# POPULATION STUDIES OF THE RARE SPECIES *VIOLA BRITTONIANA* POLLARD IN MASSACHUSETTS

1991 and 1992

Sally A. Zielinski, Ph.D.

Note: This document should be read in conjunction with the attached report of 1990 research

TABLE OF CONTENTS


I. INTRODUCTION

A. Background
B. Emergence and Population Size
C. Flowering and Fruiting
D. Population Dynamics and Structure
E. Preservation of Seed; Fruit and Seed Characteristics; Dispersal
F. Association: Nearest Neighbors
G. Limiting Factors: Litter Depth
H. Threatened Populations
I. Search for Additional Populations
J. Management Plan
K. Public Awareness
L. Goals and Objectives

II. METHODS

A. Study Sites
B. Emergence and Population Size
C. Flowering and Fruiting
D. Population Dynamics and Structure
E. Preservation of Seed; Fruit and Seed Characteristics; Dispersal
F. Association: Nearest Neighbors
G. Limiting Factors: Litter Depth
H. Threatened Populations
I. Search for Additional Populations

III. RESULTS AND DISCUSSION

A. Summary of Major Results and Conclusions
B. Emergence and Population Size
C. Flowering and Fruiting
D. Population Dynamics and Structure
E. Preservation of Seed; Fruit and Seed Characteristics; Dispersal
F. Association: Nearest Neighbors
G. Limiting Factors: Litter Depth
H. Threatened Populations
I. Search for Additional Populations
J. Management Plan
K. Public Awareness

## TABLE OF CONTENTS (Continued)


IV. LIST OF TABLES, FIGURES AND APPENDICES

Tables

| | |
|---|---|
| 1a,b | Plant Emergence |
| 2 | Soil and Air Temperature at Time of Emergence |
| 3 | Population Size |
| 4 | Flowering Patterns |
| 5 | Flowering and Fruiting |
| 6 | Population Dynamics |
| 7 | Reproductive Behavior in Successive Years |
| 8 | Plant Size vs. Reproductive Stage |
| 9 | Fruit Characteristics |
| 10 | Seed Characteristics |
| 11 | Nearest Neighbors |
| 12 | Litter Removal |

Figures

| | |
|---|---|
| 1a,b | Plant Emergence Patterns |
| 2a | Soil Temperature at Time of Plant Emergence |
| 2b | Air Temperature at Time of Plant Emergence |
| 3a,b | Distribution of Numbers of Leaves |
| 4 | Plant Size vs. Reproductive Stage |
| 5a,b,c | Litter Profiles |
| 6a,b,c, d,e,f,g | Plant Distribution at Different Litter Depths |
| 7 | Minuteman National Park |

Appendices

| | |
|---|---|
| A | Article in MACC Newsletter |

V. ACKNOWLEDGEMENTS

VI. REFERENCES

# POPULATION STUDIES OF THE RARE SPECIES VIOLA BRITTONIANA POLLARD IN MASSACHUSETTS

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## I. INTRODUCTION

### A. Background

Viola brittoniana Pollard, Britton's or the coast violet, is listed as rare and threatened in Massachusetts. Recent information from the Massachusetts Natural Heritage and Endangered Species Program (NHESP) has suggested that the species may also be rare throughout its range.

Historical descriptions and observations of existing sites in Massachusetts suggest that V. brittoniana populations are declining, both in number and size (NHESP, pers obs). Tuckerman found V. brittoniana to be abundant in Concord in 1839. However, it was already sparse and localized in Massachusetts by 1909 (Brewster 1909). While there are 14 documented occurrences prior to 1978, only 6 extant populations had been found prior to 1992. Two of these are imminently threatened.

Five of these populations occur along the Concord River - with three of these in Concord, and one each in Carlisle and Bedford. A population along the Neponset River in Milton has been regarded as variety pectinata. It is unclear whether this population is V. brittoniana or a separate species.

Britton's is a stemless blue violet found in or just above river flood plains. Aside from its association with rivers, streams and sometimes trails, there was a notable lack of information about V. brittoniana until the present work began in 1989. The only exceptions were the taxonomic and hybridization studies of Brainerd (1921, 1924), Gershoy (1928) and Russell (1965).

Preliminary observations in 1989 at the Carlisle site and detailed research during 1990 at both Carlisle and Bedford provided insight into the population ecology and dynamics of Britton's violet - including emergence and reproductive patterns, population size and structure, association with other plant species, and litter depth as a limiting factor in the distribution of individuals within a population (Zielinski 1990).

In 1991 and 1992 detailed work continued at the Carlisle and Bedford sites. Limited observations were made at two sites in Concord (designated Concord1 and Concord2) and at the Milton pectinata site.

That referred to here as Concord1 is identified simply as Concord in the 1990 report.

## B. Emergence and Population Size

In 1990 all plants in the Carlisle and Bedford populations had been tagged and mapped as they emerged. Emergence began at the end of April at both sites as well as at Concord1. Emergence of individuals within populations was observed to occur over many weeks. While individual plants were not followed at the Concord1 site, a similar pattern of emergence was evident. Preliminary observations had been made at the Carlisle site in 1989 and indicated emergence also began at the very end of April.

Multi-year and multi-site studies of emergence are needed to determine whether this pattern is repeated annually. Temperature monitoring is needed to help identify the temperature at which emergence occurs.

Population size is a measure of the vigor or health of a population. Tracking size is essential in determining whether populations of a rare plant are stable, declining or expanding.

Population counts were made in 1990 at the Carlisle, Bedford and Concord1 sites. The number of individuals was counted again in 1991 and 1992 in order to track population size on a long term basis.

## C. Flowering and Fruiting

During 1990 the number of chasmogamous (CH) and/or cleistogamous (CL) flowers and developing or mature fruits was determined for each plant in Carlisle and Bedford, and for the Concord1 population as a whole.

Population profiles developed in 1990 included patterns of plant emergence, relation of flowering time and type of flowers to fruiting success, relation of size and date of emergence to reproductive success, length of growing season vs. size, and the proportion of reproductive vs. non-reproductive individuals in the population.

V. brittoniana flowers later than any other violets in the local area. In general both flowering and fruiting occurred slightly earlier in Bedford than Carlisle. At both sites only a small proportion of each population produced CH flowers - one to three percent.

The fraction of flowers initiating fruits, a reflection of pollination success and other factors, was also very low. CL flowering was similarly low but considerably heavier than CH flowering. Around half the plants producing CL flowers matured fruit. Early emergence was related to greater flowering and reproductive success.

Differences in levels of flowering and fruiting between sites are common in plants. In addition levels often vary from year to year in a given population. Additional observations are needed to assess whether this

site-to-site variation occurs annually, and whether year-to-year variation occurs.

### D. Population Dynamics and Structure

The dynamics of a plant population include the birth and death rates of individuals. Viola brittoniana does not reproduce via underground rhizomes and therefore all recruits are assumed to come from CH and CL seeds. The dynamics of the Carlisle and Bedford populations were investigated in 1991.

Many plants will not flower until they reach a certain size (Harper 1974). Cook (1978) suggested it is not unusual for violets to live 10 years. He found that, in their first season, violets usually produce only two or three small leaves and certainly no flowers. The second year there are generally five or six strong leaves, but no flowers. The third year CL flowers are produced, with CH in the fourth. Lifespan and the pattern of CH vs. CL flowering are unknown for Britton's violet. A project was undertaken in 1991 to elicit this pattern through comparison of plant size and reproductive stage.

### E. Preservation of Seed; Fruit and Seed Characteristics; Dispersal

The rare status of Viola brittoniana throughout its range makes it essential to preserve genetic material from this plant. Near the end of the 1991 reproductive period the opportunity arose to add V. brittoniana seed to the New England Wild Flower Society's rare plant seed bank.

In addition, while the number of CH and CL capsules produced in the Carlisle and Bedford populations was determined in 1990 and similar studies planned for 1991, the total number of seeds (and potential for recruiting new individuals to these populations) is unknown. Collection of a sample of CH and CL capsules is essential for better estimation of the seed production of each population as well as a rough comparison of CH and CL seed production.

The processes of capsule opening and seed ejection are unknown in V. brittoniana. Other violets are known to forcibly eject seeds (Beattie & Lyons 1975; Foy 1978). Like these V. brittoniana carries its capsules on peduncles which remain erect until or just before maturity. Therefore observations of the final stages of maturation and a test to determine whether forcible ejection occurs were planned.

Thus to achieve the above goals, in 1992 a technique was developed to gather capsules and seeds of Britton's violet from the Carlisle and Bedford populations.

Violet seeds are generally difficult to collect. While developing capsules of V. brittoniana were repeatedly observed, no mature capsules containing developed seeds have been found in four seasons of observation.

In some cases entire capsules had been removed leaving the peduncle, or aborted capsules which appeared to have bites out of them were found. In other cases capsules were found empty except for one or two seeds. It was clear that a system was needed to prevent removal of the capsules by animals and to collect mature seeds prior to ejection.

## F. Association: Nearest Neighbors

Spatial relationships among individuals of Viola brittoniana and between V. brittoniana and other species were determined in 1990 through nearest neighbor analysis. At the Carlisle site the nearest neighbor of V. brittoniana individuals was most frequently another V. brittoniana, while the most frequent associates in Bedford were other V. brittoniana and a sedge. However, it was not possible to completely identify all associates - due partly to the absence of reproductive parts. Identification continued in 1991 and 1992.

## G. Limiting Factors: Litter Depth

Most Viola brittoniana populations are found along trails. Factors which might affect the distribution of individuals with respect to distance from a trail center include soil compaction, light, moisture, competition, and litter depth.

Projects to assess litter depth as a limiting factor to V. brittoniana were begun in 1990. It was found that the depth of litter on the forest floor increases away from the trails. There is an optimum depth of 0.9 cm at which V. brittoniana plants in Carlisle and Bedford grow, flower and fruit, and there is a small range of depths at which the species is found. Britton's violet plants are generally clustered just beyond the trail edge where the litter is thin. Off the trail, where the litter is generally deeper, many of the plants are in pockets of shallower litter.

In order to determine whether litter depth varies from year to year in Carlisle and Bedford, a second year of measurements was planned for 1991. In addition litter depth was measured for the first time at the Concord1 and Milton sites.

To test whether deep litter inhibits seed germination or seedling survival, a litter removal project was initiated in 1990. Litter was removed from two plots in Carlisle and three in Bedford, and similar control plots were designated. Litter was removed from plots at each site to leave a depth of 1 cm.

Results were not expected from the litter removal experiment in its first year - 1990. Removal occurred after most plants in the populations had emerged. The experiment continued through 1991 and 1992.

## H. Threatened Populations

Disturbance to the habitats of rare plants with few populations can lead to loss of individuals and diminish the genetic diversity and population numbers necessary for the species to persist.

A major landscaping project at the Concord2 site was underway in 1990 prior to the effective date of the Massachusetts Endangered Species Act. Britton's violet individuals had been lost (Zielinski, pers. obs.). During 1991 it was essential to determine what portion of the population had been affected and to develop strategies to protect remaining plants.

At the V. brittoniana pectinata site in Milton proposed enlargement of a Metropolitan District Commission (MDC) sewer line has been proposed. This project runs directly through the population.

NHESP has assisted in modification of the project location to minimize the potential for impact on Britton's violet. It was necessary to locate all individuals on the affected part of the site and to develop mitigation strategies.

## I. Search for Additional Populations

### Minuteman National Park

The search for new populations of Britton's violet was focused on Minuteman National Park during 1992.

All but one of the known populations are found along the Concord River (the Milton population which is variety pectinata is along the Neponset). The river runs through the portion of Minuteman Park which lies in the town of Concord.

During the summer months when Britton's violet has the greatest biomass and is relatively easy to locate and identify, the areas on and just above the flood plain of the river in the park were searched.

### Additional Locations

Since the Bedford population occurs in the Great Meadows National Wildlife Refuge, and other likely habitat areas exist there, permission was obtained from the refuge to further search the river floodplain. In addition plans were made to search additional areas of the floodplain in the Town of Concord.

## J. Management Plan

There is still a great deal to learn about the habitat requirements of Britton's violet. However sufficient information has now been obtained to begin to develop a management strategy for populations in Massachusetts. Recent and potential impacts to the few known populations make it essential to formulate such a strategy. This will

be a dynamic document, to be amended as new information becomes available.

## K. Public Awareness

A search for new populations of V. brittoniana in 1990 included public education and searching likely habitats. About 50% of the upper flood plain of the Concord River in the portion of Carlisle running from Billerica to Route 225 had been searched in 1989. While no new populations were found in 1989 or 1990 publicity led to heightened public awareness of Britton's violet. A newspaper article and flyer describing the species, its importance and where to search were prepared, and a field workshop was held during the CH flowering season.

Thus a group of about 15 people in the area are currently knowledgeable about Britton's violet and actively looking for new populations along the flood plain of the Concord River in sections of Carlisle, Bedford and Concord. It is important that the process of public education be ongoing.

## L. Goals and Objectives

The overall objectives of 1991 and 1992 work were to further clarify the population ecology, dynamics and status of V. brittoniana in Massachusetts; to continue efforts to protect imminently threatened populations; to search for additional populations; and to make recommendations for the protection and management of the species. This was achieved through continuing certain projects initiated in 1990 as well as extending the scope of the research.

Specific goals for 1991 and 1992 included:

* Obtaining a second season's data on emergence and reproductive patterns
* Continuing implementation of a long term tracking program for the size and dynamics of two populations
* Continuing identification of nearest neighbors
* Extending forest litter depth studies to additional populations, as well as collecting a second season's data at two sites, and following up litter removal studies
* Development of a procedure for seed collection and collection of seeds for the New England Wild Flower Society rare plant seed bank
* Continuing efforts to protect two imminently threatened populations
* Planning and execution of a search of Minuteman National Park and other areas along the Concord River for new populations
* Continuing efforts to increase public awareness of Britton's violet in order to protect existing populations and find new ones
* Development of a management strategy.

## II. METHODS

### A. Study Sites

Detailed studies of Britton's violet populations in Carlisle and Bedford continued in 1991. Individuals in sample plots (representing approximately 50% of the population) were followed in Bedford. Five blocks were selected and data collected for all individuals within a block. Specific but less frequent observations were made at the Concord1, Concord2 and Milton sites. During 1992 work was undertaken at all but the Concord2 site.

### B. Emergence and Population Size

To monitor plant emergence patterns and population size for a second year in 1991 at the Carlisle and Bedford sites each plant was checked on April 27 and at frequent intervals throughout the growing season. The emergence date of each plant was recorded.

Individuals present in 1990 had been mapped and tagged. Individuals which re-emerged or failed to re-emerge in 1991 were noted. New individuals were assigned numbers, tagged and mapped.

In order to determine the temperature at which emergence occurs, soil and air temperature were measured at two meter intervals along the trail in Carlisle, alternating between the left and right sides, and in each plot in Bedford.

Readings of soil temperature were taken at a depth of 3 cm, within the root zone of Britton's violet, near the edge of the trail at the area where the greatest concentration of plants occurs. Measurements were made on five dates between April 27 and June 23. All were made between 2 and 7 pm and to the nearest degree centigrade.

### C. Flowering and Fruiting

In order to provide a second season's observations of flowering and fruiting for the Carlisle population and the Bedford plots, the sites were visited in 1991 near and during peak CH and CL flowering and fruiting periods.

On each observation date the numbers of flowers or fruits on each plant were recorded. Levels of CH and CL flowering and fruiting, fruiting success were determined.

In 1992 levels of flowering and fruiting were again determined through counts at or near peak flowering. However data for individual plants was generally not recorded.

## D. Population Dynamics and Structure

In order to determine the turnover rate of individuals and the birth and death rates, plants tagged in 1990 were checked to determine survival rate and new recruits tagged and mapped. Data collected for each individual - both seedlings and established plants, included number and length of leaves, and types of flowers and fruits.

As in 1990 individual plants were classified as: non-reproductive; CL flowering; CL plus CH flowering; or CH flowering. Reproductive stages as a function of plant age were determined by comparing the number of individuals in each category in 1990 with the number in 1991.

