ZOSTERA MARINA L., ITS GROWTH AND DISTRIBUTION IN THE GREAT BAY ESTUARY, NEW HAMPSHIRE[1]

STANLEY A. RIGGS, JR. AND RICHARD A. FRALICK[2]

Protected coastal and estuarine waters of New England often contain dense meadows of the marine Angiosperm *Zostera marina* L. Little was known of the ecology of *Zostera,* or eel grass as it is commonly called, until a wasting disease attributed to the parasitic marine fungus *Labyrinthula* almost exterminated the *Zostera* population in New England waters (Jepps, 1931; Renn, 1934, 1935, 1936a, 1936b; Young, 1937, 1943).

The present paper compares the seasonal growth (biomass), reproductive phenology, and local distribution of *Zostera* with seasonal variations in temperature and salinity. The results of vertical and horizontal transplants are discussed as well as the possibility of ecotypical adaptation.

METHODS AND MATERIALS

Bimonthly observations and measurements of *Zostera marina* populations were made at eight stations within the Great Bay estuary system during 1972 (Table 1). Measurements of surface water temperature and salinity were made at mean low water (MLW). Biomass was also recorded at MLW since the majority of *Zostera* plants occurred in this zone.

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[1]Jackson Estuarine Laboratory Scientific Contribution Number 27.

[2]Present address: Department of Natural Science, Plymouth State College of the University of New Hampshire, Plymouth, N.H. 03264.

Table 1. Characteristics of eight stations within the Great Bay Esturary.

Stations/ nautical miles inland	Temperature °C		Salinity ‰		Substrate
1. Jaffrey Point (0.0)	avg.	10.2	avg.	30.3	rocky outcrops with some sand
	max.	23.0	max.	32.5	
	min.	1.0	min.	26.0	
2. Pierce Island (2.0)	avg.	10.5	avg.	27.0	broken rocks, mud and silt
	max.	21.5	max.	32.0	
	min.	0.0	min.	19.0	
3. Newington Town Landing (5.5)	avg.	11.7	avg.	24.5	small rocks, mud and silt
	max.	24.0	max.	31.0	
	min.	0.4	min.	16.0	
4. Dover Point (7.0)	avg.	12.5	avg.	23.7	large rock outcroppings, mud and silt
	max.	25.0	max.	32.0	
	min.	3.0	min.	15.0	
5. Cedar Point (8.3)	avg.	13.6	avg.	22.1	mud and silt
	max.	27.0	max.	32.0	
	min.	0.0	min.	6.0	
6. Adams Point (10.7)	avg.	13.8	avg.	21.0	rock outcroppings, shale, cobble, mud and silt
	max.	28.0	max.	31.5	
	min.	0.5	min.	8.0	
7. Chapmans Landing (15.2)	avg.	14.2	avg.	5.7	mostly mud, some small rocks and boulders
	max.	26.5	max.	22.0	
	min.	0.0	min.	0.0	
8. Exeter (19.1)	avg.	14.4	avg.	3.4	mud and silt
	max.	28.1	max.	20.0	
	min.	0.0	min.	0.0	

Growth studies were initiated during March, 1972. Tagged plants (approximately 100) were established at Stations 2 through 6, and the blade length was measured according to the method of McRoy (1970). Horizontal and vertical transplants of *Zostera* were also initiated in March, and the plants were subsequently observed and measured for a period of 10 months. Each of the transplants was duplicated, one using the substrate of the original station and the other using the substrate of the new station.

McRoy (1970) showed that a rapid estimate of the standing crop of *Zostera* is possible because of a relationship between blade length and dry weight. By incorporating both the width and the length of the blades we derived and untilized the following equation for conversion to dry weight (biomass) without harvesting or damaging the plants.

