 15$	62.5	32.6	30.2	17.9	32.4	14.6	13.3	109.6	3.7	0.1	8.6	1.4	2.7	51.3
Plot LSD		15.8		8.6		13.7		33.3		2.54		9.1		22.6	
Year x T LSD		9.1		3.7		7.9		19.2		1.46		5.3		13.1	
Marsh $\bar{X}$		58.5	34.1	28.6	19.3	29.9	14.7	15.9	105.9	3.2	0.1	8.6	1.1	3.4	34.0
LSD		6.5		3.5		5.6		13.6		1.0		3.7		9.3	

Table 3. Mean standing crops ($n = 30$) of live and dead *Spartina alterniflora* (dry g weight/m^{-2}) in managed (ditched) and unditched marshes.

		Live	Dead	Ratio
Ditched	1973	672.5	687.5	0.97
	1974	755.0	810.0	0.93
Unditched	1973	517.5	367.5	1.41
	1974	447.5	365.0	1.23

substrate size to rate of *S. alterniflora* decomposition indicating a slower rate of decomposition in the ditched marsh.

The significantly lower density of *S. alterniflora* shoots in the ditched marsh is an important factor affecting the kinds and densities of organisms inhabiting the marsh. In the unditched marsh, the higher density of shoots would not allow movement of large invertebrates on marsh surface. Rockel (1969) showed a decrease in fiddler crab holes along a transect running from the ditch bank, supporting the growth of tall *S. alterniflora* (less shoot density) to the short *S. alterniflora* zone (greater shoot density). The increase in fiddler crab hole density and increased biomass of *S. alterniflora* (Table 2) indicate that the ditched marsh surface approaches the tall *S. alterniflora* end of this continuum. Lesser et al. (1976) also reported increases in *Uca* densities and *S. alterniflora* production in a Delaware ditched salt marsh. The decrease in *M. bidentatus* in the ditched marsh also supports this, because they inhabit the high marsh (Kerwin 1972).

The movement of detritus from salt marshes to adjacent estuaries has received a great deal of attention in recent years. Odum and de la Cruz (1967), Heald (1971), Schultz and Quinn (1973), and Shisler and Jobbins (1977) have shown a net export of organic carbon. Therefore, the increase in vegetative biomass and tidal circulation in the ditched marsh should eventually result in increased food sources for salt marsh-estuarine organisms.

CONCLUSIONS

The construction of a network of ditches into actual mosquito breeding depressions allows for daily circulation of tidal water. These waters carrying nutrients increased the growth of the vegetation along the ditch banks. The decrease shoot density in the ditched marsh allows easier movement of invertebrates, therefore increasing their population densities. The combination of increased biomass of vegetation and increased populations of intertidal organisms (*Uca* and isopods) moves the ditched segments of the high marsh towards the low marsh system.

ACKNOWLEDGMENTS

We thank Dr. T. L. Schulze for critically reviewing the manuscript. This research was supported by a grant to the senior author from the State Mosquito Control Commission.

References Cited

Apley, M. 1970. Field studies of life history, gonadal cycle, and reproduction in *Melampus bidentatus*. Malacologia 10:381–397.

Busch, D. A. 1975. The failure of temefos and chlorpyrifos to affect the short-term productivity of *Spartina alterniflora* and *S. patens* on a New Jersey salt marsh. Proc. N. J. Mosquito Exterm. Assoc. 62:50–55.

Broome, S. W., W. W. Woodhouse, Jr. and E. D. Seneca. 1975. The relationship of mineral nutrients to growth of *Spartina alterniflora* in North Carolina: II. The effects of N, P, and Fe fertilizers. Soil Sci. Soc. Amer. Proc. 39:301–307.

Ferrigno, F. and D. M. Jobbins. 1968. Open marsh water management. Proc. N. J. Mosquito Exterm. Assoc. 55:104–115.

Ferrigno, F., P. Slavin and D. M. Jobbins. 1975. Salt marsh water management for mosquito control. Proc. N. J. Mosquito Exterm. Assoc. 62:30–38.

Gallagher, J. L. 1975. Effect of an ammonium nitrate pulse on the growth and elemental composition of natural stands of *Spartina alterniflora* and *Juncus roemerianus*. Amer. J. Bot. 62:644–648.

Gosselink, J. G. and C. J. Kirby. 1974. Decomposition of salt marsh grass, *Spartina alterniflora* Loisel. Limnol. Oceanogr. 19:825–832.

Heald, E. J. 1971. The production of organic detritus in a south Florida estuary. Sea Grant Tech. Bull. No. 6, Univ. of Miami. 110 pp.

Kerwin, J. A. 1972. Distribution of the salt marsh snail (*Melampus bidentatus* Say) in the Poropotank River Area, Virginia. Chesapeake Sci. 13:150–153.

Lesser, C. R., F. J. Murphey and R. W. Lake. 1976. Some effects of grid system mosquito control ditching on salt marsh biota in Delaware. Mosquito News 36(1):69–77.

Nixon, S. W. and C. A. Oviatt. 1973. Analysis of local variation in the standing crop of *Spartina alterniflora*. Botanica Marina 16:103–109.

Odum, E. P. and A. A. de la Cruz. 1967. Particulate organic detritus in a Georgia salt-marsh-estuarine ecosystem, p. 383–388. *In* G. H. Lauff (ed.), *Estuaries*. Publ. Am. Assoc. Adv. Sci. 83.

Rockel, E. 1969. Marsh physiography: Influence on distribution of intertidal organisms. Proc. N. J. Mosquito Exterm. Assoc. 56:102–116.

Schultz, D. M. and J. G. Quinn. 1973. Fatty acid composition of organic detritus from *Spartina alterniflora*. Estuarine and Coastal Mar. Sci. 1:177–190.

Shea, M. L., R. S. Warren and W. A. Niering. 1975. Biochemical and transplantation studies of the growth form of *Spartina alterniflora* on Connecticut salt marshes. Ecology 56:461–466.

Shisler, J. K. and D. M. Jobbins. 1977. Tidal variations on the movement of organic carbon in salt marshes in New Jersey. Marine Biology. 40:127–134.

Smith, J. B. 1907. The New Jersey salt marsh and its improvement. Bull. N. J. Agr. Sta. 207:1–24.

Squires, E. R. and R. Good. 1974. Seasonal changes in the productivity, caloric content, and chemical composition of a population of salt marsh cord-grass (*Spartina alterniflora*). Chesapeake Sci. 15:63–71.

Sullivan, J. J. and F. C. Daiber. 1974. Response in production of cord grass, *Spartina alterniflora*, to inorganic nitrogen and phosphorus fertilizer. Chesapeake Sci. 15:121–123.

Valiela, I., J. M. Teal and W. Sass. 1973. Nutrient retention in salt marsh plots experimentally fertilized with sewage sludge. Estuarine and Coastal Mar. Sci. 1:261–269.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall. Englewood Cliff, New Jersey. 620 pp.