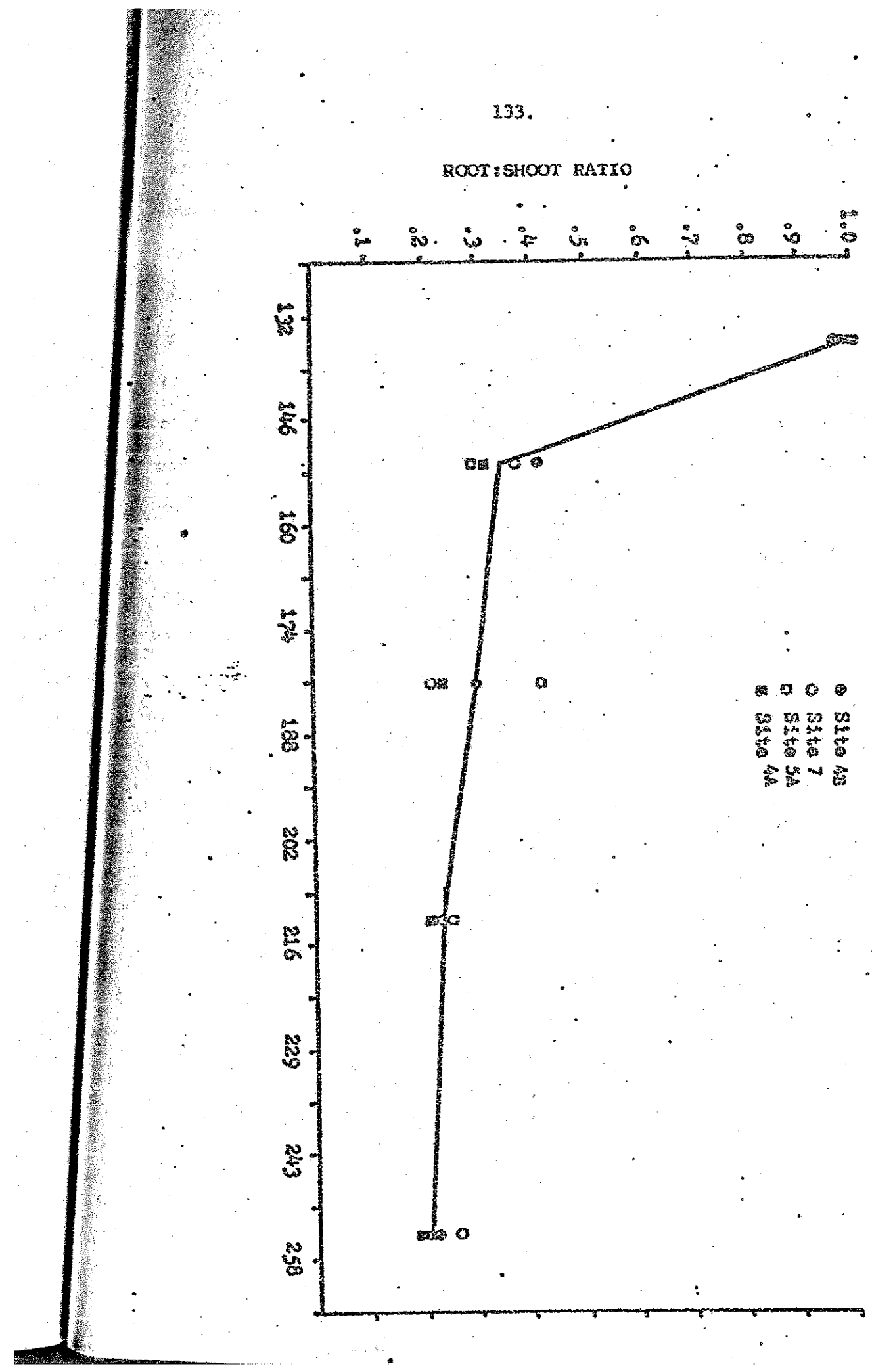
Figure 43. Seasonal patterns of the partitioning of net primary production between roots and stems in wild rice (Zizania aquatica). Refer to Figure 2 for site locations.


ROOT:SHOOT RATIO
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
132
146
160
174
188
202
216
229
243
258
Site 4B
Site 7
Site 5A
Site 4A

most of the net production went into shoot growth. Root:shoot ratios remained approximately 1:3 during the remainder of the growing season. Bray et al (1962) also found low root biomass for wild rice. They ascribed the low root biomass to be due to weak root development characteristic of many aquatic plants. This is probably true only of annual species for Dykyjova (1972) has shown that perennial species of marsh habitats have higher root:shoot ratios for wild rice were very consistant even though there was considerable difference in substrate conditions between the populations (see description of substrate properties on pages 8 - 26 of this report).

Figure 44 shows the pattern of biomass accumulation in individual plants. Growth averaged .07 g/ind/day during the period May 15 - June 29 and .44 g/ind/day during July. Toward the end of July the growth rate slowed. This coincided with the onset of flowering and fruiting phenophases. By the end of the growing season an average individual weighed 25.2 $\pm$ 3.5 g (Figure 44.)

Net primary production on an area basis is shown on Figure 45. Overall biomass accumulation followed a pattern similar to the accumulation of biomass in individual plants. Total net primary production for all sites was 2.2 g $\pm$ .6 on May 15, 41.5 g $\pm$ 6.7 on May 30, 346.3 g $\pm$ 48.4 on June 26, and 1453.4 g $\pm$ 225.1 on September 10. Net primary production data for four of the

Figure 44. Net primary production of individual wild rice (Zizania aquatica) plants in the Hamilton Marshes. All values are means (g/ind.) ± 1 standard error.

