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EFFECT OF SEDIMENT DEPTH AND SEDIMENT TYPE ON THE SURVIVAL OF *VALLISNERIA AMERICANA* MICHX GROWN FROM TUBERS

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ABSTRACT

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Sedimentation resulting from storms may have been one of the reasons for the elimination of submersed aquatic vegetation from the tidal Potomac River in the late 1930's. Laboratory studies were conducted to investigate the effects of different depths of overlying sediment and composition of sediment on the survival of *Vallisneria americana* Michx (wildcelery) grown from tubers. Survival of plants grown from tubers decreased significantly with increasing sediment depth. Survival of tubers declined from 90% or more when buried in 10 cm to no survival in greater than 25 cm of sediment. Survival with depth in sand was significantly lower than in silty clay.

Field investigation determined that the majority of tubers in *Vallisneria* beds are distributed between 10 and 20 cm in depth in silty clay and between 5 and 15 cm in depth in sand. Based on the field distribution of tubers and on the percent survival of plants growing from tubers at each depth in the laboratory experiment, we suggest that the deposition of 10 cm or more of sediment by severe storms such as occurred in the 1930s could contribute to the loss of vegetation in the tidal Potomac River.

INTRODUCTION

A survey of the distribution and abundance of submersed aquatic macrophytes in the tidal Potomac River and Estuary from 1978 to 1981 documented the fact that the freshwater tidal river above Quantico, Virginia (Fig. 1) had little vegetation, and that plant populations were largely confined to the transition zone of the estuary where fresh and brackish water mix (Haramis and Carter, 1983). Before the late 1930's, the tidal Potomac River contained aquatic macrophytes in abundance, chiefly *Vallisneria american* Michx, *Ceratophyllum demersum* L. and *Potamogeton* spp. including *Potamogeton crispus* L. (Seaman, 1875; Cumming et al., 1916; The Secretary of the Treasury, 1933). The loss of aquatic plants was reported by Martin and Uhler in 1939. We hypothesize that one of the factors