Plant size was compared with the type of reproduction. Plant size was determined through measurements of the number of leaves on each plant and the length of each leaf. Leaf length was measured from the base of the petiole to the tip of the blade. The sum of all leaf lengths was used as an indicator of plant size.

Leaf counts and measurements were made on August 16 after the plants were fully leafed out. This time was chosen after observations in 1990 indicated that V. brittoniana plants continue to produce leaves throughout the spring and summer and leaves once formed persisted unless eaten by herbivores.

## E. Preservation of Seed; Fruit and Seed Characteristics; Dispersal

Since capsule production is low in the Carlisle and Bedford populations only a few capsules were collected during 1992 in order to minimize disturbance. The mean number of seeds per collected capsule, times the estimated number of capsules, was calculated for each seed type to estimate total seed production.

A system of enclosing developing capsules in porous bags was developed. Capsules were enclosed by wrapping a small square of nylon, approximately 5 x 5 cm, around the capsule and upper end of the peduncle, and stapling it in place. Care was taken to prevent staples from penetrating the peduncle.

The first CH capsules were bagged on June 7, 1992, approximately two weeks following flowering. Since it was difficult to tell through the bag whether a capsule was mature, bagged capsules were left in place for several weeks to maximize their chance of ripening, then collected - with their stems intact.

If a capsule was not already open, the stem was placed in water until full maturation and opening occurred. Since these stems were not stiff enough to hold a capsule upright, each was placed in a small bottle with a narrow neck which allowed the capsule to rest outside the water. Ripening capsules were observed several times a day in order to observe morphological changes during capsule maturation and in particular the process of ejection.

The container with the capsule was then set inside a larger and taller container in order to test whether Britton's violet forcibly ejects its seeds. The circular rim of the larger container extended 13 cm above and 18 cm to each side of the top of suspended capsules.

As each capsule opened the number of mature seeds was counted to estimate both the number of seeds per capsule and total seed production. The total number of seeds produced in a population of Britton's violet is equal to the number of capsules times the number of seeds per capsule.

Seeds were subsequently stored in paper envelopes. Several months after collection ten seeds from each capsule with mature healthy seeds were randomly selected and weighed using a Mettler AE100 balance. The mean number of mature seeds per capsule collected was used to estimate mean seed weight per capsule in the population. This was done for both CH and CL capsules.

**F. Association: Nearest Neighbors**

Specimens of plants which had not been completely identified in 1990 were collected and their field locations noted.

**G. Limiting Factors: Litter Depth**

In order to profile the variation in litter depth with distance from the trail center for a second season in Carlisle and Bedford during 1991, depth was again measured at 0.1 m intervals along transects running perpendicular to the trail and extending 1.5 m to either side of the center. Transects were placed at the same locations as in 1990 - at the 2 m and 5 m points in Carlisle and at the 20, 40 and 60 m points in Bedford. At Concord1 similar measurements were made. A transect was placed at approximately the 20 m point.

The litter depth in which V. brittoniana individuals were growing was measured to the nearest 0.1 cm prior to leaf fall in late summer for plants at Carlisle and Bedford. Similar measurements were made at Concord1 and Milton in 1991. Measurements were made using the same depth micrometer as in 1990. At Carlisle and Bedford litter depth was measured in 1991 only for those plants which were present and measured in 1990. At Milton individuals both in the red maple swamp and along the trail were sampled.

The two pairs of plots (treatment and control) in Carlisle and the three in Bedford were visited several times during the 1991 and 1992 growing seasons to observe whether new individuals had emerged, and to document the survivorship of any seedlings. Newly accumulated litter was removed prior to the beginning of plant activity in late April as plants were beginning to emerge, and again in August prior to leaf fall. Litter was pulled back to leave a depth of 1 cm.

## H. Threatened Populations

At the Concord2 site all individuals were located and counted in 1991. Mitigation and management strategies were discussed.

At Milton all plants lying in the path of the sewer line enlargement were located and counted. Consultation occurred regarding mitigation, protective controls during construction, and restoration of habitat when the project is complete.

## I. Search for Additional Populations

Minuteman National Park was surveyed between July and October of 1992. This time period was chosen because V. brittoniana plants are larger and easier to find during summer and early fall than in spring. In addition water levels are lower at this time allowing greater visibility of the floodplain vegetation and drier conditions for walking. The Park provided the assistance of an intern on several days.

Areas within the 1 year flood line were surveyed, though Britton's violet is not known to occur in areas with annual inundation. Areas at the upper end of the 1 year flood line and ranging to several hundred meters beyond the 100 year flood line were intensively searched.

# III. RESULTS AND DISCUSSION

## A. Summary of Major Results and Conclusions

Three years of detailed observations and experiments at two Viola brittoniana sites in Massachusetts and general observations at other sites have revealed considerable information about this threatened species. The points listed in the summary below are discussed in the following sections.

Major results and conclusions include:

* Individuals emerge over a several month period beginning at the end of April.
* Emergence time varies little from year to year.
* Seedlings emerge later than established plants.
* Only large, early emerging plants flower.
* Emergence occurs when soil temperature is about 16-17 degrees C.

* Population size is increasing at some sites and decreasing in others.
* There are at least 658 plants currently in Massachusetts.

* The proportion of plants flowering and fruiting in any year is low in the woodland populations.
* A given individual may not flower every year.
* Chasmogamous and cleistogamous flowering may alternate as the primary means of seed production.
* Fruit set is higher, as expected, in cleistogamous flowers.

* Cleistogamous flowers produce more and heavier seeds than chasmogamous.

* New recruits from seed are occurring at all sites, sometimes in large cohorts.
* Some full size seed is not viable.
* Capsule maturation, opening and seed ejection were observed and described.
* The species forcibly ejects seeds and has adaptations for diplochory.
* A technique for collecting seed has been developed.
* Over 100 seeds have been provided to the New England Wild Flower Society's rare plant seed bank.

* There is a general trend in individuals from non-flowering to cleistogamous flowering to cleistogamous plus chasmogamous flowering to chasmogamous flowering.
* Reproductive stages occur with increasing plant size.

* Leaves are continuously produced throughout the season.
* Most plants have 1 or 2 leaves.
* A growing population has more larger leaves per plant than a declining one.

* Litter depth is a limiting factor in distribution.
* Few individuals grow in litter deeper than 1 cm.
* Plants emerged in areas where litter was experimentally removed.

* The species is found in the 10-100 year floodplain of rivers and not in areas annually inundated.
* A typical plant is along a trail in an area with a thin to moderate canopy, sparse forest floor vegetation, and thin litter.

* No populations were found in Minuteman National Park. There is little typical habitat within the park.
* A new population was found in Concord.

* Two populations are currently under threat of damage or elimination.
* A management plan should include permanent protection of potential as well as actual habitat, creation of buffer zones around populations, removal of invasive and very dense vegetation, maintenance of trails as trails, and prohibition of motorized vehicles.

* Public awareness of the species has been considerably enhanced through presentations, workshops and articles .

## B. Emergence and Population Size

### Emergence

As in 1990 emergence of individuals in 1991 began at the end of April and occurred over 3 1/2 months (Table 1a&b). The 1991 pattern of emergence was similar to 1990 with numbers of individuals continuing to emerge through late summer (Figures 1a&b).

Table 1a: PLANT EMERGENCE 1990

| Date | Day of Year | Total Plants Emerged | | | | |
|---|---|---|---|---|---|---|
| | | CARLISLE | BEDFORD * | CONCORD 1 | CONCORD 2 | MILTON |
| Apr 28 | 118 | 2 | | | | |
| Apr 30 | 120 | | 5 | 1 | | |
| May 6 | 126 | | 29 | 21 | | |
| May 8 | 128 | 36 | | | | |
| May 14 | 134 | | 49 | 28 | | |
| May 17 | 137 | 48 | | | | |
| May 25 | 145 | 63 | | | >19 | >200 |
| May 26 | 146 | | 128 | 65 | | |
| May 31 | 151 | | 141 | 76 | | |
| Jun 6 | 157 | 70 | | | | |
| Jun 8 | 159 | | 170 | 94 | | |
| Jun 14 | 165 | 81 | 186 | 97 | | |
| Jun 22 | 173 | | 193 | | | |
| Jun 29 | 180 | 87 | | | | |
| Jul 9 | 190 | | 194 | | | |
| Jul 13 | 194 | 88 | | | | |
| Jul 26 | 207 | 88 | 211 | | | |
| Aug 14 | 226 | 89 | | 99 | | |
| Sep 4 | 247 | 89 | | | | |
| Sep 6 | 249 | | 211 | | | |

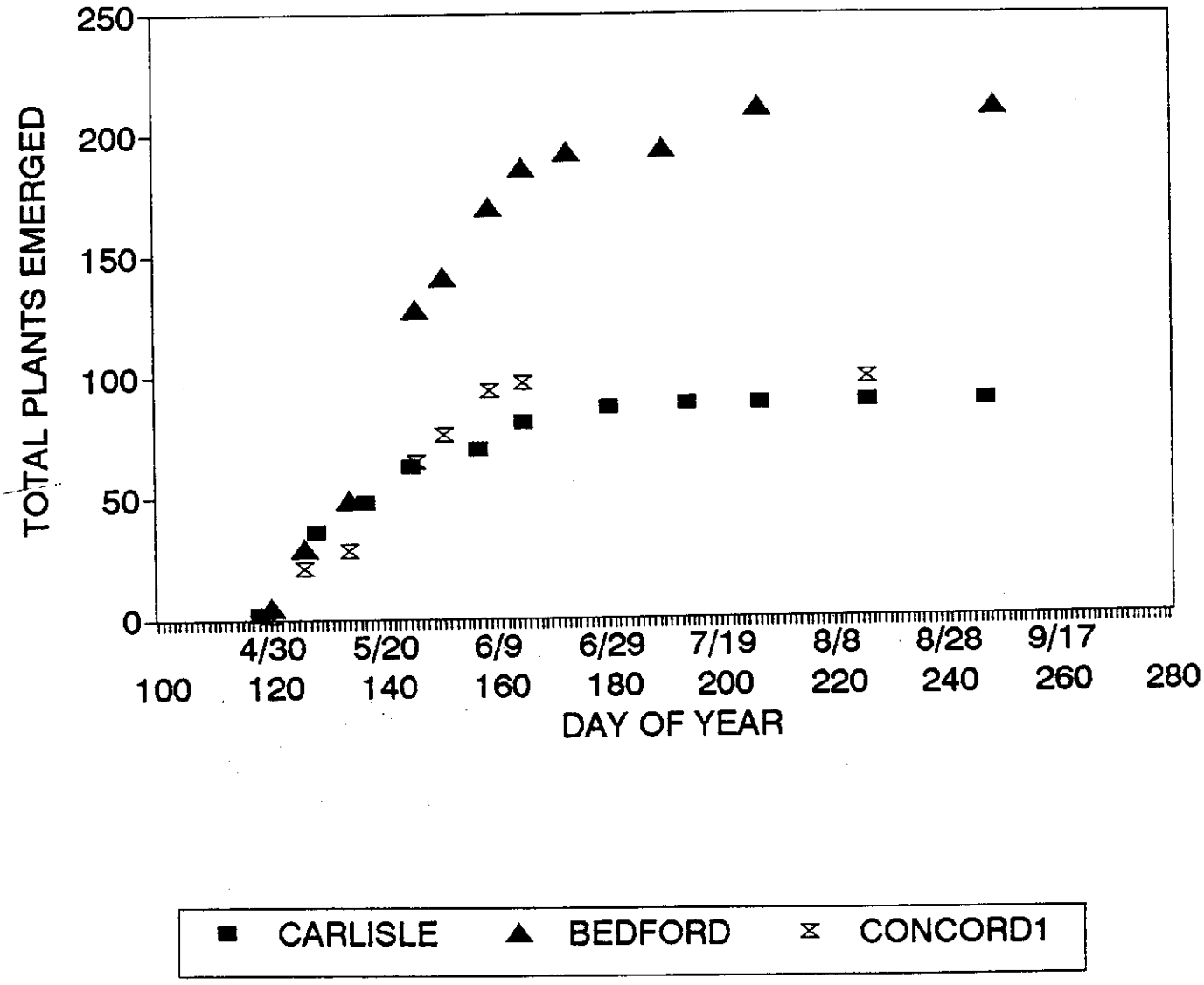
* Entire population

Table 1b: PLANT EMERGENCE 1991

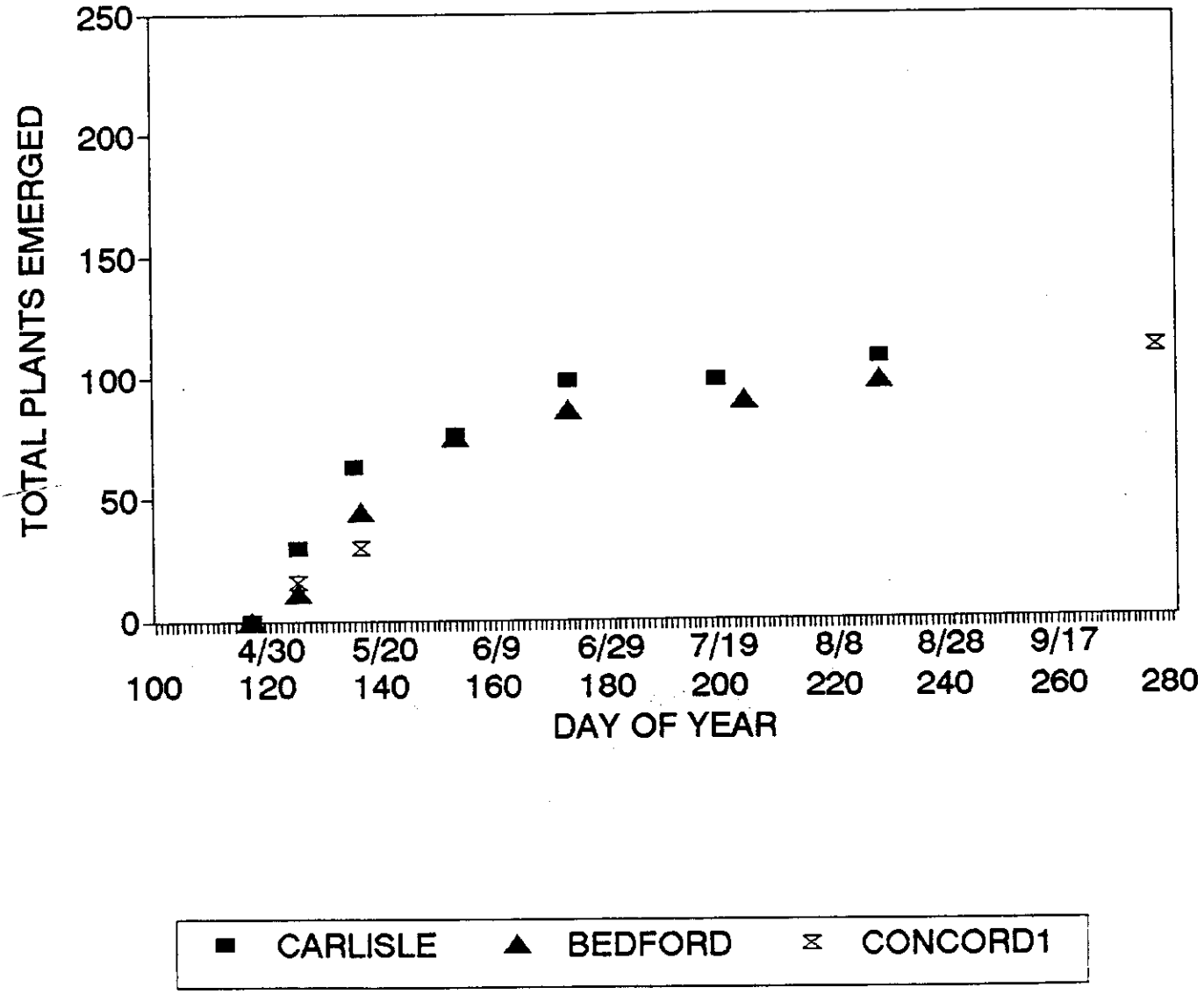
| Date | Day of Year | Total Plants Emerged | | | | |
|---|---|---|---|---|---|---|
| | | CARLISLE | BEDFORD PLOTS ONLY * | CONCORD 1 | CONCORD 2 | MILTON |
| Apr 27 | 117 | 0 | 0 | 0 | | |
| May 5 | 125 | 30 | 11 | 16 | | |
| May 15 | 135 | 64 | | | | |
| May 16 | 136 | | 44 | 30 | | |
| May 23 | 143 | | | | 52 | |
| Jun 2 | 153 | 77 | 75 | | | |
| Jun 23 | 173 | 97 | 86 | | | |
| Jul 18 | 199 | 97 | | | | |
| Jul 23 | 204 | | 90 | | | |
| Aug 16 | 228 | 106 | 97 | | | |
| Oct 4 | 277 | | | 111 | | >200 |

* Total population on August 16: 185

Figure 1a:
PLANT EMERGENCE PATTERN 1990



# Figure 1b:
# PLANT EMERGENCE PATTERN 1991



Throughout the emergence period there was a steady increase in soil temperature from around 15.5 to 20 degrees C (Table 2; Figure 2a). On April 27 mean soil temperature was 15.4 degrees in Carlisle compared to 15.8 degrees in Bedford. No plants were visible on April 27.