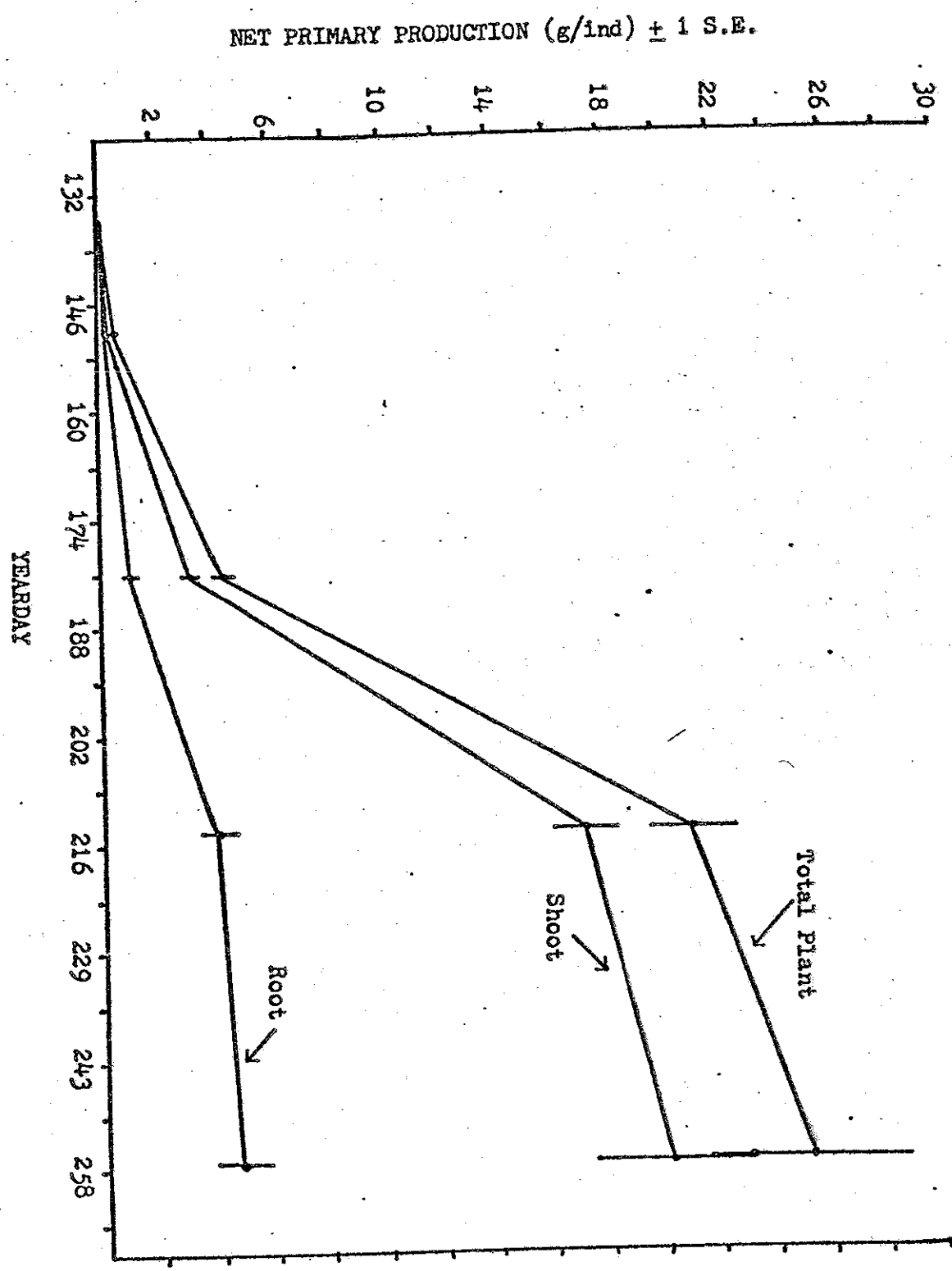

NET PRIMARY PRODUCTION (g/ind) ± 1 S.E.
2
6
10
14
18
22
26
30
YEARDAY
132
146
160
174
188
202
216
229
243
258
Root
Shoot
Total Plant

Figure 45. Net primary production of wild rice (Zizania aquatica) in the Hamilton Marshes. All values are means (g/m^2) $\pm$ 1 standard error. ($g/m^2 \times 10^{-2}$ = T/Ha)

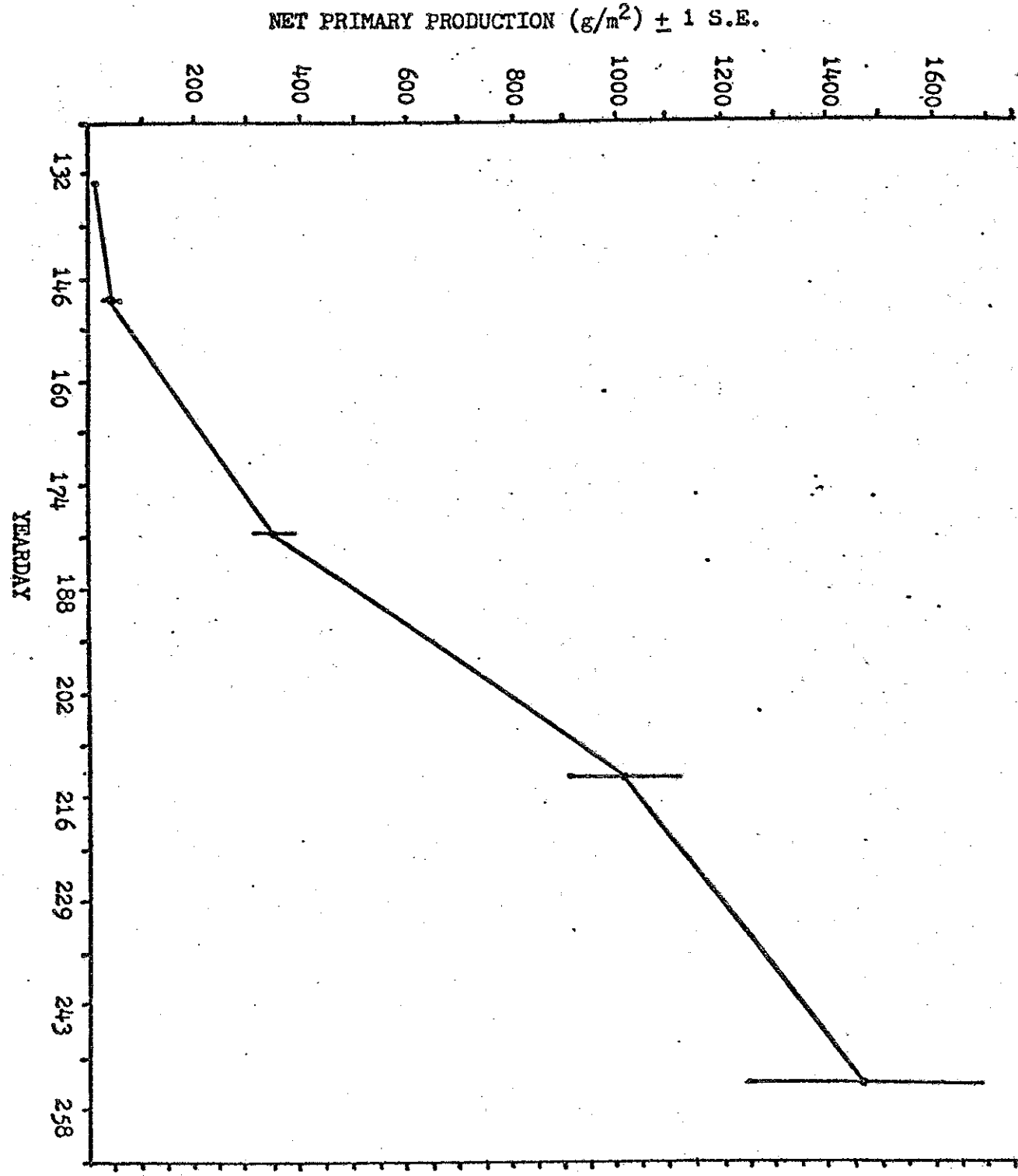

NET PRIMARY PRODUCTION (g/m²) ± 1 S.E.
200
400
600
800
1000
1200
1400
1600
YEARDAY
132
146
160
174
188
202
216
229
243
258

Table 10

Density changes in wild rice populations. Values are mean number of plants/m^2.