Formula Example:

$$Y = (0.308 \times 10^{-4})\ (x) - 48.2 \times 10^{-4}$$

$$Y = \text{dry wt. (grams)}$$

$$x = L \times W\ \text{(mm)}$$

blade width = 5 mm

blade length = 100 mm

$L \times W = 500$

$Y = (0.308 \times 10^{-4})\ (500) - 48.2 \times 10^{-4}$

predicted $- 10.6 \times 10^{-3}$ g dry wt.

actual $- 10.8 \times 10^{-3}$ g dry wt.

A linear regression was performed between the predicted dry weight and the actual dry weight, and a correlation coefficient of 0.99 was obtained.

Temperature was recorded with a laboratory grade, submersible, mercury thermometer. Salinity was determined with a set of hydrometers (G.M. Manufacturing Co., N.Y.) and the readings were corrected to 15°C.

Hydrographic factors: Figure 1 shows the seasonal variation in temperature at two representative stations for 12 months. Stations 1 and 2 exhibited similar temperature values with maximum temperatures of 23.0° and 21.5° C occurring in July and minimum temperatures 1° and 0° C occurring in January, February, and December. Stations 3 and 4 exhibited maximum temperature values of 25.0° to 26.0° C in July with minimum values of 0° C during the winter months. Stations 6, 7, and 8 showed the greatest ranges in temperature with maximum values of 27.5° C in July and minimum values of 0° C in January, February, and December.