At both sites plants had emerged by the May 5 observation date when soil temperature was 16.2 degrees in Carlisle and 17.0 in Bedford. This suggests that Viola brittoniana growth begins below 16 degrees. Soil at the Bedford site was consistently warmer than Carlisle. The difference was slight - zero to 0.8 degrees.

Air temperature showed much greater fluctuation than soil temperature and increased only 1-3 degrees overall from April until June (Figure 2b).

The fact that air temperature patterns were less regular at both sites may reflect a more immediate response to weather changes. All measurements were taken in the afternoon to early evening but wind velocity and amount of sun were highly variable.

Air temperature was consistently higher than soil temperature at both sites but the difference between them varied from one to eight degrees (Table 2).

**Population Size**

The Carlisle population is clearly growing while the Bedford plots show a small decline in numbers from 1990. As Table 3 indicates plant numbers have more than doubled in Carlisle since 1989 with a steady increase from 69 plants in 1989 to 160 individuals in 1992.

The Bedford population, on the other hand, is undergoing a slow decline. The total population numbered 211 plants in 1990 and declined to 178 in 1992. There has been no obvious recent human disturbance at either site, however at Bedford a section of the population is being heavily overgrown with Rubus hispidus. Few of the plants present in this section in 1990 were found in 1992.

The population numbers include the two plants from Carlisle and six from Bedford which were removed for taxonomic studies as well as the few seedlings which appeared in the litter removal plots.

At Concord1 the population increased from 99 plants in 1990 to 112 in 1991 then remained essentially steady at 113 in 1992.

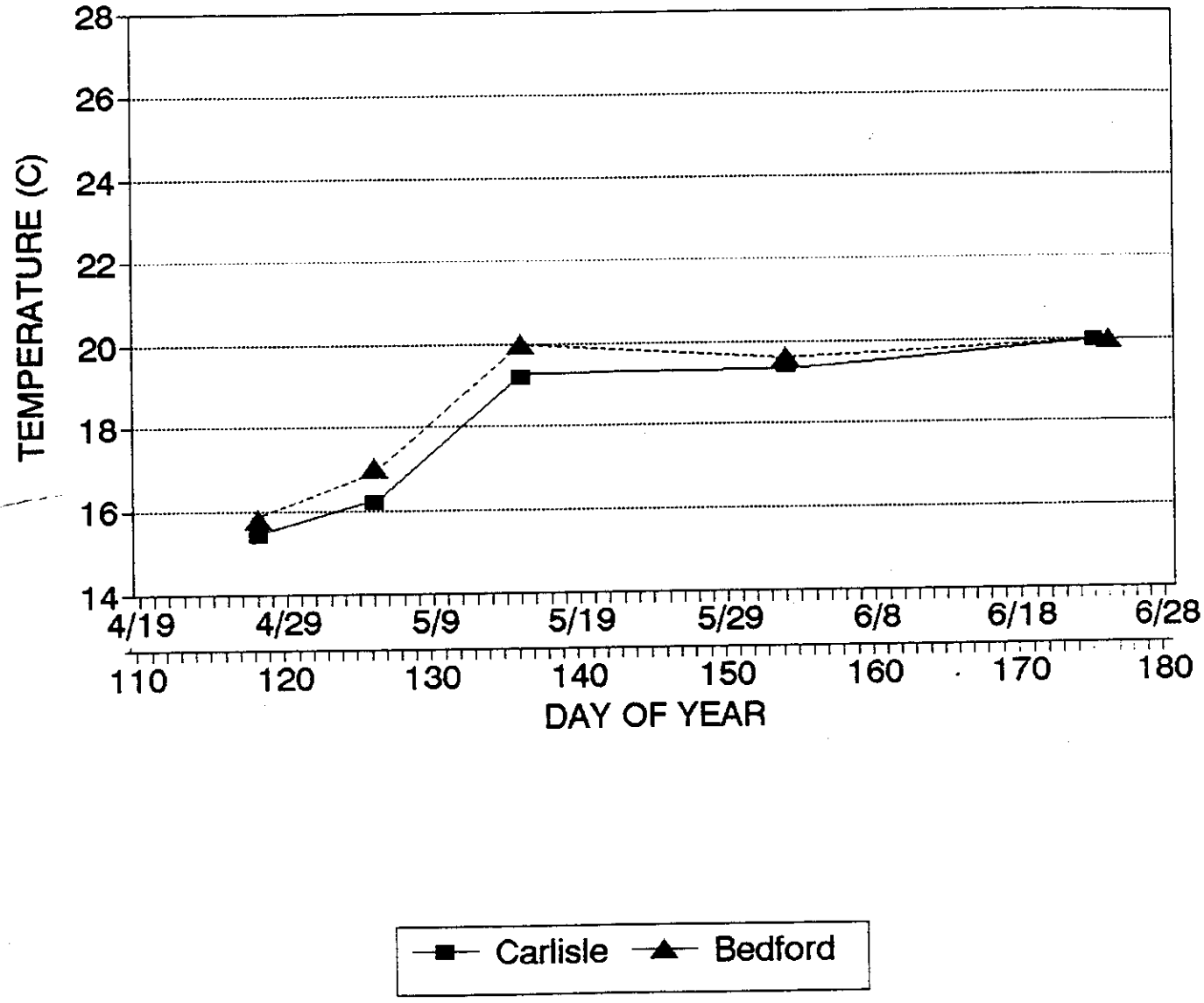
Considering the Carlisle, Bedford and Concord1 populations respectively, the sum of individuals at the 3 sites was: (89 + 211 + 99 = 399 in 1990), (106 + 185 + 112 = 403 in 1991) and (160 + 178 + 113 = 451 in 1992). Thus numbers have increased. The large cohort of seedlings in the middle of the trail in Carlisle, which makes up most of the 1992 increase over 1991, may not be able to persist in the face of foot traffic, however.

Table 2: SOIL AND AIR TEMPERATURE AT TIME OF EMERGENCE 1991 (C)

| CARLISLE | | | | BEDFORD | | | |
|---|---|---|---|---|---|---|---|
| Date | Location* | Soil | Air | Date | Plot** | Soil | Air |
| Apr 27 | 0R | 14 | 18 | Apr 27 | 1 | 15 | 21 |
| | 2L | 16 | 20 | | 2 | 16 | 24 |
| | 4R | 17 | 19 | | 3 | 15 | 22 |
| | 6L | 15 | 17 | | 4 | 17 | 23 |
| | 8R | 15 | 18 | | 5 | 16 | 22 |
| | Mean | 15.4 | 18.4 | | Mean | 15.8 | 22.4 |
| | SD | 1.0 | 1.0 | | SD | 0.7 | 1.0 |
| | Range | 14-17 | 17-20 | | Range | 15-17 | 21-24 |
| May 5 | 0R | 18 | 22 | May 5 | 1 | 17 | 27 |
| | 2L | 17 | 19 | | 2 | 18 | 25 |
| | 4R | 15 | 19 | | 3 | 16 | 25 |
| | 6L | 16 | 17 | | 4 | 18 | 23 |
| | 8R | 15 | 17 | | 5 | 16 | 28 |
| | Mean | 16.2 | 18.8 | | Mean | 17.0 | 25.6 |
| | SD | 1.2 | 1.8 | | SD | 0.9 | 1.7 |
| | Range | 15-18 | 17-22 | | Range | 16-18 | 23-28 |
| May 15 | 0R | 20 | 27 | May 16 | 1 | 21 | 26 |
| | 2L | 20 | 27 | | 2 | 20 | 25 |
| | 4R | 20 | 27 | | 3 | 20 | 25 |
| | 6L | 18 | 27 | | 4 | 19 | 25 |
| | 8R | 18 | 27 | | 5 | 20 | 25 |
| | Mean | 19.2 | 27.0 | | Mean | 20.0 | 25.2 |
| | SD | 1.0 | 0.0 | | SD | 0.6 | 0.4 |
| | Range | 18-20 | 27-27 | | Range | 19-21 | 25-26 |
| June 2 | 0R | 19 | 25 | June 2 | 1 | 19 | 25 |
| | 2L | 20 | 26 | | 2 | 19 | 24 |
| | 4R | 19 | 26 | | 3 | 20 | 24 |
| | 6L | 19 | 26 | | 4 | 20 | 24 |
| | 8R | 20 | 26 | | 5 | 20 | 24 |
| | Mean | 19.4 | 25.8 | | Mean | 19.6 | 24.2 |
| | SD | 0.5 | 0.4 | | SD | 0.5 | 0.4 |
| | Range | 19-20 | 25-26 | | Range | 19-20 | 24-25 |
| June 23 | 0R | 19 | 21 | June 23 | 1 | 18 | 22 |
| | 2L | 20 | 22 | | 2 | 19 | 22 |
| | 4R | 21 | 20 | | 3 | 22 | 24 |
| | 6L | 20 | 20 | | 4 | 21 | 23 |
| | 8R | 20 | 22 | | 5 | 20 | 24 |
| | Mean | 20.0 | 21.0 | | Mean | 20.0 | 23.0 |
| | SD | 0.6 | 0.9 | | SD | 1.4 | 0.9 |
| | Range | 19-21 | 20-22 | | Range | 18-22 | 22-24 |

*Number = meters along trail; letter = right or left side of trail.
**Plot indicates sampled subset of population.

# Figure 2a: SOIL TEMPERATURE AT TIME OF PLANT EMERGENCE 1991



## Figure 2b: AIR TEMPERATURE AT TIME OF PLANT EMERGENCE 1991

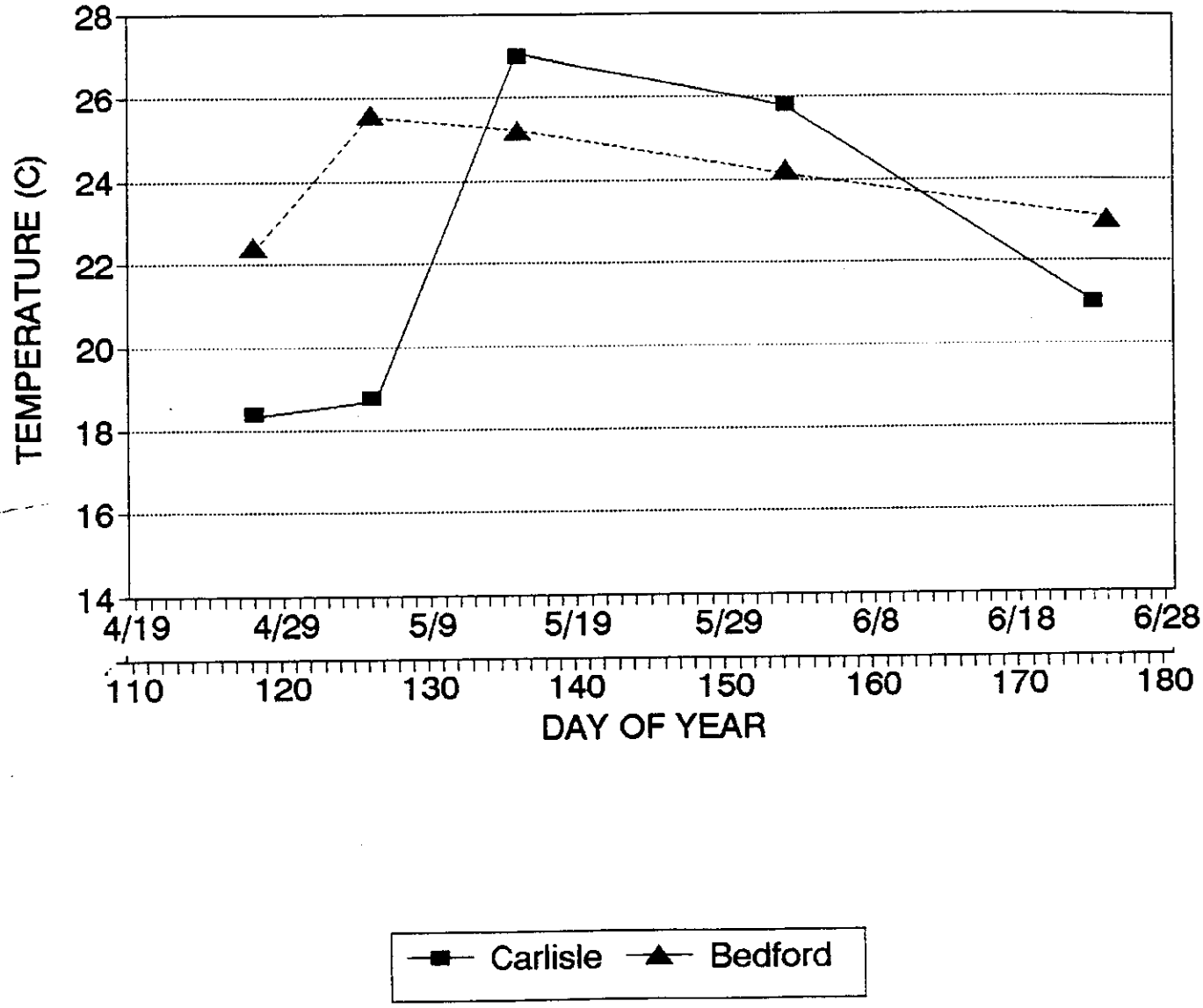


Table 3: POPULATION SIZE

| | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|
| CARLISLE | 69 | 89 | 106 | 160 |
| BEDFORD: Population | | 211 | 185 | 178 |
| Plots | | 112 | 97 | 95 |
| CONCORD1 | | 99 | 112 | 113 |
| CONCORD2 | | | 52 | |
| CONCORD3 | | | | |
| CONCORD4 | | | | >60 |

The population at the Concord2 site was 52 individuals in 1991. This site was not visited in 1992. Concord3 is inaccessible. A fourth Concord population (Concord4) found in late 1992 has 60+ plants.

Using the most current figures for each population 5 of the 6 populations of Britton's violet along the Concord River an estimate can be made of the number of individuals in Massachusetts. There are at least 658 plants. This figure is based on the 1991 count at Concord2, does not include Concord3, and uses 1992 counts at the four other sites. These figures do not include the Milton pectinata population.

## C. Flowering and Fruiting

### Flowering Patterns

Fewer than 20% of the plants in the Carlisle or Bedford populations flowered in either 1990 or 1991 (Tables 4&5). A slightly higher proportion of plants flowered in Bedford in 1990 - 19.0% versus 14.6% in Carlisle. In 1991, by contrast, a somewhat higher percentage of Carlisle plants flowered - 17% versus 11% in the Bedford plots.

In both populations in 1990, the plants which flowered overwhelmingly produced CL flowers - 13 out of 13 in Carlisle and 38 out of 40 in Bedford. By contrast only one plant in Carlisle and seven in Bedford produced CH flowers.