	Sampling Site (see Figure 1)						
Yearday	Site 1	Site 1A	Site 2	Site 3	Site 3A	Site 6	Site 7
150	211	250	N.S.	134	N.S.	216	168
155	172	N.S.	N.S.	N.S.	N.S.	212	N.S.
170	76	132	30	86	114	182	148
184	52	74	18	52	80	72	90
210	N.S.	N.S.	X	56	16	64	92
238	69	24	X	36	X	59	44

N.S. = Not sampled

X = All plants destroyed (Site 3A) or eaten (Site 2)

sites are shown in Figure 5 (Page 44). Production was similar for the four sites until July but there were differences afterward. Site 4B has the highest net annual primary production (2163.2 $\pm$ 663.2 g/m^2). Production at Sites 4B, 5A and 7 was 1619.1 $\pm$ 489.5, 823.8 $\pm$ 58.9 and 1234.2 $\pm$ 187.2 respectively.

DISCUSSION

Net primary production of wild rice in the Hamilton Marshes differed between sample areas. Total production at Sites 7 and 5 were probably least because of competition and mortality. At Site 5B there were fewer individuals that survived (Table 10) and thus production on an area basis was less than that of any other site. Many individuals at Site 5B were killed during a storm in July. Net primary production was lower at Site 7 than at Sites 4B and 4A because the individual plants were smaller. At area 4A wild rice maintained dominance throughout the growing season and individual plant size was the greatest.

There is not apparent correlation between production of wild rice and location of populations with regard to the amount of tidal activity. Based upon the greatest length of time that each area would be covered by water during a tide cycle, the areas would be ranked as follows: 4B, 5B, 7, 5A, 4A, and 5.

Table 11 compares production data for wild rice in other

Table 11. Comparison of production values for wild rice in fresh water tidal marshes.

NET PRODUCTION (g/m^2)	STATE	SOURCE
605 - 1547	Pa.	McCormick (1930)
1390	N. J.	McCormich and Ashbaugh (1972)
659 - 1125	N. J.	Present study
1699	N. J.	Jervis (1964)

geographic locations. Net primary production appears to be extremely high in tidal areas. Production in two other Delaware River freshwater tidal marshes was 605-1547 g/m^2/yr (McCormick, 1970; McCormick and Ashbaugh, 1972). Jervis (1964) has measured rice production at 1699 g/m^2/year in another New Jersey freshwater marsh. In fact, primary production of wild rice in New Jersey's freshwater tidal marshes is comparable to annual net production of salt marsh plants. Good (1965) measured a net production of 300 g/m^2 for Spartina alterniflora in New Jersey and Potera and MacNamara (1972) measured values of 191 g/m^2 for the same species in a polluted estuary. Although there is little comparable data for wild rice in inland areas of New Jersey, it appears that primary production is equal to or greater in the freshwater tidal marshes than it would be in non-tidal environments. Bray measured wild rice production at 630 g/m^2 in Minnesota (Bray et. al., 1962).

CONCLUSION

Robichaud and Buell reported that wild rice is sensitive to pollution, dredging, etc. and that, as a result of such actions, the distribution and abundance of wild rice in the Delaware River Basis has been drastically reduced. They stated that it was abundant as far north as Rancocas Creek. This study has proved that wild rice is still abundant and doing well in the Hamilton Marshes. This may be due to the fact that these marshes have not

been filled or dredged recently. Other data presented in this report have shown that the waters of the marshes are not polluted beyond acceptable standards. This study has also shown that wild rice is an invaluable component of the marsh ecosystem. We have estimated that communities of dominated by wild rice produce more than 200 tons of material per year. Future management of the marshes should include planning that will insure the existence of this valuable species.

A STUDY OF VARIOUS ASPECTS OF THE ECOLOGICAL LIFE HISTORY OF PONTEDERIA CORDATA (Pickerelweed)

by

Patricia Parkinson

INTRODUCTION

Pontederia cordata is a common aquatic plant which grows in marshy areas and on the shores of streams (Fairbrothers and Moul, 1965). Although other genera of the family Pontederiaceae have been studied, there is little literature available on Pontederia (Sculthorpe, 1967).

NOMENCLATURE AND DESCRIPTION

Pontederia cordata (P. sagittata Seubert) is an aquatic macrophyte of the family Pontederiaceae (Muenscher, 1944 and Stodola, 1967). It is a perennial with thick, creeping root-stocks and clusters of erect leaves which have fleshy petioles and heart-shaped to lanceolated blades. Leaves are borne singly on a simple stem. It is an emergent species, but can grow entirely submerged. The leaves of the submerged form, forma taenia, are ribbon-like with little or no differentiation of a blade. P. cordata also has a leaf sequence from the linear or spatulate first-formed leaves of the seedling to the mature leaf form described above (Sculthorpe, 1967). The perfect, irregular, trimerous flowers are borne on a spike, They are violet-blue, funnel-shaped, two-lipped, and hairy on the outside. There are

six stamens and the ovary is three-celled, but two of the cells are sterile. Pontederiaceae is one of only three angiosperm families in which tristyly is known to occur, and is the only monocotyledonous family exhibiting this type of floral heteromorphism (Hazen, 1918; Ornduff, 1966). In pickerelweed, the three forms are: (1) those having flowers with long styles and anthers at two levels below the stigma; (2) those having flowers with mid-length styles and one set of anthers above the stigmas, the other set below; and (3) those having flowers with short styles and anthers at two levels above the stigmas. This system promotes cross-pollination, since self-pollination or cross-pollination between stigmas and anthers not at equivalent levels is much less productive of seeds than pollination between stigmas and anthers at equivalent levels (Ornduff, 1966). Representation of the floral forms in populations is unequal. This is because, once an area is colonized, too few sexually produced generations succeed to allow equilibrium to be established. This species is insect pollinated. Nectar accumulates in the perianth tube. The lower lip of the flower serves as a landing platform for smaller insects. The upper lip is erect and has a large double blotch of bright yellow on the posterior petal segment, which probably serves as a nectar guide. Hazen (1918) observed ten species of Lepidoptera and many Hymenoptera visiting the plant in a marsh in New Jersey. Dufourea novea-angliae, a bee, visits no other plant and its

emergence coincides with the onset of flowering of pickerelweed (Sculthorpe, 1967).

The fruit, an achene bearing one seed, has crested ridges running lengthwise and a "beak" at the end, which is a persistent style base. The seeds are 3-4 mm long, ovoid ellipsoid in shape, and contain a pure white endosperm. The fruits have a period of bouyancy due to large intercellular spaces in the pericarp which allow them to be carried well away from the parent plant, which is a very competitive environment (Sculthorpe, 1967).

P. cordata is a geophyte and the stout, spongy rhizome is the organ of perennation. Vegetative reproduction by extension of the rhizomes predominates over sexual reproduction (Ornduff, 1966).

Pickerelweed is native to the Americas and its distribution is from the eastern United States south to Argentina. It was observed in several locations in the Hamilton Marshes (Whigham, 1974). It was most common along the banks of Crosswicks Creek and in the Rowan Lake, Spring Lake, and Sturgeon Pond sections of the marshes. It is, however, not restricted to those areas and populations are scattered throughout. Pickerelweed is not one of the dominant species in the Marshes. Whigham (1974) listed it as the 13th most important species. It is most commonly associated with yellow water lily, arrow arum, and water smartweed. Its contribution to the overall productivity of the marshes

was studied in 1973 and 1974 (Table 12). The differences between the 1973 and 1974 data were due to the sampling methods employed. In 1973 the sampling at each site was random and because the species is primarily concentrated in certain communities there was much variation in the harvest data. In 1974, having determined what community types exist in the marshes, the vegetation was sampled systematically. Pickerelweed appeared in many of the samples collected at several sites where is was part of the communities found there. The 1974 data shows an increase in aboveground biomass throughout the growing season with a beak biomass of approximately 592 g/m^2.