FIG. 1

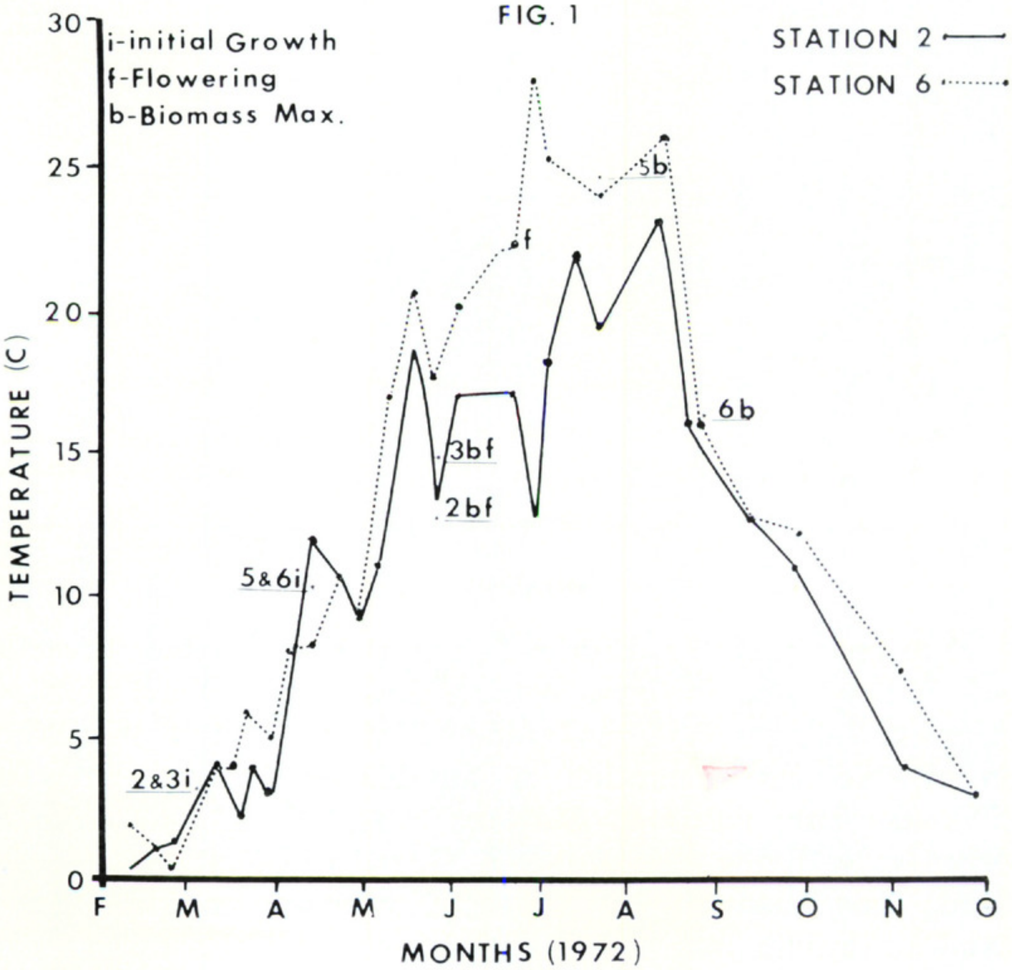