In Carlisle in 1991, 13 of 18 plants which flowered produced CH flowers. Thus CH flowering clearly dominated. In Bedford, however, CH and CL flowering was about evenly split with 7 plants producing CL and 5 producing CH flowers.

In general flowering is sparse in these woodland populations. Flowering is heavier in the Concord2 population which is unique in that it is largely in the open. This suggests that sparseness of flowering may be in part a function of low light and age structure.

The pattern of CH versus CL flowering in Carlisle suggests that the two types of flowers may alternate as the primary means of seed production in these populations. Such variability with time could be due to either environmental factors or age related factors in the plants themselves. Alternation between sexual and asexual reproduction could have implications for gene exchange and long term stability of these populations.

### Fruiting

Low levels of flowering in the Carlisle and Bedford Britton's violet populations translated to low levels of fruiting (Table 5). Fewer than 10% of plants matured fruits at either site in 1990 or 1991. A total of 8 plants matured 9 fruits in Carlisle in 1990 compared to 17 plants with 18 fruits in Bedford. These are roughly equivalent levels of reproduction since the Bedford population is twice as large as that in

Table 4: FLOWERING PATTERNS

| | 1990 | | 1991 | |
|---|---|---|---|---|
| | CARLISLE | BEDFORD | CARLISLE | BEDFORD PLOTS |
| Plants with flowers: | 13 | 40 | 18 | 11 |
| CH | 0 | 2 | 13 | 4 |
| CH & CL | 1 | 5 | 0 | 1 |
| CL | 12 | 33 | 5 | 6 |
| Plants with no flowers | 76 | 171 | 88 | 86 |
| Percent plants with flowers: | 14.6 | 19.0 | 17.0 | 11.3 |
| CH | 0 | 0.9 | 12.3 | 4.1 |
| CH & CL | 1.1 | 2.4 | 0 | 1.0 |
| CL | 13.5 | 15.6 | 4.7 | 6.2 |
| Percent plants with no flowers | 85.4 | 81.0 | 83.0 | 88.7 |
| Total plants | 89 | 211 | 106 | 97 |

Table 5: FLOWERING AND FRUITING

| | CARLISLE | | BEDFORD | |
|---|---|---|---|---|
| | Chasmo-gamous (CH) | Cleisto-gamous (CL) | Chasmo-gamous (CH) | Cleisto-gamous (CL) |
| 1990 | | | | |
| Flowers | | | | |
| Total in population | 2 | 17 | 8 | 56 |
| Total plants flowering | 1 | 13 | 7 | 38 |
| Percent plants flowering | 1.1 | 14.6 | 3.3 | 18 |
| Initiated fruits | | | | |
| Total in population | 0 | 13 | 2 | 44 |
| Total plants initiating fruits | 0 | 11 | 2 | 32 |
| Percent plants initiating fruits | 0 | 12.4 | 0.9 | 15.2 |
| Percent flowers initiating fruits | 0 | 84.6 | 28.6 | 84.2 |
| Mature fruits | | | | |
| Total in population | 0 | 9 | 0 | 18 |
| Total plants maturing fruits | 0 | 8 | 0 | 17 |
| Percent plants maturing fruits | 0 | 9.0 | 0 | 8.1 |
| Percent plants flowering maturing fruits | 0 | 61.5 | 0 | 44.7 |
| Percent flowers maturing fruits (fruit set) | 0 | 50 | 0 | 32.1 |
| Total plants in population | | 89 | | 211 |
| 1991 | | | | Plots |
| Flowers | | | | |
| Total in population | 14 | 5 | 9 | 6 |
| Total plants flowering | 13 | 5 | 5 | 6 |
| Percent plants flowering | 12.3 | 4.7 | 5.1 | 6.1 |
| Initiated fruits | | | | |
| Total in population | 14 | 5 | 7 | 5 |
| Total plants initiating fruits | 13 | 5 | 5 | 5 |
| Percent plants initiating fruits | 12.3 | 4.7 | 5.1 | 5.1 |
| Percent flowers initiating fruits | 100 | 100 | 100 | 83.3 |
| Mature fruits | | | | |
| Total in population | 10 | 3 | 1 | 3 |
| Total plants maturing fruits | 10 | 3 | 1 | 3 |
| Percent plants maturing fruits | 9.4 | 2.8 | 0.01 | 3.1 |
| Percent plants flowering maturing fruits | 76.9 | 60 | 20 | 50 |
| Percent flowers maturing fruits (fruit set) | 71.4 | 60 | 11.1 | 50 |
| Total plants in population or plots | | 106 | | 97 |

Note: Plants producing both CH and CL flowers or fruits are listed in both columns.

Carlisle. In 1991 13 CH fruits matured on 13 plants in Carlisle while only 4 fruits matured on 4 plants in Bedford.

**Fruit Initiation**

Fruit initiation, a good indicator of fertilization success (Table 5), was highly variable in CH flowers and consistently high in CL flowers.

CH fruit initiation was 0% in Carlisle and 28.6% in Bedford in 1990. By contrast in 1991, 100% of CH flowers at both sites initiated fruits. A possible explanation is that the relatively higher number of flowers in 1991 might have attracted more pollinators. Note that in Bedford the nine CH flowers were in the sample plots only. These represent about half the population.

CL fruit initiation was always over 80% in CL flowers. It was 84-85% in both populations in 1990, and 100% in Carlisle and 83% in Bedford in 1991. CL flowers, which do not open, self-fertilize. Selfing is generally associated with high fruit initiation rates.

**Fruit Set**

Reproductive success or fruit set is the proportion of flowers which develop into mature fruits. Fruit set was somewhat variable and ranged from 0% to 71% across the two years and two populations (Table 5).

CH fruit set was 0% at both sites in 1990. The lack of CH fruits is explained by poor flowering plus no fruit set. Two CH fruits were initiated in Bedford but did not mature. In Carlisle no CH fruits were initiated. In 1990 all of the fruits matured at both sites were CL. By contrast at Carlisle in 1991 the relatively higher proportion of CH flowers also had fruit set of 71.4%, which led to 10 fruits. Low fruit set of 11.1% from the 9 CH flowers in Bedford led to only 1 CH fruit.

CL fruit set was always over 30% and ranged from 32.1% in Bedford in 1990 to 60% in Carlisle in 1991. High fruit initiation rates did not always lead to more fruits. While the highest fruit set derived from a population with an initiation rate of 100% (Carlisle 1991), there were only 3 mature fruits in the population. On the other hand Carlisle in 1990 had the lowest CL fruit set (32.1%). This led to 18 mature capsules - the highest number produced by either population in either year.

Numerous plants were observed where entire developing capsules and all or part of their peduncles had vanished - presumably to herbivores. Slugs were observed on the ground adjacent to Britton's violet plants in both Carlisle and Bedford on the same day in June 1992. Herbivory, plus numerous non-viable seeds found in 1992 (see section E below), are several factors which help explain low fruiting.

## D. Population Dynamics and Structure

### Population Dynamics

The increase in population size from 89 to 106 between 1990 and 1991 in Carlisle was due to 31 new plants - nearly three times as many recruits as the 12 plants which failed to re-emerge (Table 6).

By contrast in the Bedford plots there were only 14 recruits versus 27 plants which failed to re-emerge in 1991. Overall in Bedford the population declined from 211 in 1990 to 185 in 1991. Plants which did not re-emerge are assumed to have died.

Both the Carlisle and Bedford populations are reproducing from seed. Seedlings with two cotyledons were found at both sites in 1991 and 1992.

Seedlings were defined as those plants with obvious cotyledons. Some tiny plants were observed without cotyledons. While most are probably seedlings, some of these appeared to be established plants, or at least appeared in 1991 exactly where a tagged plant had been in 1990. A judgment was made in these cases.

Most of the increase in Carlisle in 1992 is due to a large cohort of seedlings which germinated in the trail.

Seedling germination occurred later on average than emergence of mature individuals, suggesting germination may require somewhat warmer temperatures than the development of established plants. Seedling germination was observed on June 9, 1990 before any capsules matured, suggesting that some seedlings arise from seed matured in previous years.

Mortality of seedlings during their first season may be high. While this was not specifically studied, a number of seedlings which had appeared early in the season had vanished by midsummer.

### Reproductive Behavior in Successive Years

Comparison of the flowering behavior of individuals present in both 1990 and 1991 at the Carlisle and Bedford sites revealed that most plants in both Carlisle and Bedford did not flower in either year (Table 7). In Carlisle, 50 of the 87 plants present in both years, and in Bedford, 59 of 107 plants present in both years, failed to flower in either 1990 or 1991.

Most of the plants which died were non-flowering. In Carlisle no plant which was present in 1990 and failed to emerge in 1991 had flowered in 1990. None of the individuals which produced CL flowers in 1991 had flowered in 1990. In Bedford, of 27 plants which failed to re-emerge in 1991, 5 had only CL flowers in 1990 and 22 had failed to flower.

In Bedford of 17 plants with CL flowers in 1990, 14 failed to flower or died in 1991. Of the other 3 one produced CL flowers, one both floral

Table 6: POPULATION DYNAMICS

| 1990 to 1991 | CARLISLE | BEDFORD PLOTS | CONCORD1 |
|---|---|---|---|
| Number plants in 1990 | 89 | 112 | 99 |
| Number removed for study in 1990 | 2 | 6 | |
| Number from 1990 which failed to appear in 1991 | 13 | 27 | |
| Number recruits 1991 | 32 | 14 | |
| Number plants in 1991 | 106 | 98 | 112 |
| Percent change 1990-91 | +19 | -15 | +13 |

Table 7: REPRODUCTIVE BEHAVIOR IN SUCCESSIVE YEARS

C A R L I S L E

| | | 1990 | | | |
|---|---|---|---|---|---|
| | | No Flowers | Cleisto-gamous Flowers Only | Both Flower Types | Chasmo-gamous Flowers Only |
| | No Flowers | 50 | 7 | 0 | 0 |
| | Cleistogamous Flowers Only | 5 | 0 | 0 | 0 |
| 1991 | Both Flower Types | 0 | 0 | 0 | 0 |
| | Chasmogamous Flowers Only | 6 | 6 | 1 | 0 |
| | Did Not Re-emerge | 12 | 0 | 0 | 0 |
| | Total Plants | 87 | | | |

B E D F O R D

| | | 1990 | | | |
|---|---|---|---|---|---|
| | | No Flowers | Cleisto-gamous Flowers Only | Both Flower Types | Chasmo-gamous Flowers Only |
| | No Flowers | 59 | 9 | 1 | 0 |
| | Cleistogamous Flowers Only | 5 | 1 | 0 | 0 |
| 1991 | Both Flower Types | 0 | 1 | 0 | 0 |
| | Chasmogamous Flowers Only | 1 | 1 | 2 | 0 |
| | Did Not Re-emerge | 22 | 5 | 0 | 0 |
| | Total Plants | 107 | | | |

types, and one CH flowers. In the Bedford population 9 of the 12 plants which produced CL flowers in 1990 and survived failed to flower in 1991. Yet 5 of 6 plants which produced CL flowers in 1991 had not flowered in 1990.

The only plant which produced CH flowers in 1990 had also produced CL flowers. This plant produced only CH flowers in 1991. Of the other 12 plants with CH flowers in 1991 half had only CL flowers in 1990 and the rest had none.

No plant at either site with CH flowers in 1990 produced CL flowers in 1991 yet 4 of 5 plants with CH flowers in 1990 produced CH flowers in 1991. In Carlisle the only plant which produced a CH flower in 1990 produced a CH flower again in 1991.

These results suggest the following trend in Britton's violet individuals as they mature: from no flowers to CL to CL/CH mix to CH.

However an individual may not flower every year. If there is in fact a progression from non-flowering to CL flowers to CH flowers a certain fraction of plants may die before producing CH flowers. Perhaps it is also rare for a plant to produce CL flowers 2 years in a row.

**Plant Size**

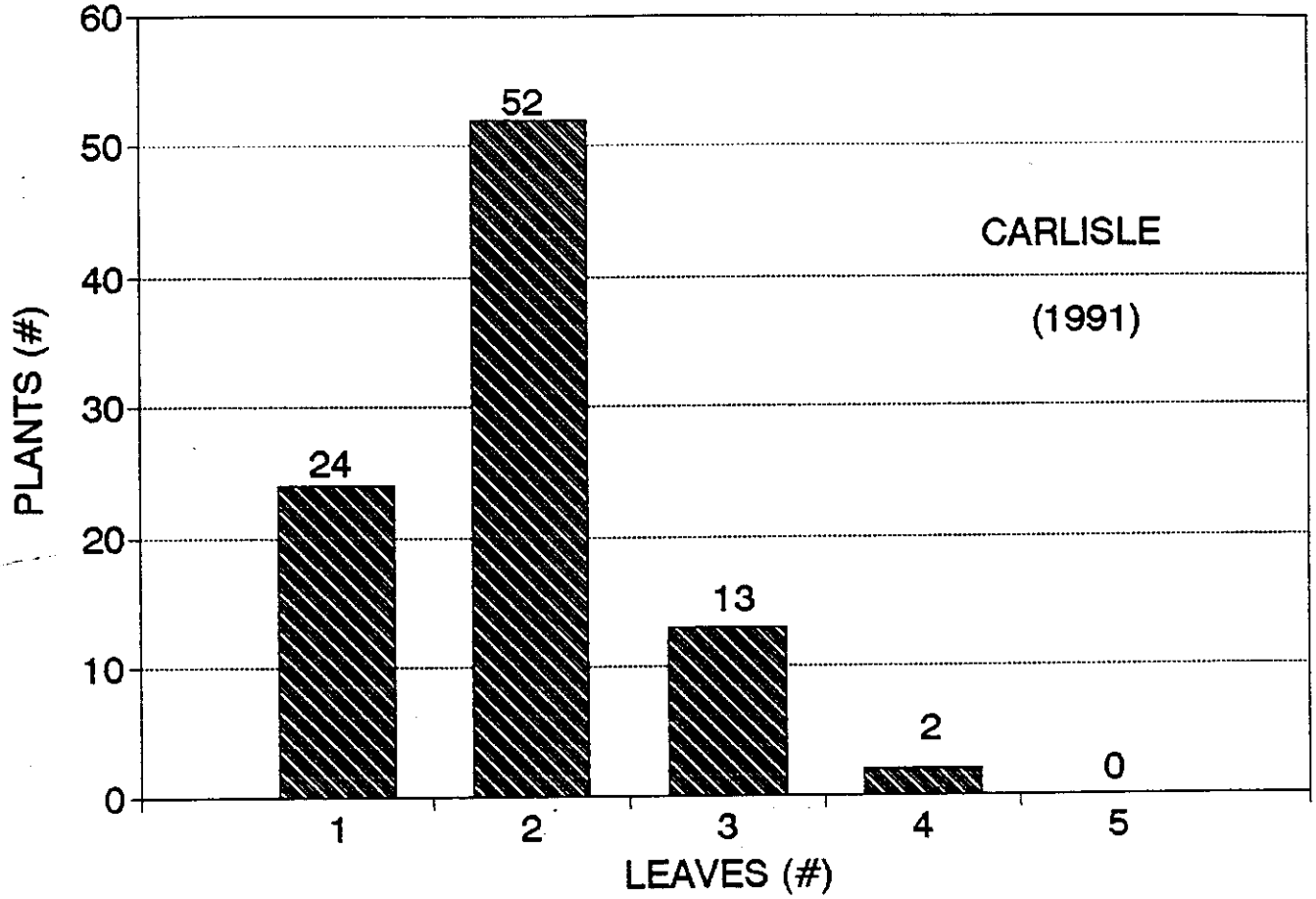
Viola brittoniana produces leaves one at a time, spring through fall. Some die or are eaten by herbivores. Thus, counts made at a given point in time are likely to underrepresent the total leaves produced by a plant over a season. An example is plant #25 in Carlisle which had only one leaf which was observed almost entirely eaten on June 23. It subsequently vanished. On August 16 the plant had one new leaf - 10 cm long and healthy.

The sum of the lengths of all leaves on a plant was used as an indicator of plant size. Ninety plants in Carlisle and 75 in the Bedford plots had leaves in mid-August when counts and measurements were made. These plants were included in the analysis.