PHENOLOGY

Pontederia cordata was in flower when phenological data was first collected on June 25, 1973. In 1974 flowers were first noted on June 21. During both years the flowering phenophase lasted for the remainder of the growing season. Fruits were first seen on July 6 and on August 3 it was first noted that some had been shed from the stalks.

TRANSPLANT EXPERIMENT

Most perennial species in the marshes appear to grow whenever temperature conditions are favorable. Dormancy thus appears to be maintained by low temperatures throughout the winter. In order to determine what factors controlled dormancy in pickerelweed, a transplant experiment was performed.

Table 12

Productivity (g/m^2) of Above-ground Portions of *Pontederia cordata* in the Hamilton Marshes.

	Sample Date (1973)					
Site No.	June 14	June 26	July 11	August 3	August 17	Average
4C	-	19.7	10.0	28.8	38.0	24.1
4B	25.6	32.4	8.3	-	-	22.1
4A	13.6	1.9	-	-	-	7.8

	Sample Date (1974)					
Site No.	May 30	June 20	July 8	July 31	August 27	Average
4C	6.2	-	-	-	-	-
4B	-	56.3	71.2	129.9	328.	
4A	48.2	-	163.1	-	-	
3	-	161.5	484.9	353.8	592.1	

Rhizomes were collected in the field in early November, 1973 after leaves began to senesce. The rhizomes were planted in soil in 5-gallon plastic pots lined with plastic bags to retain water. Larger rhizomes were cut and planted separately, with at least one growing tip present on each. They were stored outdoors until all leaves had completely died back and were then placed in a cold room (2-4°C). At the same time, 5 plants were placed in the greenhouse as controls. Rhizomes were removed ten at a time from the cold room to the greenhouse at two-week intervals after 8 to 16 weeks of cold storage. Results of this experiment are given in Table 13 .

Eighty percent of the plants that had received no cold treatment had broken dormancy after 15 days. There were not significant differences in the percentages of plants that had broken dormancy after varying periods of cold storage. The results of this experiment show that Pickerelweed will grow as long as temperature and moisture conditions are favorable. The effect of photoperiod was not studied.

SEED GERMINATION EXPERIMENTS

Seeds were collected on six occasions between September 28 and November 9, 1973. The fruits mature from the bottom of the stalk upward and drop off while still green. In order not to lose seeds between collection dates, net bags were placed over the stalks and tied below the fruits. The stalks were collected when all fruits had dropped off into the bag. The fruits were

Table 13
Percents of rhizomes
that had broken dormancy after various periods of cold storage.

Length of Cold Storage of 2-4°C	Day Number after transfer to Greenhouse		
	5	10	15
None	0	60	80
8 weeks	0	70	90
10 weeks	20	70	80
12 weeks	10	50	60
14 weeks	10	50	80
16 weeks	50	60	90

stored moist in plastic bags at room temperature until the germination experiment was begun. During this time, the fruit coats turned from green to brown and only those with dark brown coats were used for the experiments. The average number of fruits per stalk was 178 ± 97.3.

Germination pretreatments were begun 2-3 weeks after collection of the seeds. Seeds were subjected to the following treatments:

Treatment	
Stratification (2-4°C) for	31 days
Dry storage (2-4°C) for	31 days
Stored moist (20°C) for	32 days
Stored dry (20°C) for	31 days
Scarification	
Gibberellic Acid, 0.1mM	23 hours
Gibberellic Acid, 0.01mM	23 hours

As a control, 90 untreated seeds were placed in a germination chamber at 15°C. Scarification consisted of removal of the fruit coat and scratching the soft seed coat with forcepts. Each treatment consisted of three replicates of 15 seeds per replicate.

Germination was attempted at the following temperatures: 10°C, 15°C, 20°C, and 30°C. At each temperature, one group of seeds was maintained on moist filter paper (approximately 3 ml distilled water) and another group was kept in approximately 30 ml. Of the 2600 seeds used in this experiment, only 8 germinated. It was concluded that the pickerelweed seeds were in a state of deep dormancy imposed by one or both of the following factors:

(1) immaturity of the embryo or (2) a requirement for leaching of an inhibitor.

Seed ripeness, or readiness for harvest, occurs at different stages of the embryo's development in different plants; some are of considerable size and a high degree of differentiation, and in others the embryo may consist of a few undifferentiated cells. The latter type is incapable of germination without a period during which the development of the embryo is completed within the dormant seeds.

A stratification requirement is most often associated with the presence of germination-inhibiting substances in the embryos. If such embryos are excised and washed with water, frequently they will germinate; if they are simply excised and held in a humid atmosphere where leaching could not occur, the embryos remain dormant. Production of germination stimulating substances can also overcome the effects of the inhibitors.

A second series of germinations experents were initiated between 6 and 11 weeks after harvest. Fruits were washed in running water for one hour, soaked for one hour in 1.0% sodium hypochlorite, and washed again in running water for one hour. They were then stored moist in covered bowls for two to three weeks, during which time a few seeds germinated. Fruits were then placed 25 each in petri dishes on moist filter paper and placed in a cold room (2-4°C) for various stratification periods (Table 14). Three hundred of the fruits were stored dry at 2-4°C for

Table 14

Percent Germination of Seeds of *Pontederia cordata*.

Pretreatment	15°C		20°C		30°C	
	Moist	Wet	Moist	Wet	Moist	Wet
Control	0	0	0	0	4	4
Stratified 6 weeks	22	46	34	52	92	90
Stratified 8 weeks	54	64	54	44	92	88
Stratified 10 weeks	54	58	54	50	90	82
Stratified 12 weeks	46	30	56	66	82	88
Dry, 2-4°C, 8 weeks	10	2	4	4	22	14