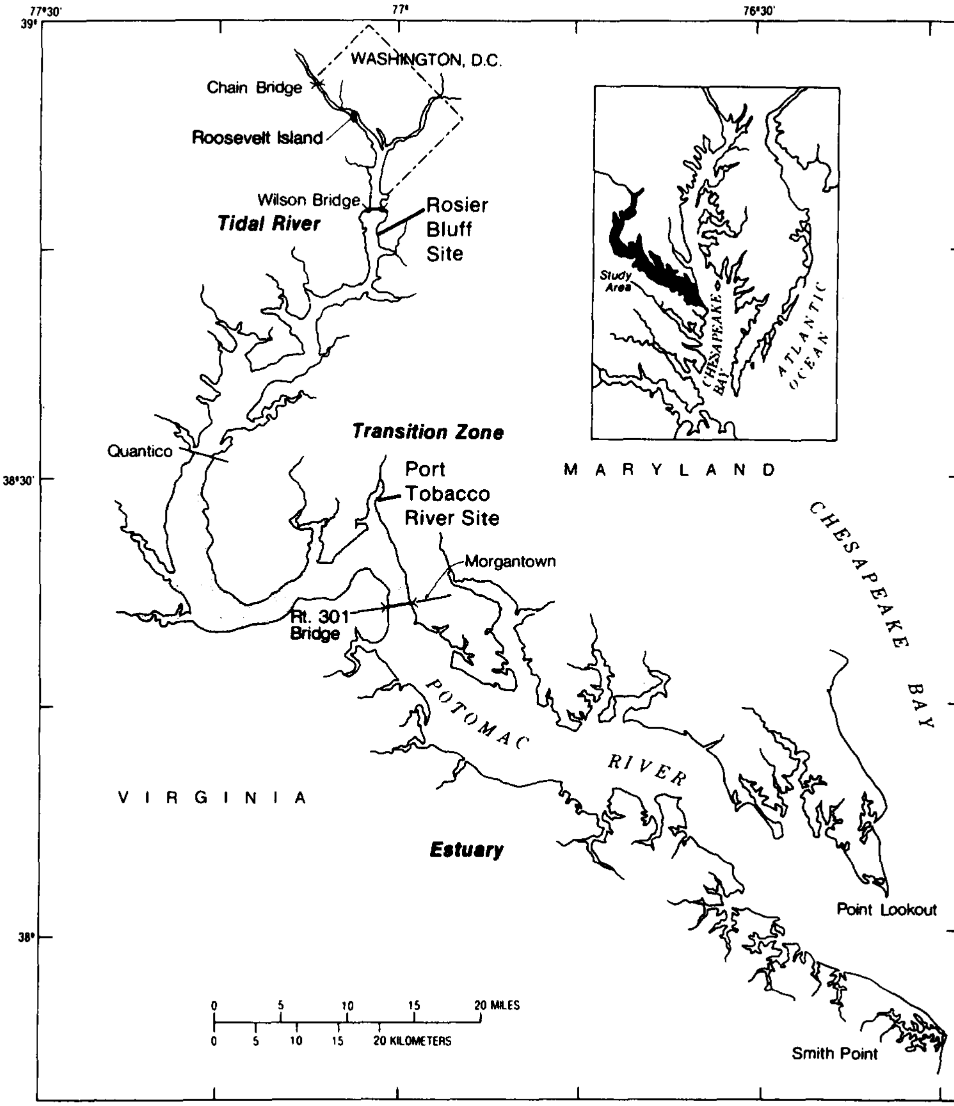


Fig. 1. Locations of sampling sites in the tidal Potomac River and Estuary.

responsible for the almost complete disappearance of submersed aquatic vegetation from the tidal river was deposition of sediment associated with extensive storms in the late 1930's (Carter et al., 1985a).

Erosion and siltation related to severe storms are known to cause extensive damage to submersed aquatic plant populations (Haslam, 1978). However, very little quantitative information is available regarding the depth of sediment which actually inhibits or prevents plant growth. Preliminary laboratory experiments conducted in 1981 and 1983 suggested that the survival of *Vallisneria* grown from tubers decreased as a function of increasing depth of overlying silty clay sediment. The objective of this study was firstly to document the distribution of *Vallisneria* tubers in natural beds and secondly to quantify the effect of deposition of sediment of different depths and composition on the survival of *Vallisneria* grown from tubers. *Vallisneria* was chosen because records show that extensive beds of this species covered the shallow flats below Washington, D.C. in the early 1900's (Cumming et al., 1916; The Secretary of the Treasury, 1933). We chose silty clay and sand because of their predominance near shore in the tidal Potomac River (Carter et al., 1985a,b).

Towards the end of the growing season, *Vallisneria* forms small tubers from the lateral bud of the rhizome. Soluble carbohydrates are translocated from the leaves into the rhizome and are stored as starch in the tubers. Each tuber, sheathed by enlarged scale leaves, is carried to some depth by the positive geotropic response of the rhizome (Sculthorpe, 1967). When mature, tubers are from 1 to 5 cm long and sub-cylindrical in shape. During the winter, the rhizomes decay leaving just the dormant tubers. In the spring, under the stimulus of rising temperatures, the basal one or two internodes of the apical bud elongate, carrying the bud up to the sediment surface. Leaves unfold and adventitious roots develop from the nodes, the tuber gradually shrinking as its food reserves are mobilized and exhausted.