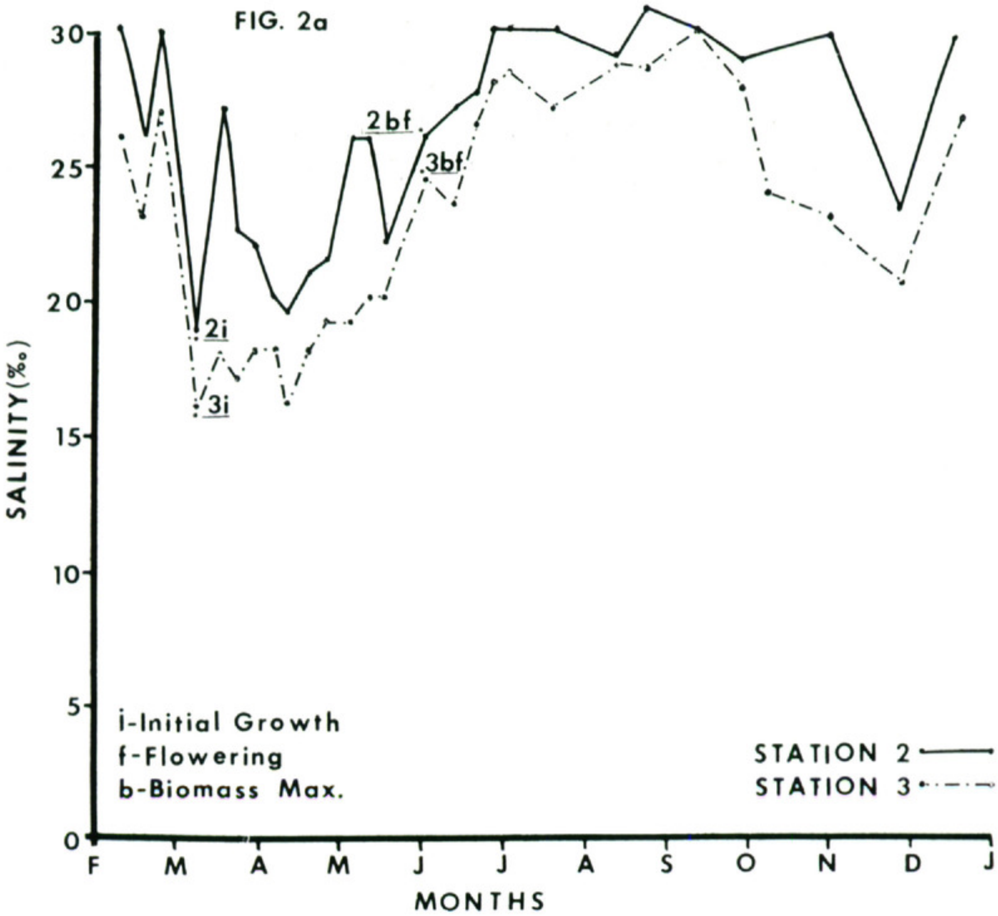
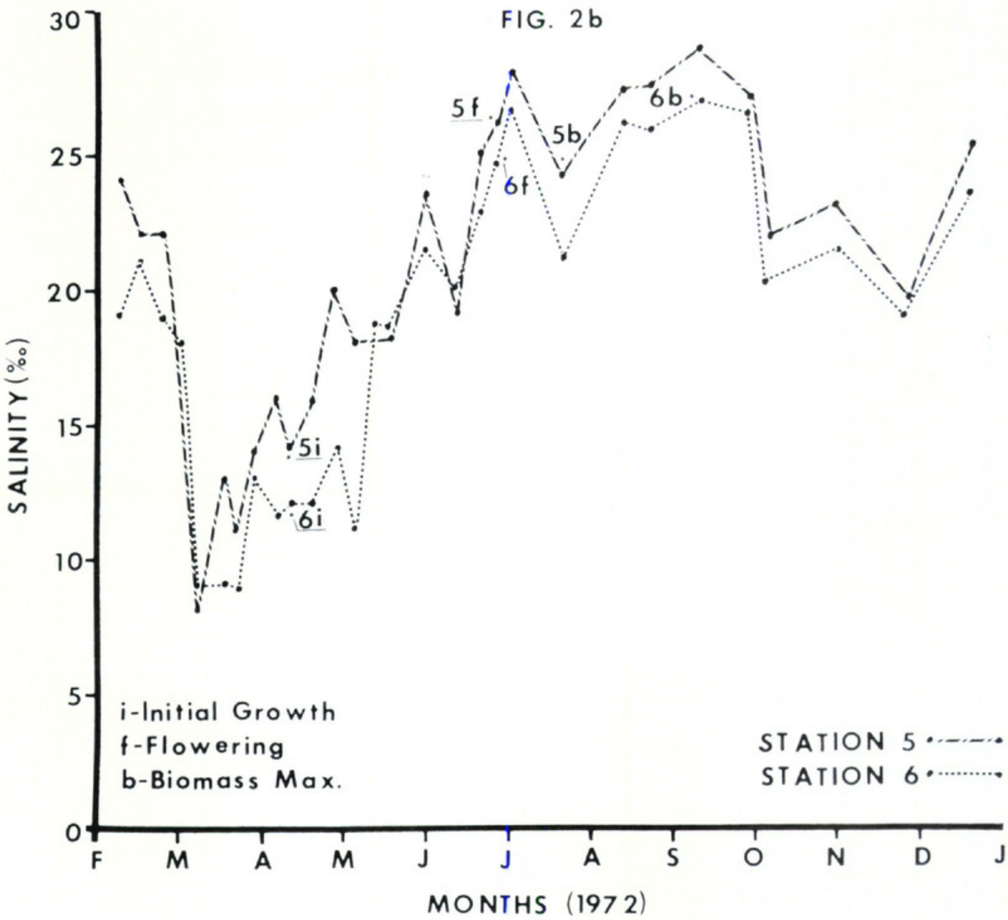