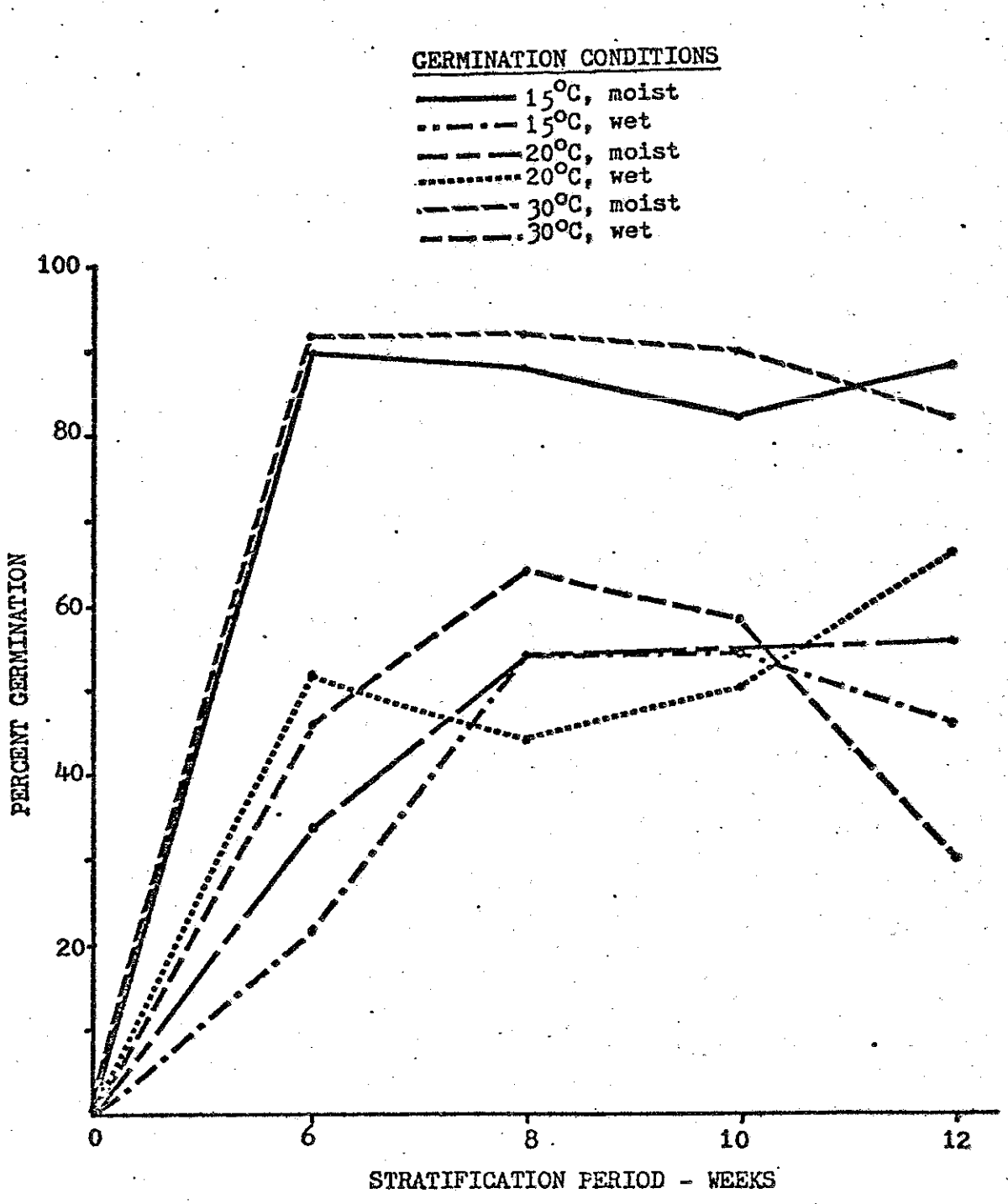
eight weeks and 300 were placed in a germination chamber at 20°C for eight weeks as a control. After the prescribed stratification periods, the fruits were transferred to germinators at 15°C, 20°C, and 30°C under both moist (3 ml) and wet (30 ml) conditions. Results of those experiments are given in Table 14. Very few seeds in the control group germinated. Similarly, seeds that were stored dry at 2-4°C did not have high germination percentages. Under a cold moist stratification regime, high germination percentages occurred for each of the four stratification periods.

A significantly greater percentage germination occurred at 30°C. There was no significant difference between seeds germinated at 15°C and 20°C. Neither were there any large differences between fruits germinated on moist filter paper and fruits submerged in water.

At 30°C germination temperature there is little difference among the various stratification periods (Figure 46). At 20°C there is a considerable difference between the 6 and 12-week stratification periods with the highest percent germination occurring in seeds that were stratified for 12 weeks and germinated wet.

At 15°C the best germination was obtained with seeds stratified for 8 and 10 weeks and the lowest with those stratified 6 weeks. Overall, the best stratification period is 8 weeks, followed by 10, 12 and 6 weeks, in that order.

Figure 45. The effects of temperature and moisture on the germination of pickerelweed (Pontederia cordata) seeds that had been stratified for periods of 6-12 weeks.


GERMINATION CONDITIONS
15°C, moist
15°C, wet
20°C, moist
20°C, wet
30°C, moist
30°C, wet
PERCENT GERMINATION
100
80
60
40
20
0
6
8
10
12
STRATIFICATION PERIOD - WEEKS

Seeds germinated rapidly at 30°C for all treatments. Maximum germination was obtained within 3 days or shortly thereafter. Germination was also more rapid at 20°C than at 15°C for all stratification periods.

Lack of germination in the first experiment may have been due to seed immaturity, a requirement for leaching of a germination inhibitor, or for production of a germination stimulator. Seeds were not washed in running water or sterilized in the first experiment. In the second experiment, a few seeds germinated while being stored in the bowls and also in the control group. The washing procedure may have removed a germination inhibitor. The second experiment was carried out three months later than the first, which allowed considerable time for maturation of the embryos. However, if dormancy were due to immaturity alone, there would have been germination in the control group. It can be concluded that the seeds of pickerelweed require at least an 8 week period after harvest for the embryo to mature before germination will occur under any circumstances. In addition, they must be stratified in order to overcome the effects of a germination inhibitor. The minimum period of stratification required was not determined in this study.

CONCLUSIONS

Pickerelweed is not a dominant plant species in the Hamilton Marshes. It occurs sporadically throughout but is common along the banks of Crosswicks Creek and side channels leading into it and the Spring Lake, Rowan Lake, and Sturgeon Pond sections of the marsh. It occurs in all habitats throughout the marshes and thus appears to be able to withstand a wide range of environmental conditions. Along the stream banks and in the Rowan Lake section it is exposed at low tide which is always covered by water in other areas. It is most commonly found growing with yellow water lily, arrow arum, and water smartweed. Although it produces a large number of seeds, few seedlings are encountered throughout the marshes. Many are undoubtedly consumed by animals. Sculthorpe (1967) has stated that they are readily consumed by ducks and muskrats. Because of the high mortality rate of seeds, the species is most successful in spreading by asexual means. As a result, one frequently encounters the species growing in clones. The mature plants have no internal dormancy mechanism and will start to grow as soon as the water and substrate temperatures begin to warm in the spring. The seeds, on the other hand, possess an internal germination inhibitor that must be removed by stratification. In addition, the embryo is immature at the time that the seeds are shed. Both of these mechanisms insure that the seeds do not germinate before the onset of cold weather.

STUDIES OF THE SEED GERMINATION AND SEED MUCILAGE OF *PELTANDRA VIRGINICA* L. (Arrow Arum)

by

David West

Introduction

Peltandra virginica (L.) Kunth. is a perennial herb arising from a thick fibrous rootstock. The species is commonly seen growing along muddy shores or advancing into shallow water of streams and ponds. Distribution is from Maine to Florida, west to Michigan, Montana and Louisiana (Gleason, 1963).

Peltandra is a member of the Araceae , a family of about 2,000 species most abundant in the tropics (Gleason, 1963). The dominant family characteristic is the typical aroid inflorescence of numerous flowers on a fleshy spadix subtended by a spathe (Fassett, 1969).