The mean number of leaves per plant was 1.91 in Carlisle and 1.68 in Bedford (Table 8). The number of leaves per plant varied from 1-4 in Carlisle and 1-5 in Bedford. Thus on average plants at both sites had fewer than 2 leaves. The distribution of individuals with varying numbers of leaves is shown in (Figures 3a&b). In Carlisle 52 of 90 plants had 2 leaves. Most Bedford plants (42 out of 75) had a single leaf.

Length of individual leaves varied from 1-35 cm in Carlisle and 1-22 cm in Bedford. Mean total leaf length was 15.5 cm in Carlisle and 12.0 cm in Bedford (Table 8). Total leaf length varied from 1-54 cm in Carlisle and 1-63 cm in Bedford. Overall plants in Carlisle had more and larger leaves.

Figure 3a:
DISTRIBUTION OF NUMBERS OF LEAVES



# Figure 3b:
# DISTRIBUTION OF NUMBERS OF LEAVES

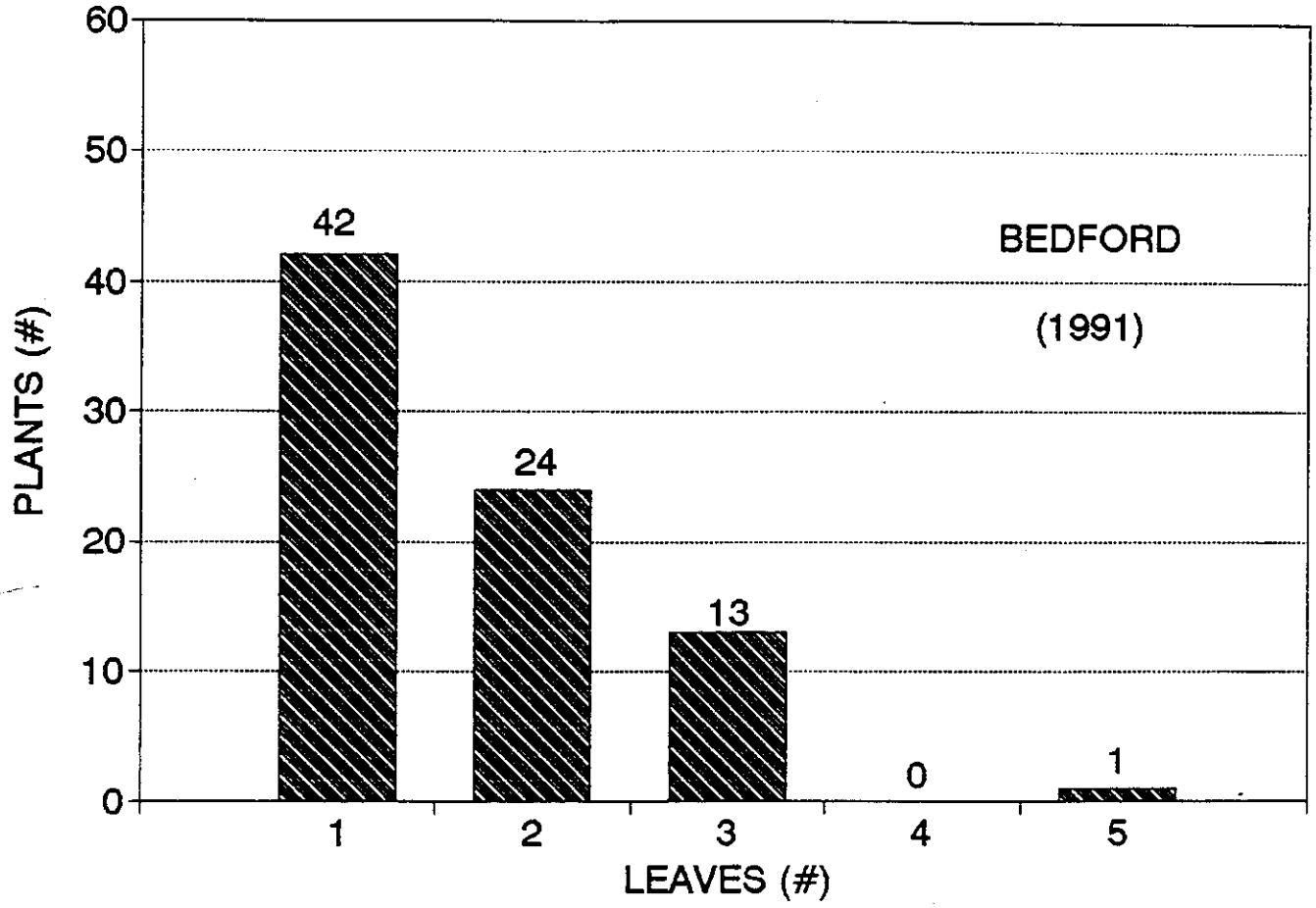


Table 8: PLANT SIZE VS. REPRODUCTIVE STAGE 1991

| | CARLISLE | BEDFORD (Plots) |
|---|---|---|
| Number leaves per plant: | | |
| Mean | 1.9 | 1.7 |
| SD | 0.7 | 0.8 |
| Range | 1-4 | 1-5 |
| Total leaf length (cm): | | |
| Mean | 15.5 | 12.0 |
| SD | 13.5 | 10.2 |
| Range | 1-54 | 1-63 |
| Non flowering plants | | |
| Mean total leaf length (cm) | 13.2 | 10.5 |
| SD total leaf length (cm) | 12.6 | 8.0 |
| # of plants | 74 | 66 |
| % of plants | 82.2 | 88.0 |
| CL flowering plants | | |
| Mean total leaf length (cm) | 20.5 | 15.6 |
| SD total leaf length (cm) | 7.9 | 8.3 |
| # of plants | 4 | 5 |
| % of plants | 4.5 | 6.7 |
| CL+CH flowering plants | | |
| Mean total leaf length (cm) | na | 21.0 |
| SD total leaf length (cm) | na | 0 |
| # of plants | 0 | 1 |
| % of plants | 0 | 1.3 |
| CH flowering plants | | |
| Mean total leaf length (cm) | 29.1 | 39.3 |
| SD total leaf length (cm) | 13.3 | 21.2 |
| # of plants | 12 | 3 |
| % of plants | 13.3 | 4.0 |
| Total plants | 90 | 75 |

### Plant Size Versus Reproductive Stage

Comparison of total leaf length with reproductive status indicated that at both sites plants which produced CH flowers were larger than those producing both CH and CL flowers, which were larger than plants with only CL flowers, which were in turn larger than plants which failed to flower (Table 8; Figures 4a&b). Carlisle had no plants with both flower types. Plants in Carlisle which did not flower or produced only CL flowers were larger than plants at the same reproductive stages in Bedford. However, plants producing only CH flowers were larger in Bedford.

These results, along with the results of the study of reproductive behavior in individual plants from year to year described above, suggest that Britton's violet individuals grow larger each season. In addition they progress the following stages: non-flowering, to CL flowering, to CL+CH flowering, to CH flowering. Most plants in each population do not flower at all in a given year. In 1992, 82.2% of the Carlisle plants and 88.0% of the Bedford plants did not flower at all. Finally, mortality studies described above indicate that most plants die before flowering.

Britton's violet fits the general pattern described by Harper (1974) and Cook (1978). They found that seedlings produce 1-3 tiny leaves in their first season. There then appears to be a pre-reproductive period of one or more years. Next CL flowers are produced for one or more seasons possibly followed by a lag of one or more seasons until CH flowers are produced. Observations during 1991 confirmed that Britton's violet is reproducing from seed. Britton's violet differs in that there is a stage where both floral types are produced - at least in some individuals.

As perennial plants mature and grow larger they have more resources available for reproduction. It is generally thought that CL flowering occurs first because fewer resources are needed. While the amount of energy Britton's violet invests in CL vs. CH flowers is unknown, it is interesting that in this species more energy appears to be invested in CL than CH fruits. (See also section E below.)

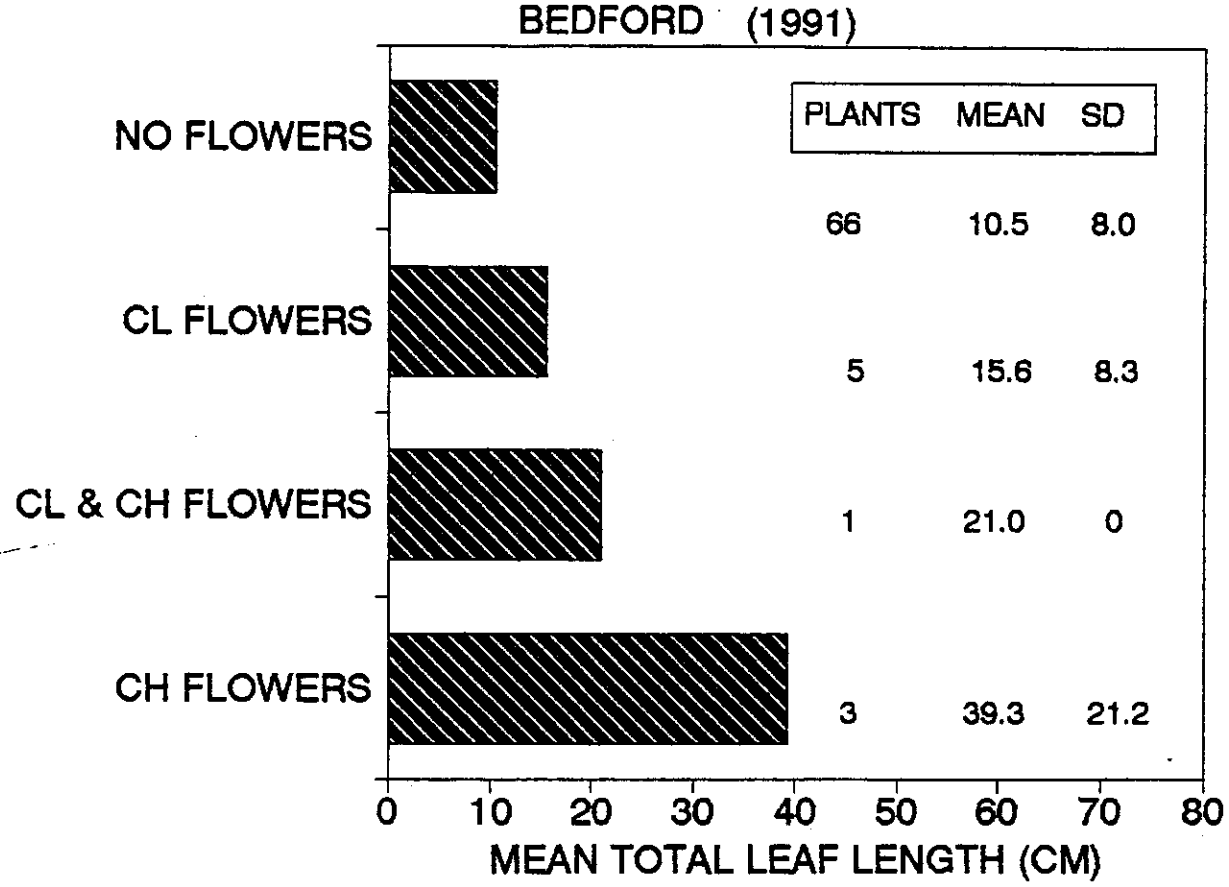
The results further suggest that plants in Carlisle may be more vigorous than those in Bedford. This in turn could explain the growth of the Carlisle population and decline at the Bedford site.

## E. Preservation of Seed; Fruit and Seed Characteristics; Dispersal

### Seed Preservation

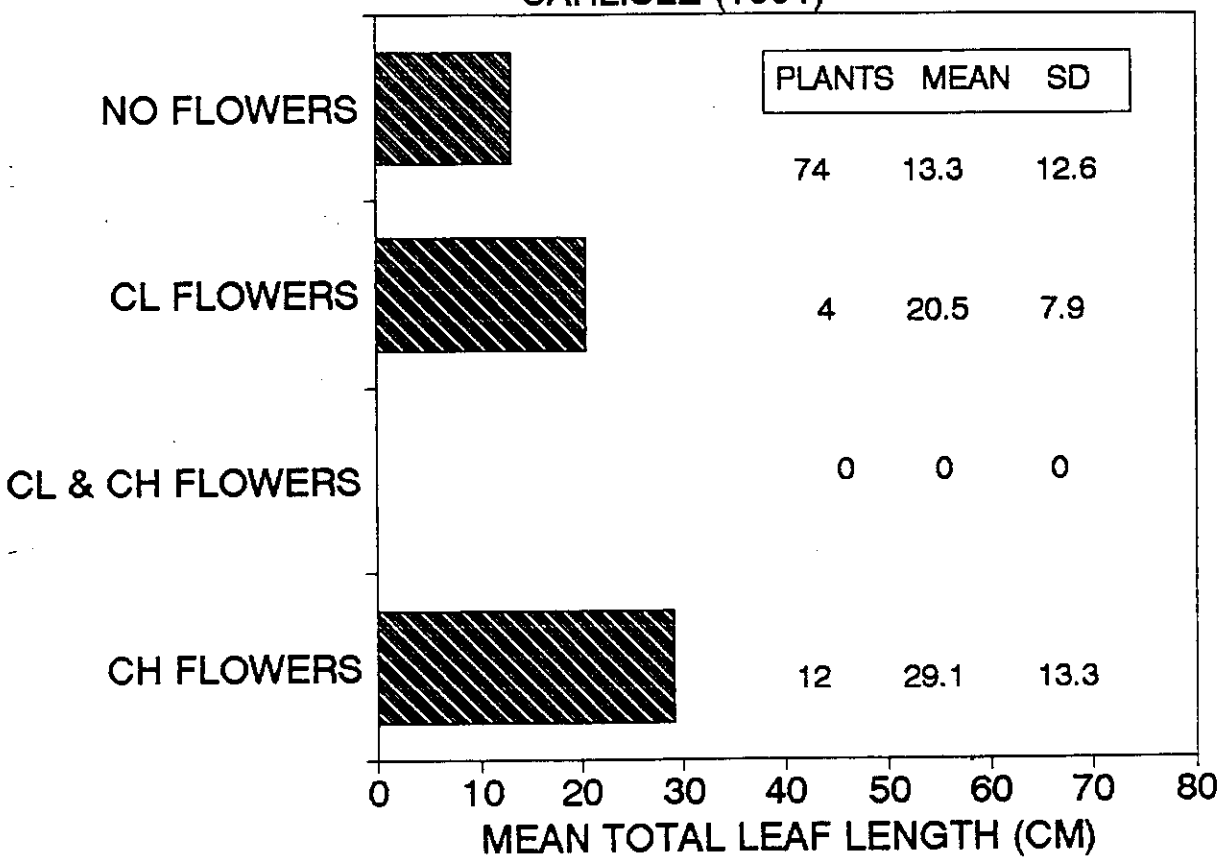
Although the opportunity to participate in the New England Wild Flower Society program came late in the 1991 Britton's violet reproductive season, two capsules were found and collected on July 18. The first, from the Concord2 site, appeared normal but contained only small, shriveled, aborted seeds. The second, from Carlisle, was open, with only two seeds left in one lobe. One was small and shriveled, the

# Figure 4a:
# PLANT SIZE VS REPRODUCTIVE STATUS



# Figure 4b:
# PLANT SIZE VS REPRODUCTIVE STATUS

CARLISLE (1991)



other appeared healthy. This was ultimately sent to the New England Wild Flower Society.

Approximately 25% of the capsules in the Carlisle and Bedford populations were collected with a goal of obtaining about 10% of the seed. Since these populations flower and fruit sparsely relatively few fruits were produced. A total of six CL capsules were gathered from Carlisle and 4 CH and 2 CL from Bedford (Table 10). The Carlisle population produced no CH fruits in 1992. (From these capsules 123 seeds were sent to the New England Wild Flower Society.)

Previous observations that most capsules either disappear (possibly to predators) before reaching maturity or are open before they can be collected suggested that they should be enclosed and protected while seeds are relatively immature.