METHODS

In January, 1984, silty clay sediment and tubers of *Vallisneria americana* were collected with a post-hole digger from the Port Tobacco River (a Potomac Estuary tributary); sand was collected from the Potomac River at Rosier Bluff, Maryland (Fig. 1), where *Vallisneria* had been successfully transplanted in 1980. All sediment was sieved to remove tubers. In the laboratory, 240 tubers, 2—5 cm in length, were randomly divided into groups of 10. Each group was randomly selected and planted in containers (19 cm in diameter) previously filled with 5 cm of silty clay or sand. Tubers were embedded in the sediment so that the apical bud was level with the sediment surface. Tubers were then buried with silty clay or sand at 6 different depths. Including the 5-cm planting layer, the total depth of sediment was 10, 15, 20, 25, 30 and 35 cm. Two replicates of each depth were made with each sediment-type. The sediment was covered with 8—10 cm of aerated fresh water from the river. The sides of the transparent containers were wrapped to the level of the sediment so that illumination was from the top. Light intensity was maintained at 24 $\mu E\ m^{-2}\ s^{-1}$ for 14 h per day and room temperature was maintained at 18—22°C. Observations were recorded weekly. After 7 weeks, plants and tubers were dug up. The number of tubers producing a viable plant was recorded. Sprouts developed from rhizomes were not counted. If the plants never reached the soil surface or the leaves never unfolded or turned green and roots did not develop, the plants were considered non-viable.

In the field, we examined the natural distribution of *Vallisneria* tubers. In January, 1984, 10 cores (14 cm in diameter) were taken in silty clay in the Port Tobacco River and 10 in sand at Rosier Bluff using a post-hole digger. All cores were divided into 4 sections by sediment depth, 0—5, 5—10, 10—15 and 15—20 cm, and the number of tubers per section was recorded. In silty clay we were able to obtain cores deeper than 20 cm by immediately returning to the same hole to get a second core. The data from 20—30 cm depth are somewhat suspect because the holes may have partially caved in before the lower core was taken.

RESULTS

The laboratory experiments showed that there was a significant decrease in survival of plants from tubers as depth increased (Fig. 2). In both types of sediment, 90% or more of the tubers survived when buried to 10 cm; survival decreased to zero in greater than 25 cm of sediment. There was also a significant difference between the survival of plants grown from tubers in silty clay and sand. Survival with depth was lower in sand than in silty clay. All successful plants had appeared above the soil within 3 weeks in silty clay and within 4 weeks in sand.

Field results are plotted in Figs. 3 and 4. In the *Vallisneria* bed in sand, the majority of the tubers were located between 5 and 15 cm depth. The average number of tubers per core was 3 and the range was 0—7 tubers. In silty clay, the majority of the tubers were located between 10 and 20 cm depth with an average of 6 tubers and a range of 0—17 tubers per core.

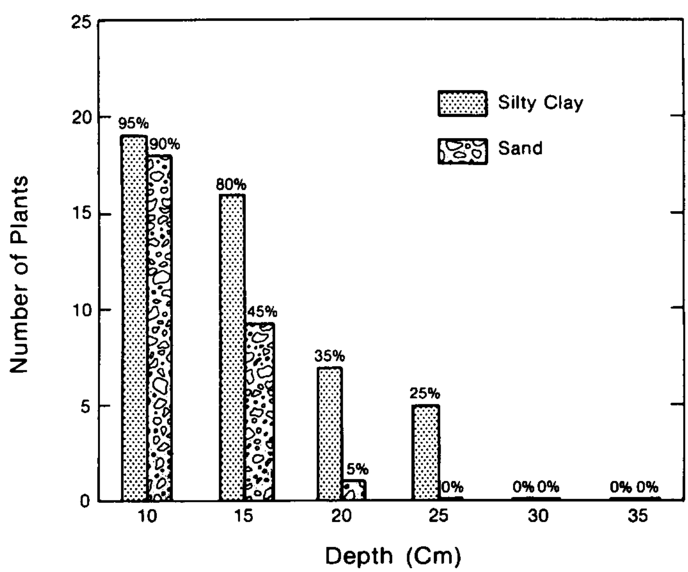
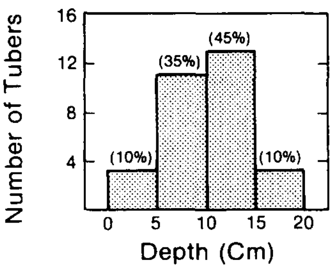


Fig. 2. Number of viable plants grown from *Vallisneria* tubers versus depth of silty clay and sand after 7 weeks.