Whigham (1974) in his study of a fresh water tidal marsh in New Jersey, found the species to be widespread throughout the marsh. He also showed the species to be the fourth most important species of the open marsh vegetation. The study also indicated that *Peltandra*, unlike the yellow water lily (*Nuphar advena*), does not do well under conditions of continual complete submergence. Thus, *Peltandra* grows on the relatively higher ground adjacent to the stream channels in which *Nuphar* thrives.

Peltandra begins to flower from June to late July. Fruiting lasts from August to early September at which time the fruit, a head of green berries begins to swell. By late November, all of the multiple fruits have been dispersed.

Peltandra seeds will not germinate in their intact condition after dispersal. Seed dormancy of many species have been extensively studied with Vegis (1964) giving a general definition of seed dormancy as being a condition under which germination and establishment are possible only within a narrow range of environmental conditions. Barton (1965) states that there are basically two kinds of dormancy: ectogenous, influenced by external factors such as light, temperature, water, etc., and endogenous, conditioned by the internal physiology of the seed. Furthermore, Sculthorpe (1967) reports that the overwhelming majority of aquatic angiosperms exhibit ectogenous dormancy. Sculthorpe also states that in most species this dormancy is simply due to containment of the embryo within the pericarp. Hart (1928) suggests in her germination studies of Peltandra that dormancy was due to the containment of the embryo within the pericarp. One purpose of this study was to determine the dormancy mechanism in seeds of Peltandra virginica. The second objective of the study was to determine the purpose of the mucilage found in each Peltandra seed. The muscilage is located between the embryo and the seed coat.

Materials and Methods

Peltandra seeds were collected between early September and November from the Hamilton Marshes. The seeds were then stored in distilled water at room temperature.

The seeds, on the average, consist of a large, well developed and slightly curved embryo whose plumule is about eight millimeters long, lying in a groove along a large mass of endosperm. A translucent pericarp surrounds the entire embryo with a two to three millimeter thick layer of mucilage surrounding the pericarp. A dark green to black seed coat encloses the mucilage and embryo.

Experiments were conducted to determine relative germination rates of seeds which had various components of the fruit removed, effects of temperature and stratification on germination, and effects of the seed mucilage on seedling development and seed dessication. For each of the above experiments the methodology was as follows:

I. Effects of Removal of the Fruit Components

All germination tests were conducted in petri dishes filled half way with distilled water and kept at room temperature. Twenty intact fruits were washed and placed in petri dishes. Seed coats were removed from a second set of 20 seeds. From a third set of twenty seeds, the seed coats and mucilages were removed. Seed coats and mucilage were removed from the next

three sets of fruits (20 seeds per set) followed by partial or entire removal of the pericarp. From one set, about one half of the pericarp was removed from the end of the embryo nearest the tip of the plumule. A second set was prepared by removing about one half of the pericarp on the opposite end of the embryo, thus exposing the embryonic root nodules. The entire pericarp was removed from the final set of 20 fruits. There were three replications of each of the above experiments. Germination was considered to have occurred when the tip of the plumule rose above its groove in the endosperm.

II. Stratification Experiments

Two stratification experiments were performed. In the first experiment the seed coats, mucilage, and pericarp were removed from each fruit leaving only the bare embryo. Twenty embryos were stored at each of the following temperatures: 0°, 5°, 10°, 20°, and 24°C. Germination, percentages were determined after two weeks of stratification at the above temperatures. The second experiment involved the effects of various periods of stratification on germination. Forty seeds were prepared in each of the following categories: intact fruit, seed coat removed, seed coat and mucilage removed, and seed coat, mucilage, and pericarp removed. All of the seeds were then placed in water at 5°C. Ten seeds from each of the above categories were removed weekly and placed in water at room temperature. After two weeks at room temperature, germination percentages were recorded for each category.

III. The Effects of Seed Mucilage on Seedling Development and Seed Dessication

The seed coats were removed from 40 seeds and, in addition, mucilage was removed from 20 of those seeds. The two sets of 20 seeds were then placed in water at room temperature. The day that each seed germinated was recorded.

Experiments were designed to determine if the mucilage had any effect on seed desiccation and thus any effect on germination. Three categories were established: entire fruits, fruits with the seed coat removed, and fruits with the seed coat and mucilage removed. One hundred seeds were used in the first category and 40 in the following two. All of the seeds were placed on dry filter paper at room temperature. Periodically (weekly for the entire fruits, daily for the other two categories), several dry seeds from each category were removed. If the seed coat or mucilage were present, they were removed and the seeds placed in water at room temperature. Two weeks after being placed in water, the total germination for each time period of dryness and each category was recorded.

RESULTS

I. Effect of Removal of Fruit Components

Significant differences in germination rates were obtained through removal of various parts of the fruit. Results are given in Table 15 . After 2 weeks, 3.3 percent of the intact fruits had germinated and 10% had germinated after four weeks. With removal

Table 15

Germination rates of Peltandra virginica seeds after removal of various parts of the fruit. Each treatment consisted of 60 seeds. All germination tests were conducted at room temperature.

Time (Days)	Entire fruits	Seed coat removed	Seed coat and mucilage removed	Seed coat and mucilage removed, pericap removed from plumule and of embryo	Seed coat and mucilage removed, pericap removed, from radicle and of embryo	Seed coat, mucilage, and entire pericap removed
1	0	0	0	0	0	25
2	0	0	0	0	21.7	45
4	0	0	0	20	40	56.7
5	0	0	40	55	70	70
7	0	50	46.7	63.3	80	80
10	0	70	81.7	88.3	81.7	80
14	3.3					
15	-	75	83.5	88.3	96.7	81.7
21	8.3					
28	10.0					

of the seed coat, germination had occurred in 50% of the seeds in only seven days (Table 15). Seventy-five percent had germinated within 15 days. When the seed coats and mucilage were removed 40% of the seeds germinated within five days and 83.3% germinated in 15 days.

Partial or entire removal of the pericarp reduced the time required for germination. With partical removal of the pericarp near the radicle, 21.7% of the seeds germinated after only two days while 96.7% had germinated after 15 days (Table 15). With the entire pericarp removed, 25% of the seeds germinated after 1 day, 45% after two days, and 81.7% after 15 days. The slowest germination occurred when the pericarp was partially removed from near the plumule end of the seed. In four days 20% of the seeds had germinated (Table 15). After 35 days, there was no significant difference between this and any other treatment.

II. Stratification Experiments

Cold temperatures greatly reduced germination of Peltandra seeds. Bare embryos failed to grow after two weeks at 0°C and 5°C (Table 16). As temperature increased there was a corresponding increase in germination. Ten percent of the embryos germinated at 10°C, 75% at 20°C, and 95% at 24°C.

Although embryos will not grow below 5°C, it appears that the length of exposure to cold temperatures or the condition of the

Table 16

Germination of seeds of Peltandra virginica after 2 weeks in water at temperatures ranging from 0 to 24 degrees centigrade. The seed coat, mucilage, and pericarp were removed from all seeds. There were 20 seeds at each temperature.