In 1992 only capsules bagged after reaching full size but prior to reaching maturity, did in fact mature seeds. No smaller capsules matured possibly because they were unable to survive handling without damage.

Some of the bagged capsules had already shed their seeds inside the nylon bags when collected. Others finished maturing while their stems were in water.

All capsules which were still green when the bags were opened matured, and each shed its seeds within one week. Most of the full size opaque green capsules took about 5 days to open. However at least one capsule collected when close to full size required an additional 17 days to open.

**Fruit and Seed Characteristics**

The mean number of full size seeds in the two intact CH capsules from Bedford was 34.5 (Tables 9 & 10). The five CL capsules collected at the two sites contained an average of 43.2 seeds. These results suggest CL capsules may produce more seeds in these populations than CH capsules. (Cook (1978) indicated that violets produce far more seed through CL than CH reproduction.)

Using the above estimates of seeds per capsule and the number of capsules of each type produced in 1990 from Table 5, the estimated total number of CH and CL seeds produced was 0 CH and 389 CL in Carlisle and 0 CH and 778 CL in Bedford. In 1991, by contrast, Carlisle plants produced an estimated 345 CH and 130 CL seeds, while Bedford plants produced 35 CH and 130 CL seeds. Thus overall seed production was greater in Bedford in 1990 and Carlisle in 1991.

In addition, at the 2 sites combined, CL seed production was greater in 1990 and CH seed production in 1991.

Not all these seeds were viable, however, since many full size hollow seeds were found. Of the 4 CH capsules collected 3 contained full size but non-viable seeds. Two of these 3 had produced over 30 full size

Table 9: FRUIT CHARACTERISTICS

| Site | Capsule Number | Capsule Type | Number Seeds in Capsule | Capsule Condition | Number Seeds to NEWFS | Mean Seed Weight (mg) |
|---|---|---|---|---|---|---|
| CARLISLE | G | CL | 47 | intact | 35 | 0.58 |
| | H | CL | 47 | intact | 35 | 0.48 |
| | I | CL | 1 | open | 1 | |
| | J | CL | 51 | intact | 35 | 0.50 |
| | K | CL | 17 | open | 17 | 0.50 |
| | L | CL | 21 | intact | 0 | 0.60 |
| BEDFORD | A | CH | 19 | open | 14 | 0.40 |
| | B | CH | 36 | intact | 0 | |
| | C | CH | 33 | intact | 0 | |
| | D | CH | 6 | open | 0 | |
| | E | CL | 50 | intact | 0 | 0.22 |
| | F | CL | 12 | open | 12 | |

Table 10: SEED CHARACTERISTICS

| | | Mature Seeds in Intact Capsules | | | Weight of Healthy Seeds | | |
|---|---|---|---|---|---|---|---|
| | Capsule Type | Capsules (#) | Mean | Range | Capsules (#) | Mean/ Seed (mg) | Total Seed Weight (mg) |
| CARLISLE | CH | 0 | - | - | 0 | - | - |
| | CL | 4 | 41.5 | 21-41 | 5 | 0.51 | 21.10 |
| BEDFORD | CH | 2 | 34.5 | 33-36 | 1 | 0.40 | 13.80 |
| | CL | 1 | 50.0 | 0 | 1 | 0.22 | 11.00 |
| BOTH SITES | CH | 2 | 34.5 | 33-36 | 1 | 0.40 | 13.80 |
| | CL | 5 | 43.2 | 21-51 | 6 | 0.46 | 19.90 |

seeds, yet all were hollow and disintegrated when touched. The fourth CH capsule contained 14 healthy seeds as well as 5 small shriveled ones. The healthy CH and CL seeds were similar in appearance. They are roughly egg-shaped, pale tan in color, smooth surfaced, and have a conspicuous transparent attached body which appears to be an eliasome.

The mean weight of CH seeds was 0.40 mg in the 1 CH capsule sampled, while the mean weight of CL seeds was 0.46 mg when seeds from both sites were averaged. Overall seed mass weight for the CH capsules was 13.8 mg compared to 19.9 mg for the CL capsules.

Further research and larger sample sizes might confirm that CL fruits have more and heavier seeds than CH fruits.

**Seed Dispersal**

As indicated earlier no fully mature intact capsules have been seen in the field in 4 years. Seeds from the capsules whose stems were in water were found both inside and up to 31 cm outside the large container. Seeds cleared the rim of the larger container and, in order to do this, were ejected at least 13 cm upward and 18 cm outward. This provides a clear indication that forcible ejection occurs in V. Brittoniana.

Ejection was observed to occur as follows. As a capsule reached full size it became somewhat transparent, suture lines were clearly visible, and seeds could be seen inside. The three lobes of the capsule then gradually split apart beginning at the tip of the capsule. Splitting took at least several hours and seeds became clearly visible in each of the three open canoe-shaped lobes. The lobes then appeared to dry out and contract apparently providing the force for ejection.

Forcible ejection does not always imply that seeds will be dispersed very far from the plant. One capsule was found at Bedford which had been pointed directly downward and seeds were deposited in a tight pile just beneath it.

Most mature capsules observed in the field are open. A few contain one or two seeds. Those observed were always at the tips of the lobes. Apparently these are caught in the lobe and not forcibly ejected.

One hundred and twenty-three seeds from the capsules collected were forwarded to the New England Wild Flower Society (Table 9).

**F. Association: Nearest Neighbors**

Additional associates of Britton's violet were identified. These include: Aster vimineus in Carlisle; Sphagnum sp. in Bedford; Pilea pumila in Bedford; and Rosa multiflora at both Carlisle and Bedford (Table 11). Identification of some of the grasses and grass-like plants was partially completed. Grass 1 is likely to be a Panicum or Agrostis species. Grass 3 might also be a Panicum. Samples of these plants have been collected and pressed.

Table 11: ASSOCIATED SPECIES

| SCIENTIFIC NAME | COMMON NAME | CARLISLE | BEDFORD |
|---|---|---|---|
| Acer rubrum | red maple | | * |
| Alnus incana | speckled alder | * | |
| Aster vimineus | small white aster | * | |
| Cyperaceae 1 | sedge | | * |
| Cyperaceae 2 | sedge | | * |
| Gramineae 1 | grass | * | * |
| Gramineae 2 | grass | | * |
| Gramineae 3 | grass | | * |
| Maianthemum canadense | canada mayflower | * | |
| Musci ssp.* | moss | * | * |
| Onoclea sensibilis | sensitive fern | | * |
| Pilea pumila** | clearweed | | * |
| Pinus strobus | white pine | * | |
| Polytricum sp. | haircap moss | * | |
| Quercus alba | white oak | * | |
| Rhamnus frangula | european buckthorn | * | * |
| Rosa multiflora | multiflora rose | * | * |
| Rubus hispidus | swamp dewberry | | * |
| Rubus occidentalis | black raspberry | | * |
| Sphagnum sp. | sphagnum moss | | * |
| Spiraea latifolia | meadowsweet | | * |
| Thelypteris thelypteroides | marsh fern | * | |
| Uvularia sessilifolia | wild oats | | * |

* one to three species, not Polytrichum or Sphagnum
** probable

## G. Limiting Factors: Litter Depth

### Litter Profile

Litter depth measurements had been made along transects perpendicular to the trail at Carlisle and Bedford in 1990 (Figure 5a) and at the same sites in 1991 (Figure 5b). Similar transect measurements were also made at Concord1 in 1991. At this site the trail is considerably wider than at Carlisle or Bedford (Figure 5c). At each site and in different years litter depth increased with distance from the trail center.

While litter depth was considerably deeper in Bedford than Carlisle in 1990, depths at the two sites were roughly similar in 1991. Litter profiles indicate a rather narrow area on each side of the trail at all 3 sites where litter is about 1 cm deep or less. This is where Britton's violet individuals are concentrated.

### Litter Depth Beneath Plants

Measurements of litter depth beneath individual Britton's violet plants at Carlisle and Bedford in 1990 are shown in Figures 6a&b. Measurements repeated at the same sites in 1991 and taken at Concord1 in 1991 (Figures 6c,d&e) confirm that most individuals in these populations grow at litter depths of less than 1 cm.

This also appears to be the case for those few V. brittoniana pectinata measured in Milton which are found along the trail (Figure 6f). However, the Milton plants growing in the red maple swamp are in considerably deeper litter (Figure 6g). No individual measured was growing in litter shallower than 1.5 cm. Depths beneath plants ranged from 1.5 -4.2 cm. This is one more characteristic in which the pectinata population differs from the plants at the other Britton's violet sites.

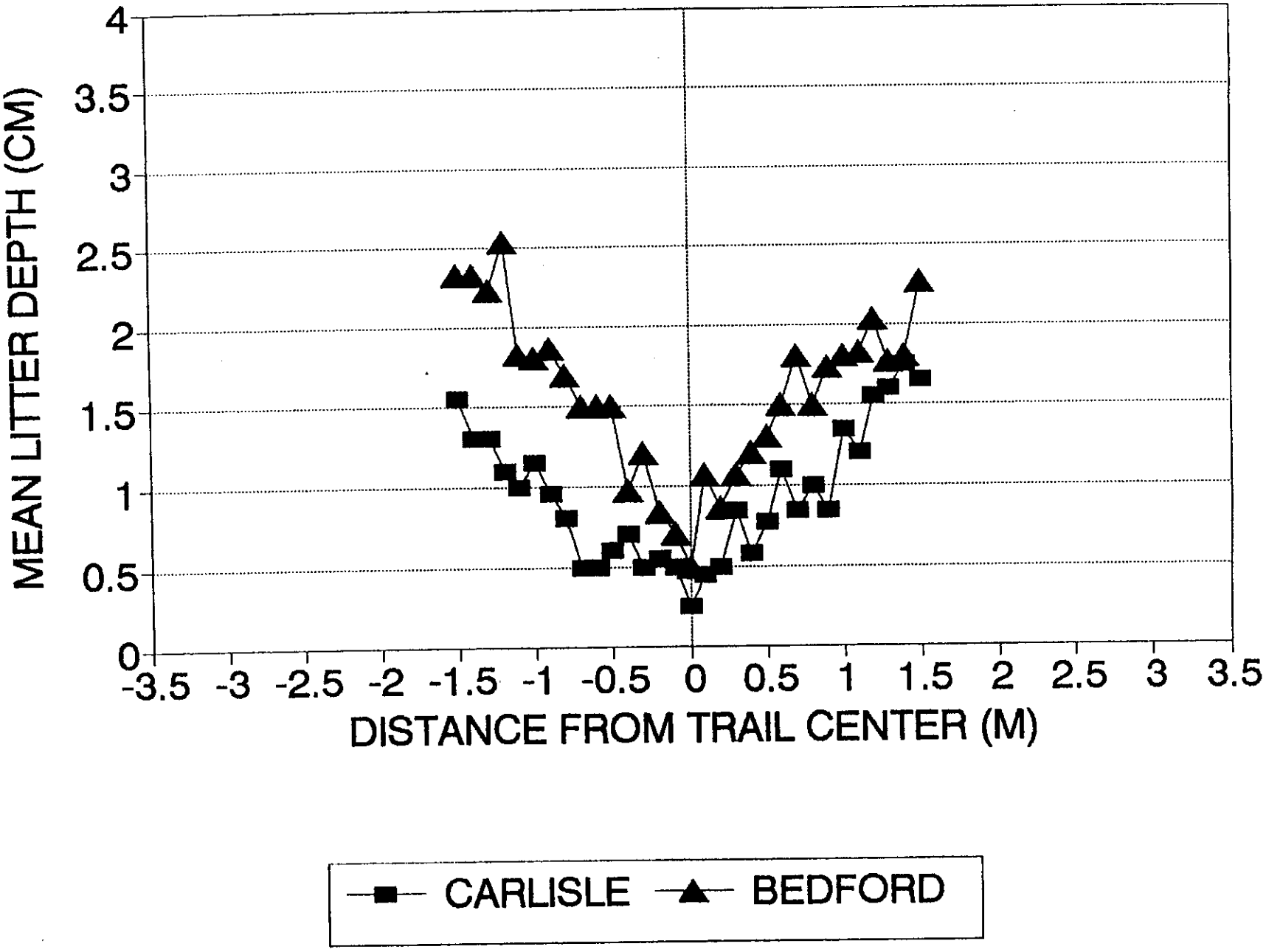
### Litter Removal Project

Britton's violet plants appeared in both control and treatment plots during 1991 and 1992, but in much greater numbers in the treatment plots (Table 12). Overall, at both sites combined and over 3 years, 21 new plants appeared in treatment plots and only 1 in a control plot. All but 2 of the seedlings were at the Carlisle site.

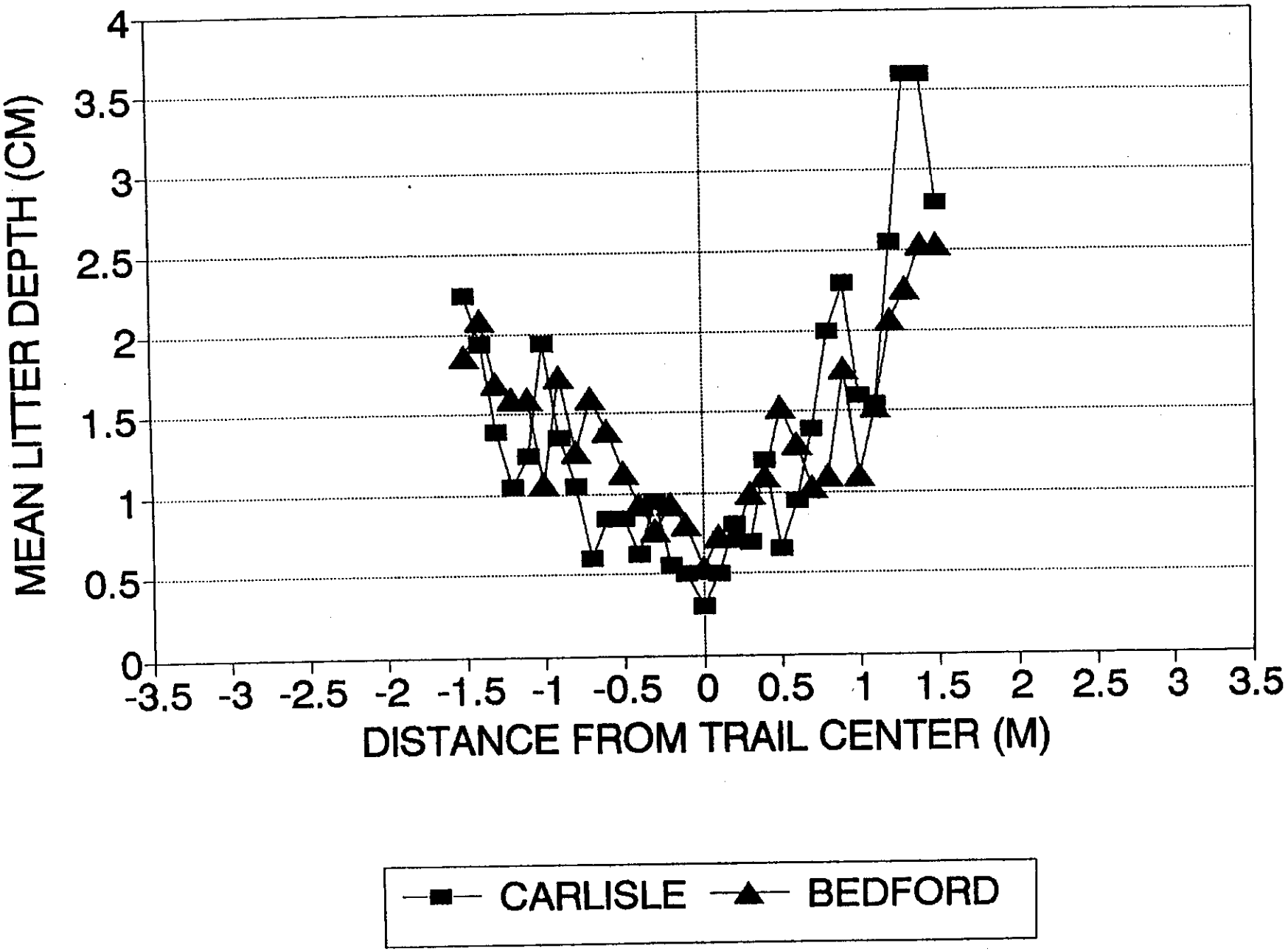
The single seedling which had been found beneath the litter at the time of removal in Bedford Treatment Plot 1 in June of 1990 was not present in 1991. However in 1991, 1 seedling was found in Treatment Plot 2 in Bedford. It survived through September 1991 but did not reappear in the spring of 1992. One new seedling appeared in Treatment Plot 1 in 1992.