Figure 2 shows the seasonal variation of salinity at four representative stations for 12 months. The values are consistent with the proximity of each station to the open coast. Thus, Station 1 had a seasonal salinity range of 26.0 to 32.5 o/oo.; Station 2 showed a range of 19.0 to 32.0 o/oo.; Station 6 had a range of 8.00 to 21.0 o/oo., while Station 8 had the lowest salinities within a range of 0.0 to 20.0 o/oo.



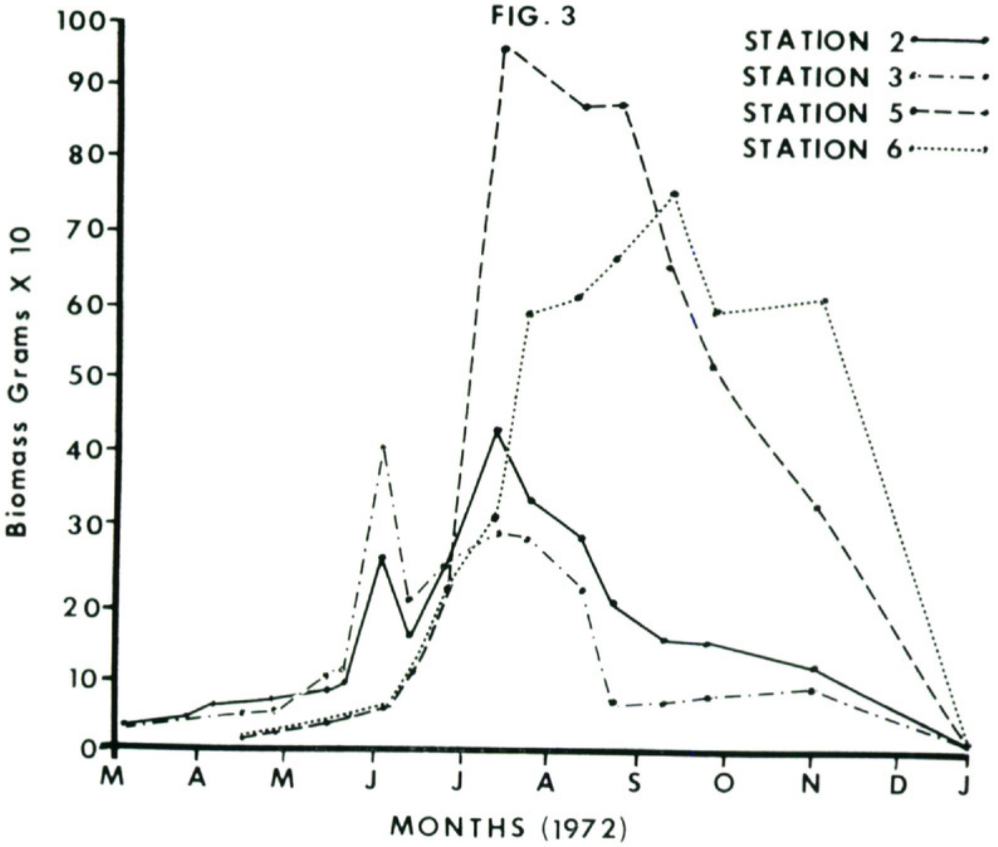
Seasonal growth: Figure 3 indicates that active growth of *Zostera* was initiated during March and April at Stations 2, 3, 5, and 6. The plants at Stations 2 and 3 exhibited a conspicuous elongation of the blades (1 to 3 cm) in March. The plants at Stations 5 and 6 did not initiate growth until the end of April. Growth at Stations 2, 3, 5, and 6 declined rapidly during November and December and no growth was recorded in January and February. No



growth was observed at Stations 1, 7, and 8 throughout the season. The growth at Station 4 is not illustrated because the colony was considered subtidal, while all other stations were intertidal.

Standing crop: Figure 3 illustrates the seasonal variation in standing crop of *Zostera* at several stations. Minimum values were apparent from December through March. Maximum standing crop values were recorded in August at Station 5. The plants at Station 6 reached their maximum biomass in late September. Two peaks were evident at Stations 2 and 3; the first occurred in mid-June and the second in early August. The initial peak in biomass was associated with flowering, while a decrease in early July was attributed to the abscission of floral parts. In some