TEMPERATURE (C)	% GERMINATION
0	0
5	0
10	10
20	75
24	95

fruit exposed to those temperatures has little effect on the ability of the seed to germinate when placed at room temperature. Eighty percent of the entire fruits kept at 5°C for one week germinated after two weeks at room temperature (Table17). Fruits kept for four weeks at 5°C also had high germination percentages (Table 17). High germination percentages were recorded for the other classes of seeds which were stored at 5°C for periods of 1-4 weeks (Table 17.).

III. Seed Mucilage effects on germination and dessication

Results of the experiment to determine the effects of desiccation on germination appear in Table 18. The data indicates that entire fruits are not affected by drying. Germination significantly decreases with dry storage when the seed coat is removed. All seeds germinate after one day of dry storage. Germination percentages started to drop after 5 days of dessication and all seeds fail to germinate after eight days. A similar pattern occurred when both the seed coats and mucilage were removed.

DISCUSSION

Seed dormancy in Peltandra virginica is primarily imposed by the seed coat. The thick seed coat is extremely resistant to mechanical damage and to microbial decomposition. As evidence of the seed coats impermeability, water had penetrated only 10% of

Table 17

Germination of seeds of Peltandra virginica at room temperature following periods of cold, wet treatment ranging from one to four weeks. The seeds were divided into four classes depending on how much of the fruit was removed. Each class contained 40 seeds, with 10 removed weekly. All parts of the fruit were removed from the 10 seeds before being placed in water at room temperature for two weeks.

Time (weeks)	Entire fruit	Seed coat removed	Seed coat and mucilage removed	Seed coat, mucilage and entire pericarp removed
1	80	90	100	90
2	90	90	76	80
3	100	70	60	90
4	90	80	90	80

Table 18

The effects of various periods of desiccation on the germination of seeds of Peltandra virginica. Three classes of seeds were placed on dry filter paper at room temperature: entire fruits, fruits with the seed coat removed, and fruits with the seed coat and mucilage removed. Periodically some of the dry seeds were removed, the remaining parts of the fruit removed and then placed in water at room temperature for two weeks.

Length of dry period (Days)	Entire fruits	Seed coats removed	Seed coats and mucilage removed
1	90	100	80
2		80	80
3		80	80
4		80	60
5	80	40	20
6			0
7	90	20	0
8		0	
9		0	
14	70		
21	80		
28	90		
42	80		

the intact seeds (Table 15). Mucilage may also serve to inhibit germination somewhat since, with its removal, germination was initiated in 5 instead of 7 days (Table 15). The pericarp also appears to inhibit germination. Twenty-five percent of the seeds with the entire pericarp removed germinate in only one day and 80 percent after five days (Table 15). Partial removal of the pericarp was only effective in initiating germination earlier when it was removed from near the root end of the embryo. Partial removal of the pericarp near the roots resulted in a 21.7% germination rate of within the first two days. These results agree with Hart (1928) who suggested that partial dormancy was due to containment of the embryo within the pericarp. Edwards (1933) also reported the pericarp to be an obstacle to germination.

Temperature can also serve to hold seeds in a dormant condition. Seeds only germinated at temperatures above 10°C. In the marshes, the onset of the growing season corresponds with that temperature threshold. In the field, if seeds are to successfully survive they must be able to survive long periods of cold. Seeds stratified for periods varying from 1-4 weeks at 5°C all had high germination percentages once they were placed at room temperatures and the seed coats, if present, were removed. This is true regardless of the condition of the fruit since even seeds with

the entire pericarp removed show high germination percentages following the cold treatment. These results differ from those found by Adams (1927) from studies on Crataegus mollis. He found that after-ripening at 5°C was greatly influenced by the structures surrounding the embryo, namely the testa and carpel. Parkinson (1973) has shown that Pickerelweed, a common plant in the marshes, also requires a period of after-ripening before the seeds will germinate. Mucilage has virtually no effect on germination or in protection of the embryo from cold temperatures.

Mucilage does not provide protection from dessication damage. Gutterman (1967) suggested this for the mucilage of Blepharis persica seeds. However, the data indicates that such is not the case for Peltandra (Table 18.). When the seed coat is removed, the mucilage quickly dries out and flakes off the embryo. The seeds continue to dessicate and the germination fails to occur after seven days. With the mucilage removed prior to the drying period, the seed appears to dry out slightly faster with no germination occurring five days. With the seed coat intact, seeds remained viable after six weeks of dry storage. Examination of those seeds showed that the seed coat remained pliable and that the mucilage had shrunk but was still in the gel state. This suggests the possibility that the mucilage is capable of keeping both the seed coat and embryo from drying out if the seed coat is intact.

Kozlowski (1972) has reported that seed mucilages may reduce the specific weight of seeds in water. This does not seem to be true for Peltandra. The intact fruit is bouyant in water, however, with removal of the seed coat, the embryo losses its bouyancy as the mucilage absorbs water. The embryo itself is not bouyant, therefore the fruits' bouyancy is probably due to air trapped between the mucilage and seed coat. In the winter the mucilage freezes to the marsh surface when the temperatures are below 0°C. This serves to hold the seeds in place and prevent them from being washed away.

Both Kozlowski (1972) and Ferry (1959) state that seed mucilages have a large capacity to absorb water and swell. This is especially true for Peltandra where, on the average, the seed mucilage is capable of absorbing better than twice its weight in water. Preliminary field studies also indicate that about ten percent of the seeds collected during early December have some amount of mucilage exuding through the seed coat. This is indicated by the observation that through swelling, the mucilage is able to enlarge a small tear in the seed coat into an area large enough for the embryo to escape. Once this is accomplished, the seeds will be held in a dormant state by low temperatures. When substrate temperatures rise above 5-10°C, the seeds will germinate because the muscilage will have caused a break in the seed coat. On January 16, 1975, we collected a number of arrow arum seeds from the marshes. All of the seeds

that had had the seed coat removed or otherwise broken germinated within 2 days of being returned to the laboratory and placed at room temperatures. None of the seeds that we collected which had the seed coats intact germinated.

The following ecological strategy has evolved in Peltandra virginica. When the seeds are shed from the parent plant, most of the seed coats are intact and the seeds are buoyant. Thus the seeds are able to be dispersed throughout the marshes. As one would expect, arrow arum seeds are ubiquitous and are found in habitats where the species doesn't grow. Seeds are held dormant as long as the seed coat is intact. During the late autumn, the muscilage expands and causes a break in the seed coat. It has not been determined whether or not the muscilage expands because water had moved across the seed coat or whether the water was generated internally via respiration. Preliminary studies of seed metabolism have shown that there is an increased respiration rate just prior to germination. Since respiration is strongly temperature dependent, some metabolic water would be generated prior to the onset of cold temperatures. The seeds could germinate in the marshes whenever the seed coats are broken but water and substrate temperatures are low enough to hold the seeds in a dormant state. A few germinated seeds were observed prior to the onset of cold weather. The seeds are able to withstand extended cold periods and are viable once substrate and water temperatures reach 5 - 10^{o}C in the spring. These temperatures coincide with the beginning of

the growing season for mature arrow arum plants and with the onset of germination of arrow arum seeds. Evidence to support much of these conclusions was seen in the field in the fall of 1974. The seed coats of a number of seeds were broken before the onset of cold weather and those seeds germinated. Thus, the seed coat and muscilage appear to be the most important components in the ecology of arrow arum seeds.