Three seedlings were observed in Carlisle Treatment Plot 1 in June 1991. All survived until June 1992. By August 1992 there were a total of 15 plants in Treatment Plot 1. Also, by August 4, seedlings had germinated in Treatment Plot 2. Control Plot 1, by contrast, had just 1 seedling,

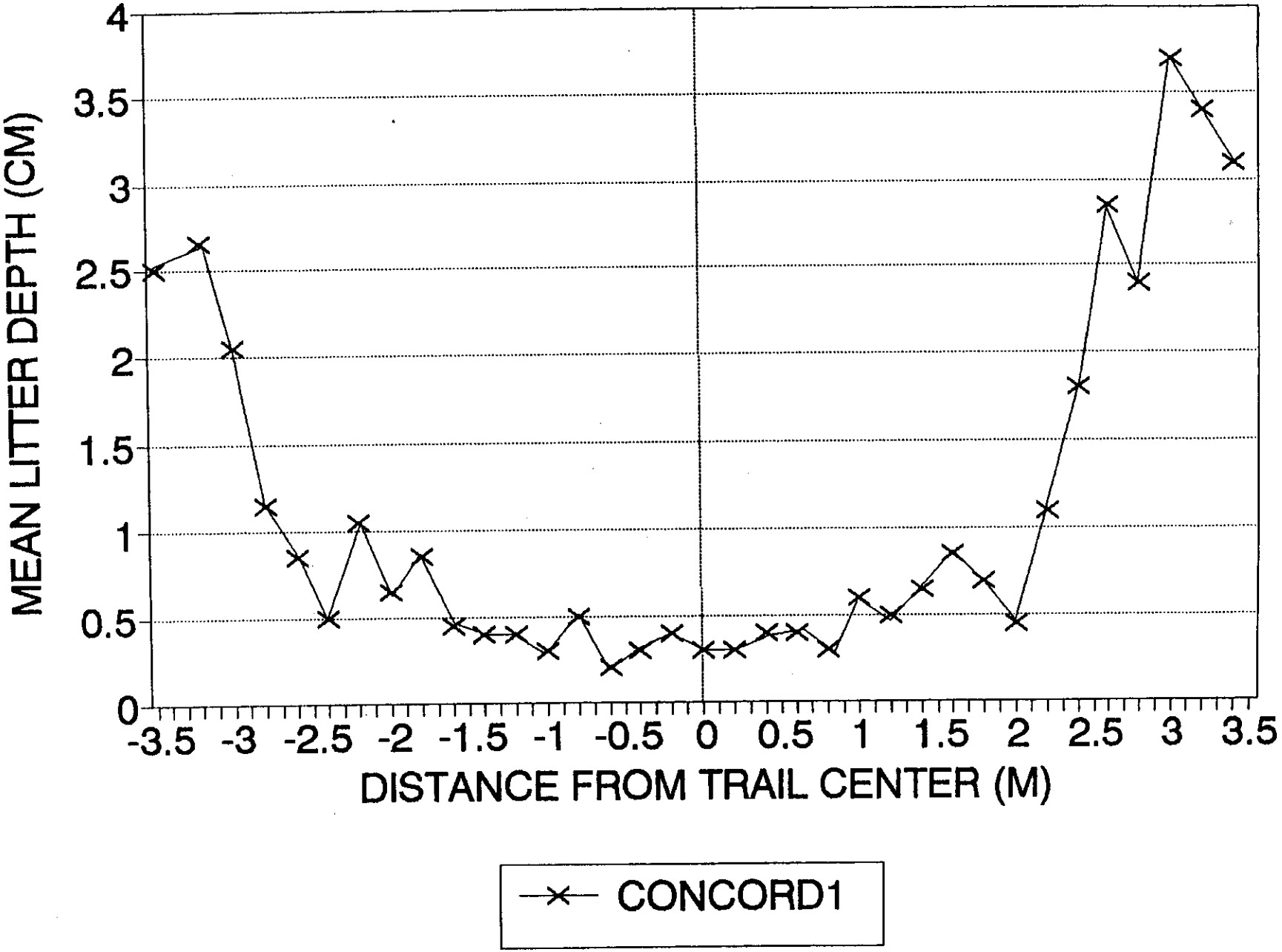
# Figure 5a: LITTER DEPTH PROFILE 1990



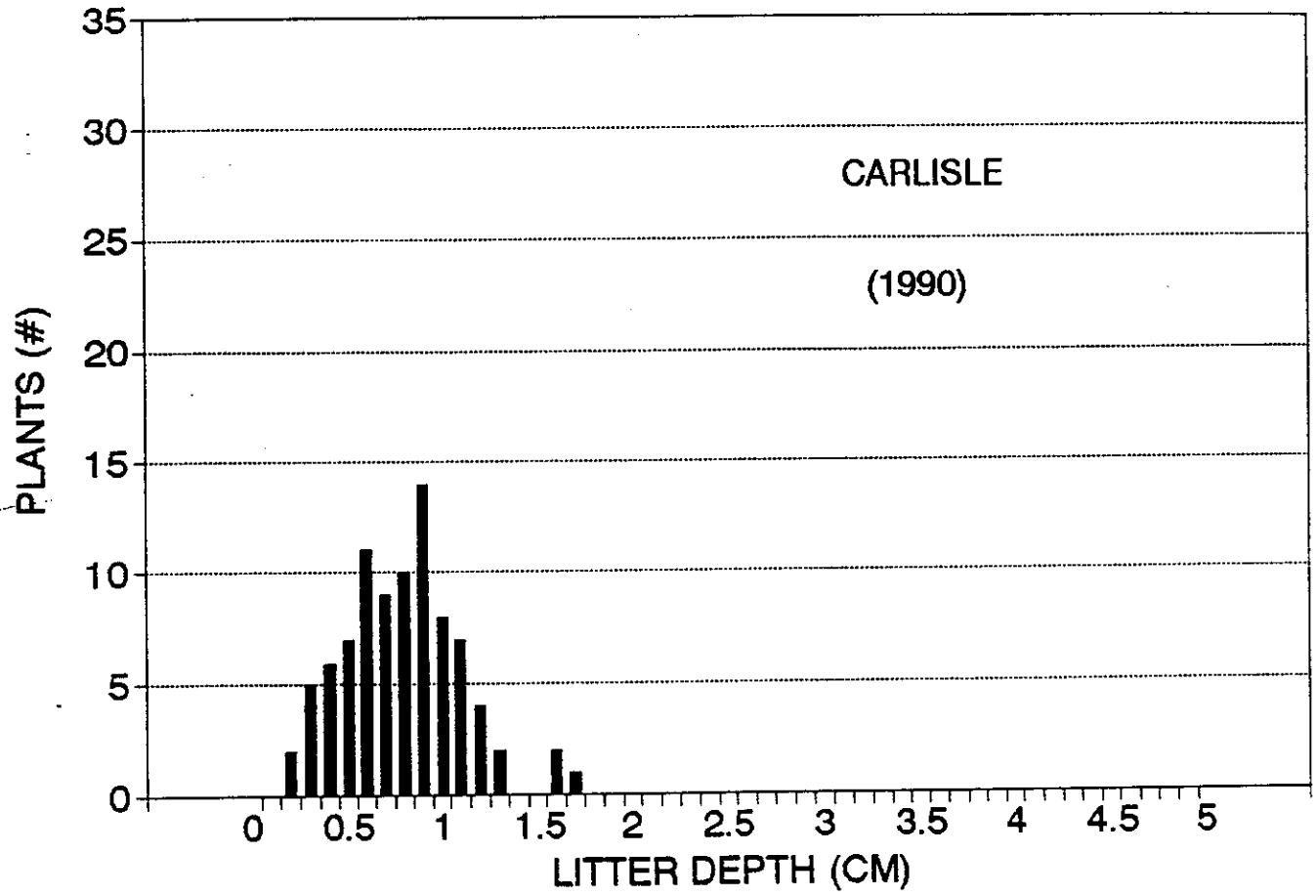
# Figure 5b: LITTER DEPTH PROFILE 1991



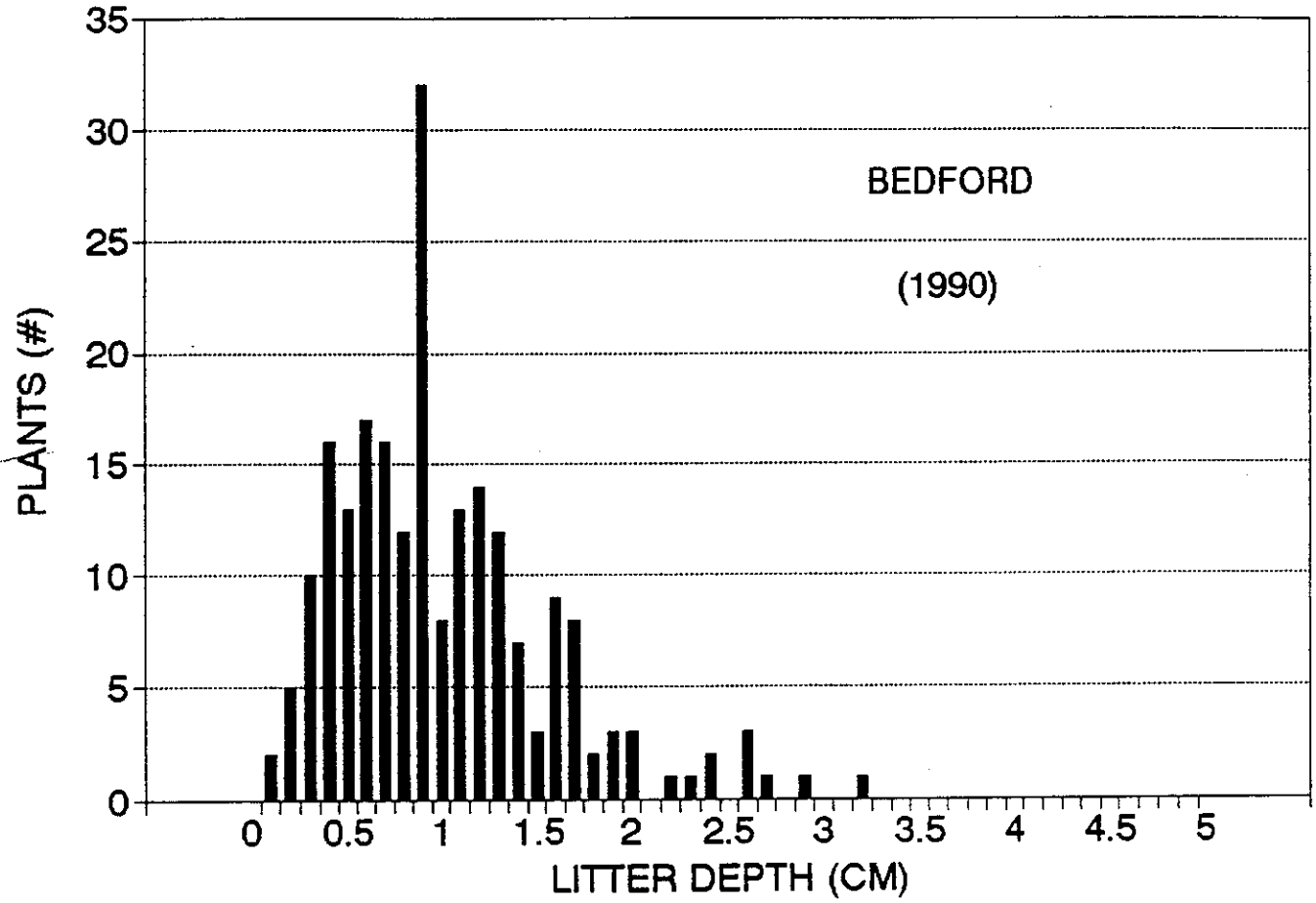
# Figure 5c: LITTER DEPTH PROFILE 1991



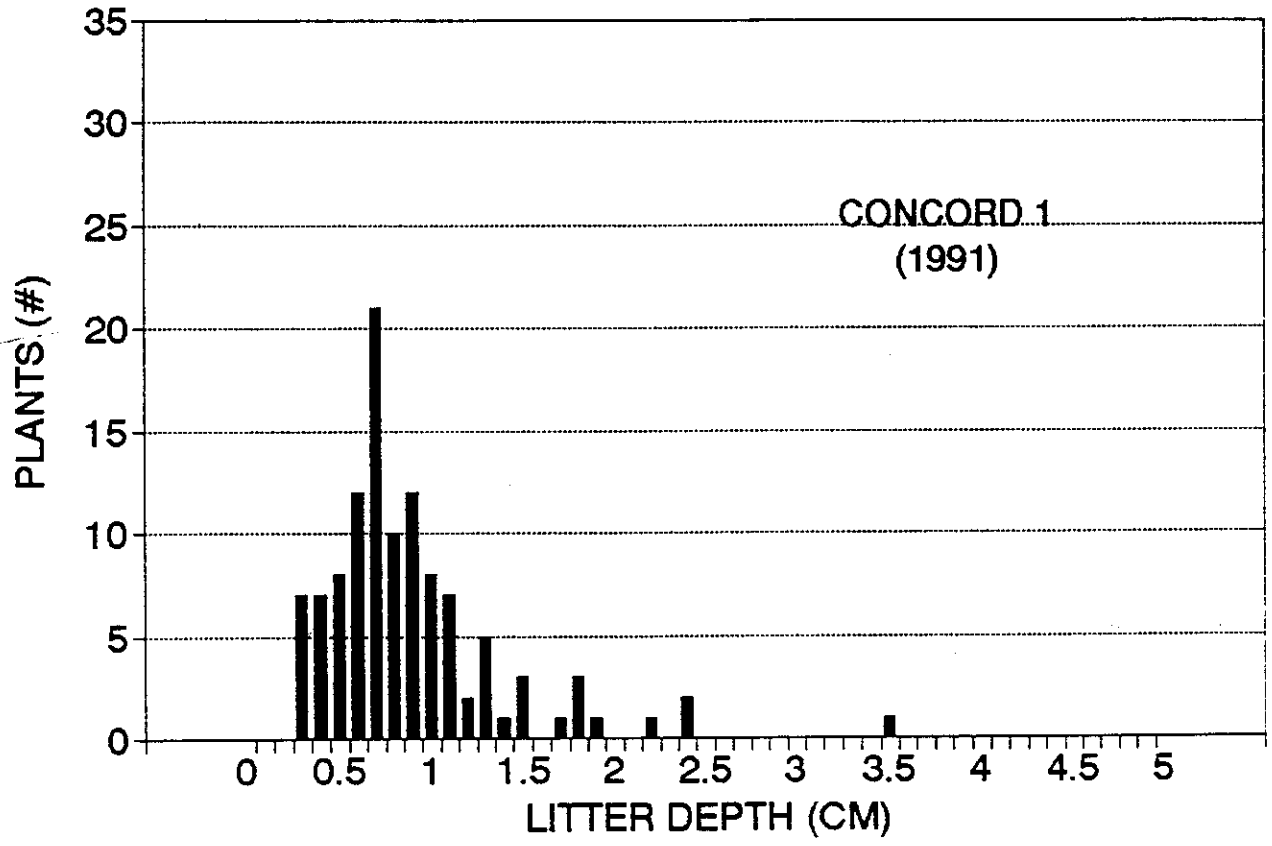
# Figure 6a: PLANT DISTRIBUTION AT DIFFERENT LITTER DEPTHS