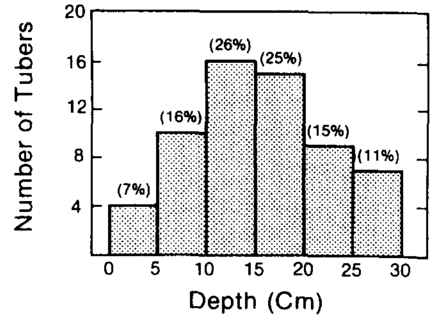


Fig. 3. Number of *Vallisneria* tubers versus depth in sand beds in the Potomac River at Rosier Bluff, Maryland.

Fig. 4. Number of *Vallisneria* tubers versus depth in silty clay beds in the Port Tobacco River, Maryland.

DISCUSSION AND CONCLUSIONS

The natural distribution range of tubers in sand or silt assures that when annual sedimentation occurs, a percentage of the tubers remains at an optimum depth for establishing new plants. Pb-210 analyses of 7 cores taken in 1981 in the Potomac River Estuary indicate that sediment is accumulating at rates ranging from 0.16 to 1.80 cm year^{-1}, being lowest on shallow-water flats near shore and near the mouth, and increasing towards the head of the estuary (Knebel et al., 1981). Flow in the autumn and winter of 1984 was average; the amount of sediment accumulated during 1984, therefore, should be less than 2 cm. Tubers covered with less than 2 cm of sediment remain at optimum depth for sprouting new plants, according to our laboratory data.

Severe storms can cause extensive damage to submersed aquatic plant populations (Bayley et al., 1968; Haslam, 1978). Erosion may remove plants and increased turbidity, scouring action and deposition may change the light conditions and the composition of the bottom sediments and smother the plant beds. According to the Chesapeake Research Consortium (1976), the impact of Hurricane Agnes on the upper Chesapeake Bay (Fig. 1) was mostly depositional. The Susquehanna Flats, heavily colonized by submersed aquatic vegetation, received 15—25 cm of sediment. Following the storm, populations of *Vallisneria americana*, *Najas* sp. and *Elodea canadensis* Michx fell to zero in previously vegetated areas and there was no recovery by 1975. Although it is not possible to estimate the amount of scour or deposition in the tidal Potomac River caused by the 1930 storms, it is interesting that Hirschberg and Schubel (1979) found sediment deposition of more than 20 cm in the upper Chesapeake Bay, which they attributed to the severe storm of 1936.

Frequency and intensity of storms are important because plant tolerance is dictated by regrowth potential in the interval between storms. After