FIG. 3

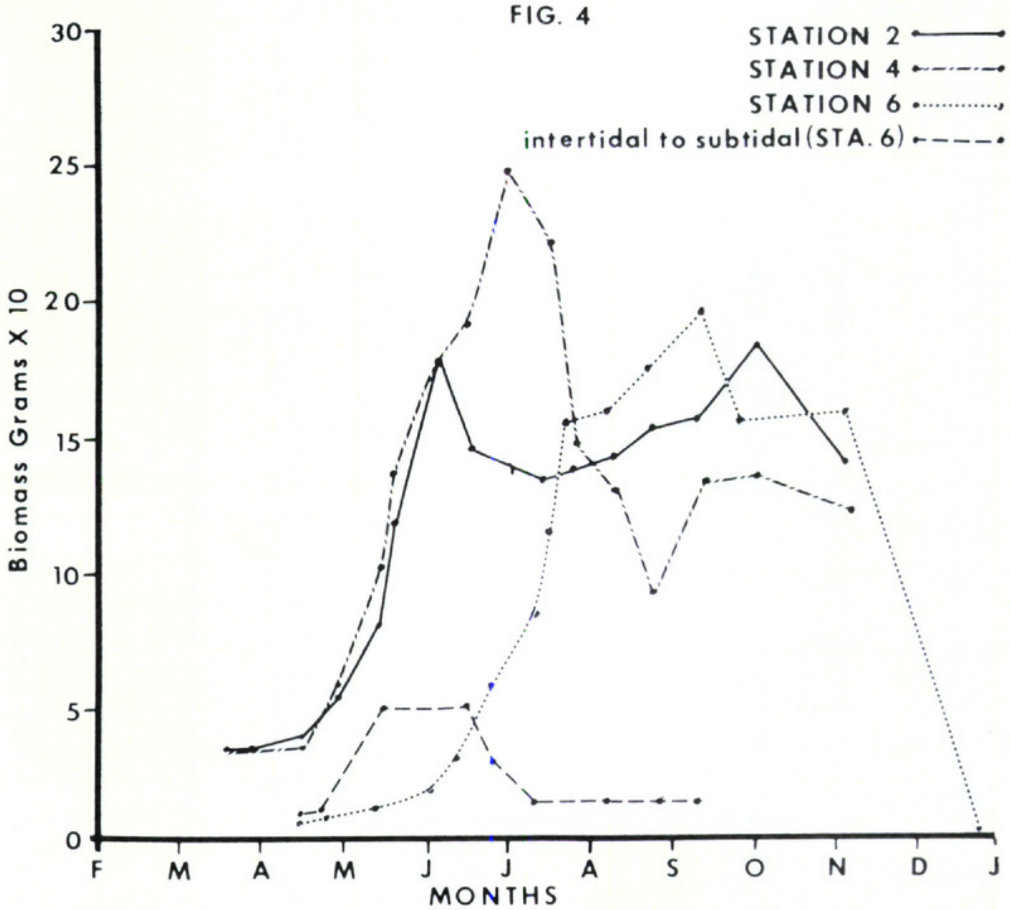


cases vegetative turions without reproductive parts remained intact and continued to grow.

A general decline in standing crop was apparent at nearly all stations by late September, and although some growth continued until December, no significant increase in biomass was recorded at any station after October. The process of floral abscission was not apparent at Station 6 until early October.

Horizontal transplants: Transplants were also initiated between various stations during the spring. In all cases the plants showed their maximum standing crop values at the same time as the original populations from which they were derived. For example, *Zostera* transplanted from station 2 to 6 reached a maximum standing crop value in mid-June, while the original material at Station 6 did not peak until late September (Fig. 4). *Zostera* at Station 4 reached a maximum standing crop value in July.

FIG. 4



Transplants of *Zostera* plants (9.0 to 16.0 cm long) from Station 2 to 8 died within a week. Differential responses to transplanting were observed when smaller plants (2.0 to 8.0 cm long) survived a transplant between the same stations for more than 30 days.

DISCUSSION

Within the Great Bay Estuary system, *Zostera* first initiated growth, flowered, and reached maximum biomass at the stations nearest the coast. Stations further up in the estuary initiated growth, flowered, and reached a maximum biomass some three months later than stations close to the coast.

The initial growth of *Zostera*, in contrast to Setchell's 1929 findings, is neither restricted to a specific 5 degree temperature isotherm, nor to temperatures greater than 10° C. Although *Zostera* has been observed living beneath winter sea ice (McRoy, 1969), to our knowledge its growth has not previously been measured at temperatures below 10° C.