ENVIRONMENTAL EDUCATION

Another goal of our work was to consider the feasibility of using the marshes as an outdoor educational facility. It is our opinion that the marshes can be used for that purpose and that serious thought should be given to the development of a township outdoor environmental education program utilizing the Hamilton Marshes as a focal point.

We feel that the most appropriate site for an outdoor educational facility is an island and adjacent marshland located near the Hamilton Township Sewage Treatment Plant (Fig. 46). We consider this to be the best site for the following reasons:

1. All major marsh habitats are in close proximity to the island.
2. Its proximity to the sewage plant would make it easier to provide security if any permanent facilities were to be constructed.
3. The sewage plant could be used as an integral part of educational programs that would be developed.
4. It is close to Crosswicks Creek, Watsons Creek and other unnamed channels which can all be used for canoe trails.
5. The island is large and is covered with mature forests. There is enough additional area for the establishment of fields and plantations of other trees, etc.
6. We have seen no evidence that the island is regularly flooded.
7. The entire area is owned by the township.
8. Figure 46 also shows that the island is horseshoe shaped and that it encloses a section of marsh. It would be feasible to dike that area, dredge it, and create a ground water fed fresh water lake. The lake could be used for boating, fishing, attracting birds, etc.

We propose that the Township seriously consider establishing an environmental study center in the Hamilton Marshes and recommend the following timetable to accomplish its development:

Fiscal Year 1976

1. The Hamilton Township Environmental Commission working with Township schools (including teachers, students, and administrators) should establish the need for a Township environmental education facility.
2. A comprehensive plan for the environmental education center should be developed. This plan should consider alignment of nature trails and catwalks in the marsh and forest areas, placement and design of facilities including museum and interpretive buildings, and location of fields and plantations. The Delaware and Raritan Canal Commission should be contacted during this phase regarding their plans to develop the first lock area of the Delaware and Raritan Canal at Bordentown. It would be entirely feasible to link the Hamilton facility with the canal facility.
3. Grant funds should be sought for the development of the center.

Fiscal Year 1977

1. Build trails, catwalks, and clear island areas for plantations, fields, etc.
2. Develop curricular materials for grades K-12 (this should be done by Township educators).

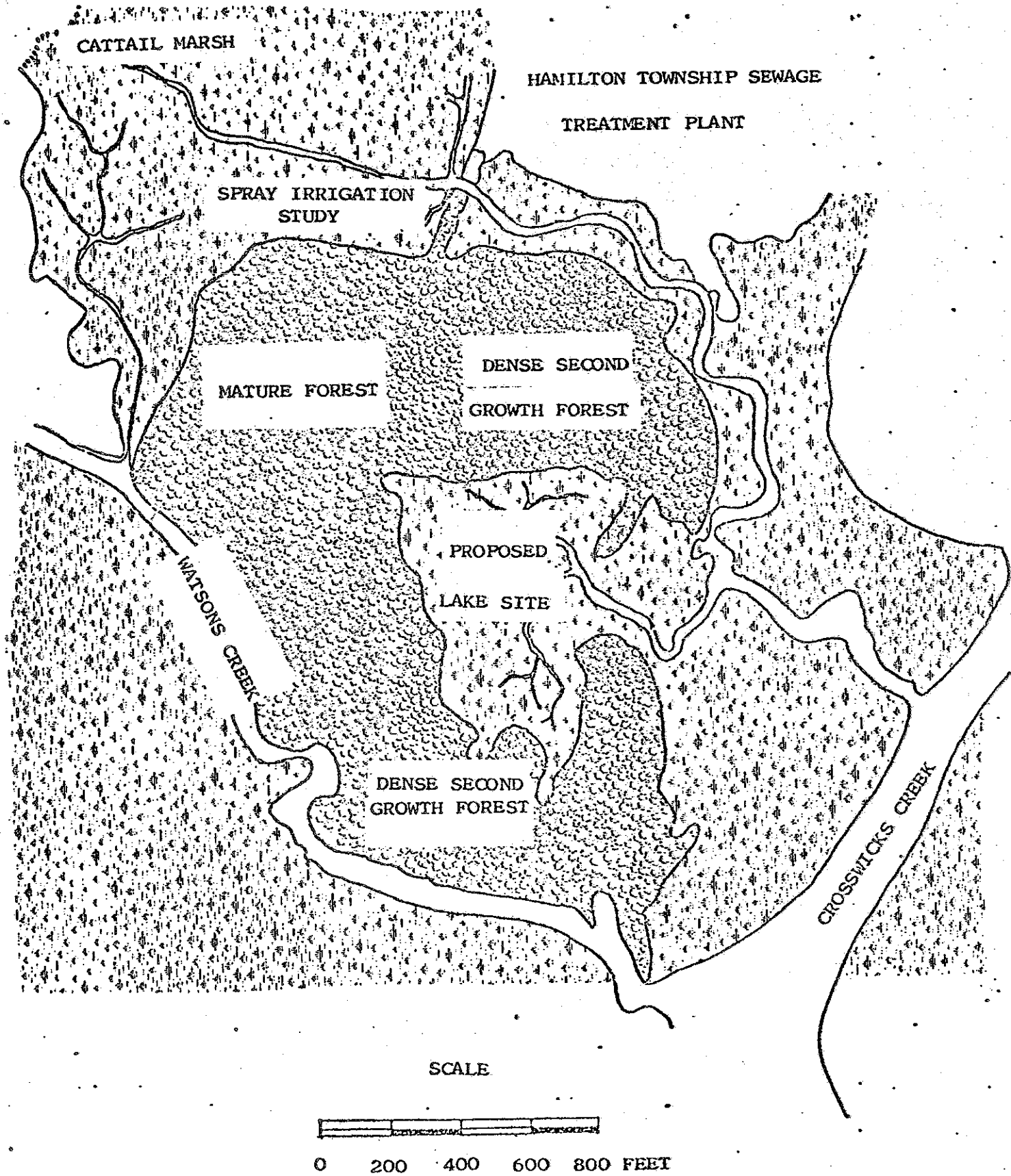
Fiscal Year 1978 and beyond

1. Build museum and interpretive buildings. An environmental education facility involves people, land, and buildings. As described in the National Audubon Societies bulletin on A Nature Center for Your Community, "to run a nature center efficiently, one must have a place where people can meet. An education building, then with an orientation-assembly room, exhibits, displays, book store, offices, restrooms, and a workshop, is essential". This phase of development would be the most expensive and should be

undertaken after the center is established and its future assured. The area has a rich pre and posteuropean history that should be included in the planning of the center.

2. Plans should be formulated for the creation of the proposed lake. We recommend that this project be given early consideration because it would be feasible to use the dredged material to fill, completely or in part, the sludge lagoons at the sewage plant. The latter will apparently be drained and filled whenever construction begins on the expansion of the sewage plant. This fill would save the Township money and it would then be economically feasible to construct the proposed lake.

PROPOSED SITE FOR HAMILTON TOWNSHIP ENVIRONMENTAL STUDY CENTER



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