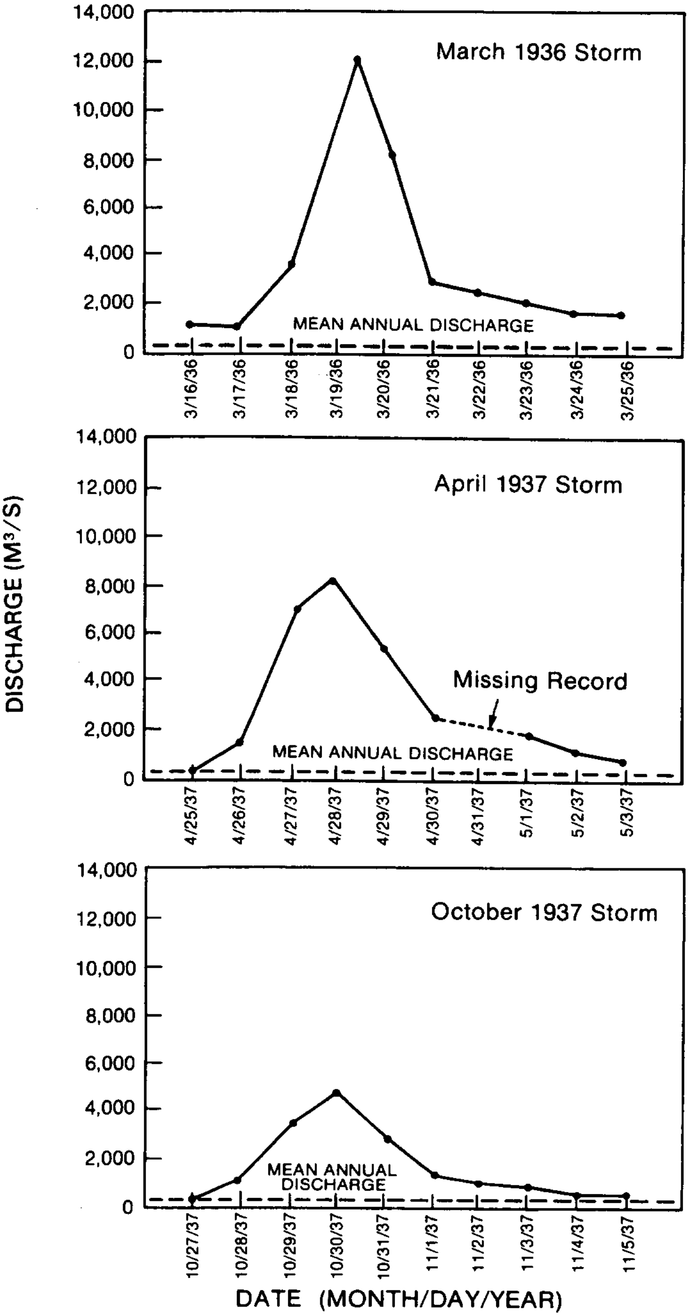


Fig. 5. Discharge during storm events measured at the Potomac River near Washington, DC, in cubic meters per second (Grover, 1937, 1939, 1940).

exceptionally severe storms, years or decades may be required for recovery (Haslam, 1978). High discharges lasting several days are more damaging than short ones and, given equal discharge, storms in which the discharge increases very rapidly are more damaging than those where the discharge increases more slowly. Stormflows in the winter and spring cause the most erosion because there is no vegetative cover to protect the soil; plant roots and rhizomes do not form a strong anchoring mat until later in the growing season (Haslam, 1978). Damage at the end of the annual growth period may lower biomass leaving the stands sparse and susceptible to damage from later storms. Storm damage occurring several years in a row may lead to a decrease in or total loss of plant populations.

It is possible that the effects of three major storms that occurred within a 19-month period (March 1936—October 1937) (Fig. 5) could have totally devastated the submersed aquatic vegetation in the reach below Washington, DC, by covering the beds with sediment before the growing season or by scouring the bottom and carrying away roots, rhizomes, seeds and winter buds. The March 1936 storm had the most rapid rise in discharge and the highest discharge, and occurred when the plant beds were most vulnerable to erosion. Assuming damage was heavy, but that pockets of plants survived, the subsequent storms of April 1937 and October 1937, could have removed any regrowth. The October 1937 storm, hitting an already weakened population at the end of the growing season, could have eliminated most of the submersed aquatic vegetation in the tidal river except for pockets too small to provide sufficient material for revegetation.

Many factors, both natural and man-related, have been implicated in the decline of submersed aquatic vegetation populations in the tidal Potomac River (Martin and Uhler, 1939; Jaworski et al., 1971; Phillips et al., 1978; Carter et al., 1983, 1985a). Isolation of the factors responsible for the decline of plants is difficult because of the presence and interaction of multiple factors. In this experiment only the effect of sedimentation was examined. The results show that the sedimentation related to storm events cannot be ignored as a possible contributor to the elimination of submersed aquatic vegetation in the tidal Potomac River in the late 1930s.