The initial period of maximum biomass did not appear to be related to any specific temperature range. Thus, plants at Stations 2 and 3 reached their maximum biomass at 18° C, while it was attained at 25° C at Station 5 and 16° C at Station 6.

The flowering period is not restricted to a specific temperature isotherm (15° to 20° C) as suggested by Setchell, 1929. *Zostera* flowered in the spring at Stations 2 and 3 when the temperatures were about 17.0° C. At Station 6 flowering did not take place until fall despite an increase in temperature up to 28.0° C.

There was a correspondence between peak biomass and high salinity at each site. Thus, *Zostera* plants at Stations 2 and 3 reached their first maximum biomass at salinities of 26.0 o/oo and 24.0 o/oo respectively, while maximum biomass at Station 5 was reached at a salinity of 25.0 o/oo — 40 days later than at Station 2. *Zostera* plants at Station 6 reached maximum biomass at a salinity of 27.0 o/oo, in September, nearly 100 days later than at Stations 2 and 3.

The time of flowering was also correlated with salinity. Thus, *Zostera* plants at Stations 2 and 3 initiated flowering when the salinities were 26.0 and 24.0 o/oo. The plants at Stations 5 and 6 also initiated flowers at the same salinities, but approximately three weeks later than at Stations 2 and 3.

It appears that *Zostera marina* maintains its original growth patterns even after being transplanted to new locations. Thus, transplants from Stations 2 and 4 to 6 followed a pattern of growth and development similar to that of the plants in their original colony. In no case did transplanted *Zostera* follow a sequence of growth and phenological development parallel to patterns in plants originating in the new location.

The horizontal transfer of *Zostera* colonies within the estuary had no noticeable effects on their development. Vertical transplants (intertidal to subtidal) frequently showed a decrease in their rate of development. Thus, when young seedlings (1 to 3.0 cm long) were transplanted vertically their development was conspicuously slowed (Fig. 4). In contrast, transplants from the subtidal to the intertidal zone were consistently successful. Transplants to brackish waters with salinities of 4.0 to 5.0 o/oo did poorly. The greatest level of success in transplants to brackish water occurred when plants 3 cm or less in length, originating at stations close to the brackish water, were transplanted with their rhizomes intact.

A distinct potential for vegetative propagation was obvious throughout our transplant studies. In most cases transplants of individual *Zostera* plants responded favorably. The only exception occurred with transplants from intertidal to subtidal locations.

A lack of clear correlation was evident between the onset of the plants' various phenological phases and temperature. However, there was some indication that the onset of various phenological stages may be, in part, related to moderate salinity ranges of 24 to 27 o/oo. In all instances, phenological development started in plants nearer the open coast and progressed up the estuary. A tendency of *Zostera* to form ecotypes between stations which differed in their seasonal salinity patterns was obvious. However, further studies to determine the effects of temperature related salinity tolerances may be warranted. McMillan (1956) has noted a tendency for some Graminae to adapt towards different habitats. In addition Biebl and McRoy (1971) have noted that *Zostera* may exhibit a physiological adaptation to a particular environment. This fact was obvious in our investigations because *Zostera* could be collected in distinctly subtidal habitats at depths as great as 6 meters. Since there is no possibility of these plants ever being exposed to the atmosphere, we consider them to be good examples of adaptation to a subtidal existence.

Our results indicate that *Zostera marina* may undergo successful ecotypical adaptation toward a particular environment. This adaptation is probably more closely related to moderate salinities than specific temperatures. We also have shown that transplants of *Zostera* between habitats is feasible.

The mathematical formula employed in this investigation proved to be an accurate method of assessing biomass for *Zostera* without harvesting the plants.

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DEPARTMENT OF BOTANY AND PLANT PATHOLOGY
AND JACKSON ESTUARINE LABORATORY
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE 03824