REFERENCES

Bayley, S., Rabin, H. and Southwick, C.H., 1968. Recent decline in the distribution and abundance of Eurasian milfoil in Chesapeake Bay. Chesapeake Sci., 9: 173—181.

Carter, V., Gammon, P.T. and Bartow, N., 1983. Submersed aquatic plants of the tidal Potomac River. U.S. Geological Survey Bulletin 1543, 58 pp.

Carter, V., Paschal, J.E. and Bartow, N., 1985a. Distribution and abundance of submersed aquatic vegetation in the tidal Potomac River and Estuary, Maryland and Virginia, May 1978 to November 1981 — A water quality study of the tidal Potomac River and Estuary. U.S. Geol. Surv., Water-Supply Pap. 2234A, pp. 1—46.

Carter, V., Rybicki, N.B., Anderson, R.T., Trombley, T.J. and Zynjuk, G.L., 1985b. Data on the distribution and abundance of submersed aquatic vegetation in the tidal Potomac River and transition zone of the Potomac Estuary, Maryland, Virginia, and the District of Columbia, 1983 and 1984. U.S. Geol. Surv. Open-File Rep. 85—82, pp. 1—46.

Chesapeake Research Consortium, Inc., 1976. The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. CRC Publication No. 54, John Hopkins University Press, Baltimore, MD, pp. 1—29.

Cumming, H.S., Purdy, W.C. and Ritter, H.P., 1916. Investigations of the pollution and sanitary conditions of the Potomac watershed. Treasury Dept., U.S. Public Health Serv. Hygienic Bull. 104, 231 pp.

Grover, N.C., 1937. The floods of March 1936. U.S. Geol. Surv., Water-Supply Pap. 800, 351 pp.

Grover, N.C., 1939. Surface water supply of the United States 1937. U.S. Geol. Surv. Water-Supply Pap. 821, 441 pp.

Grover, N.C., 1940. Surface water supply of the United States. U.S. Geol. Surv. Water-Supply Pap. 851, 496 pp.

Haramis, G.M. and Carter, V., 1983. Distribution of submersed aquatic macrophytes in the tidal Potomac River. Aquat. Bot., 15: 65—79.

Haslam, S.M., 1978. River Plants. Cambridge University Press, New York, 396 pp.

Hirschberg, D.J. and Schubel, J.R., 1979. Recent geochemical history of flood deposits in the northern Chesapeake Bay. Est. Coast. Mar. Sci., 9: 771—784.

Jaworski, N.A., Lear, D.W., Jr. and Villa, O., Jr., 1971. Nutrient management in the Potomac estuary. In: G.E. Likens (Editor), Nutrients and Eutrophication: The Limiting Nutrient Controversy. Am. Soc. Limnol. Oceanogr., Inc., Lawrence, Kansas, pp. 246—273.

Knebel, J.H., Martin, A.E., Glenn, J.L. and Needell, S.W., 1981. Bull. Geol. Soc. Am., Part I, v. 92, pp. 578—589.

Martin, A.C. and Uhler, F.M., 1939. Food for game ducks in the United States and Canada. U.S. Dep. Agric. Tech. Bull. 634, Washington, DC, 308 pp.

Phillips, G.L., Eminson, D. and Moss, B., 1978. A mechanism to account for macrophyte decline in progressively eutrophicated freshwaters. Aquat. Bot., 4: 103—126.

Sculthorpe, C.D., 1967. The Biology of Aquatic Vascular Plants. Edward Arnold, London, 610 pp.

Seaman, W.H., 1875. Remarks of the flora of the Potomac. Field and Forest: Bull. Potomac-side Nat. Club, 1: 21—25.

The Secretary of the Treasury, 1933. Disposal of sewage in the Potomac River. Senate Document no. 172, 72nd Congress, 65 pp.