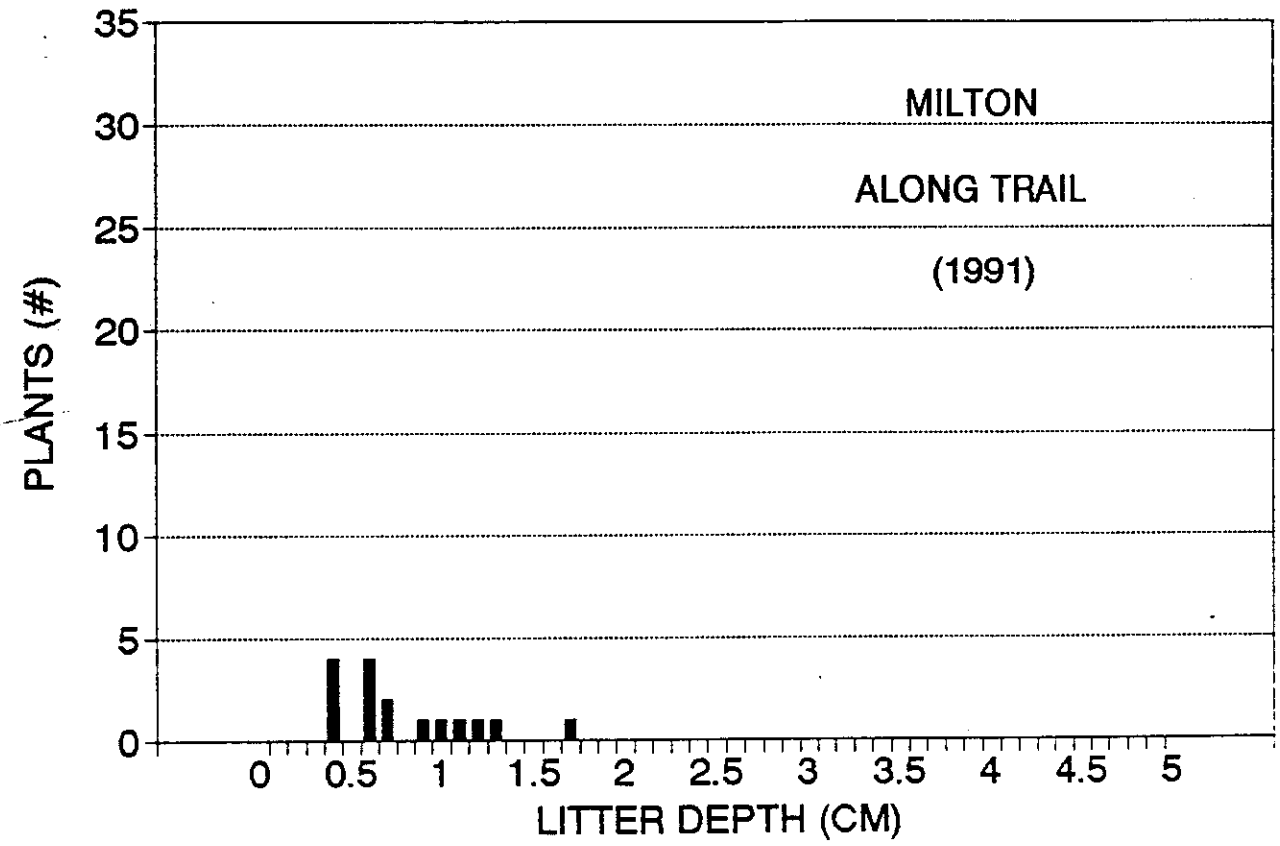
# Figure 6b: PLANT DISTRIBUTION AT DIFFERENT LITTER DEPTHS



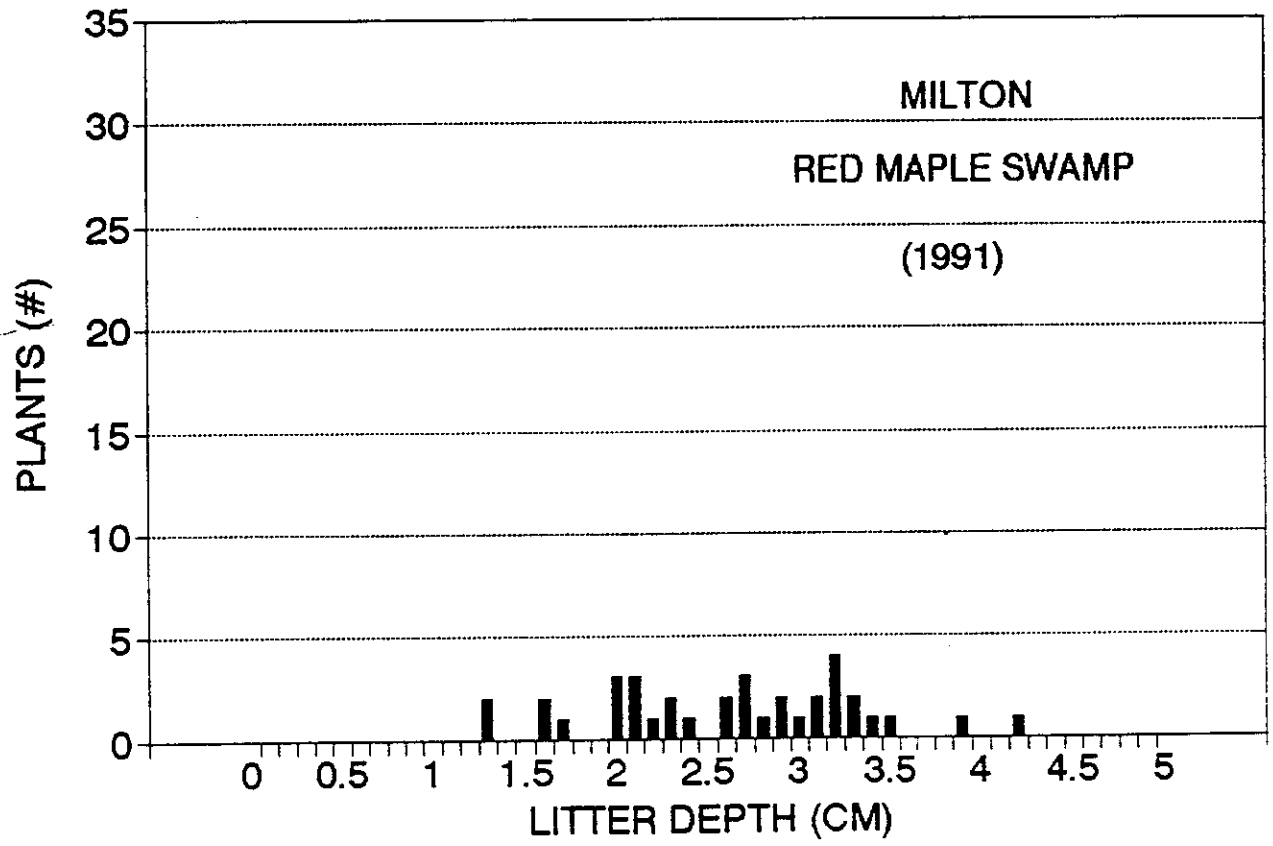
# Figure 6e: PLANT DISTRIBUTION AT DIFFERENT LITTER DEPTHS



# Figure 6f: PLANT DISTRIBUTION AT DIFFERENT LITTER DEPTHS



# Figure 6g: PLANT DISTRIBUTION AT DIFFERENT LITTER DEPTHS



which appeared in 1992. There were no plants in Control Plot 2. Thus during the 2 years of the experiment a total of 19 plants emerged in the treatment plots and just 1 in the control plots.

Heavy germination occurred in the trail adjacent to Treatment Plot 1 in 1992. Thirty plants were present in June. By August even more seedlings had emerged in the trail at Carlisle and a total of at least 60 was present. This suggests that litter is limiting because the seedlings only emerged in the first three meters of the trail where there is little litter.

These results support the hypothesis that litter much deeper than 1 cm limits the growth of Britton's violet individuals and the distribution of individuals within Britton's violet populations.

This is evidenced by the concentration of individual in areas of shallow litter and the emergence of new plants in the experimental plots in which litter was removed.

The results are also consistent with informal observations made at other Britton's violet sites. The Concord1 population is growing in thin litter. The Concord2 site has little litter - most plants are growing in a mowed field.

Higher reproductive levels in the sun suggest that V. brittoniana may be adapted primarily to open areas with little litter. If this is the case the species may only be able to survive in forested areas if the litter is shallow.

Continued use and maintenance of trails by humans and animals may be essential to the populations' survival by creating areas with thin litter. Increased soil fertility from animal use of the trail, decreased competition from other plants, or increased light may also be important.

The fact that one seedling had been found beneath litter suggests that seed is present and even germinates beneath deep litter. However the tiny plants may not be able to penetrate the deep litter. This may explain how deep litter limits Britton's violet.

## H. Threatened Populations

### Concord2 Site

An estimated half of the Britton's violet habitat at the Concord2 site has been eliminated by a road and landscaping project which was permitted prior to the effective date of the Massachusetts Endangered Species Act (Zielinski, pers. obs.).

During 1991 the Concord2 site was visited on numerous occasions to identify, locate and count individuals and to assist NHESP and the Concord Natural Resources Commission (NRC) in formulating a management plan and mitigation strategies for the population. An agreement between the landowner, NHESP and the NRC allows access to the site for study.

Construction closely abuts the remaining plants and even with mitigation measures their long term survival is doubtful.

**Milton Site**

In Milton proposed expansion of the Metropolitan District Commission (MDC) sewer line would occur directly through the portion of the V. brittoniana pectinata population which lies along the trail (and also disturb the habitats of seven other rare species).

A visit to the site in the fall of 1991 was devoted to litter depth measurements and consultation with the Massachusetts Water Resources Authority (MWRA) and the Metropolitan District Commission (MDC) which led to a slight shift in project location. However the project continues to affect a significant portion of the population.

Substantial time was spent in both 1991 and 1992 in locating Britton's violet plants and assisting in developing mitigation strategies as well as in assisting in a project to determine whether this population is V. brittoniana variety pectinata or a separate species. If it should in fact prove to be a separate species this will be the only known population.

Since the beginning of the author's research it has been clear that there are ecological as well as morphological differences between the V. brittoniana pectinata population on the Neponset River and those along the Concord. The former is found both in a red maple swamp which may be annually inundated and along a trail which is not. Annual inundation is unknown in any of the V. brittoniana along the Concord River. In addition the plants in the red maple swamp are found at a considerably greater litter depth than those on the Concord River.

Russell (1965) described pectinate individuals growing with typical V. brittoniana individuals and suggested that this may be a case of genetic dimorphism rather than hybridization. The present work suggests that this is doubtful. The two types do not occur together at any of the Concord River sites, nor at the V. brittoniana pectinata site on the Neponset River.

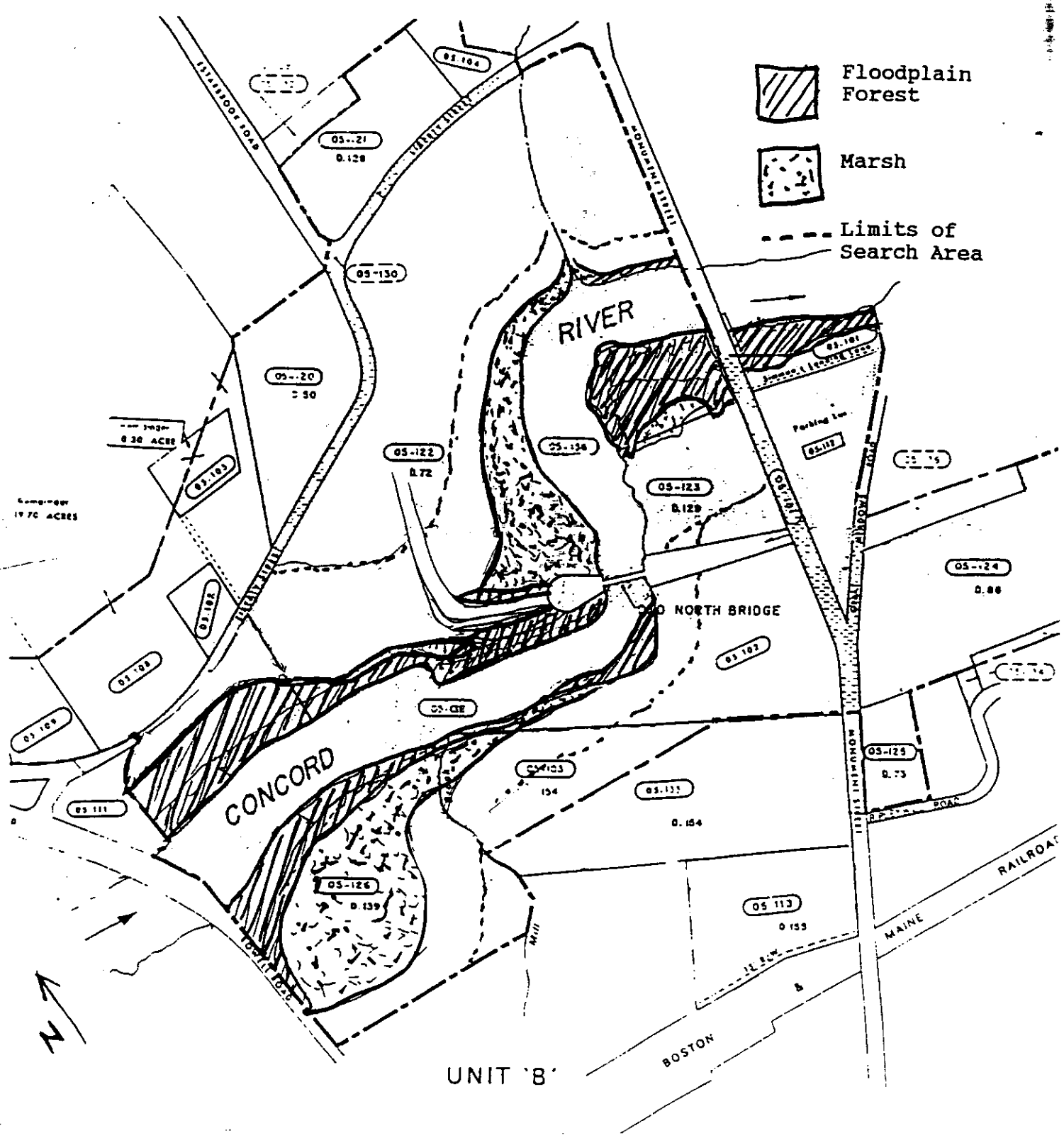
Work is currently underway to describe genetic differences between these groups (Kesseli, pers. com.). Breeding studies are also needed to test the biological species concept in these populations.

**Need for Greater Protection**

Of the six known Britton's violet sites in Massachusetts (including the new population found in 1992 but not counting the Viola brittoniana pectinata site) four are on public land and two on private land. Neither the state Endangered Species Law or the Massachusetts Wetlands Protection Act, nor public ownership of the habitat areas are adequate to protect this species. If Britton's violet is as rare in the southerly part of its range as it is in Massachusetts it is imperative that steps be taken immediately to pursue federal listing.

Figure 7

MINUTEMAN NATIONAL PARK



This zone is in many areas wooded and in others consists of grassy lawn or formal gardens. Much of the Park has been cleared of natural vegetation. Lawn and formal gardens extend in some areas to the edge of the marsh. In other areas lawn abuts wooded swamp or the river bank.

East of Monument Street a trail separates the floodplain forest from a red maple swamp. Both the trail and swamp were thoroughly searched. This is because they more closely resemble known Britton's violet habitat than any other area in the park. But, unlike trails where other V. Brittoniana populations are found this one is bordered and partially overgrown with Polygonum cuspidatum (japanese knotweed). This Polygonum is very invasive with little other vegetation beneath it. Removal of this plant could create potential habitat for V. Brittoniana.

The northern bank of the river just west of Monument Street consists of very steep wooded bank at approximately 45 degrees which rises about 10 m above the water. Since most of this area lies on or above the 10-100 year floodplain it was intensively searched.

The Park contains little 'typical' Britton's violet habitat as defined by a trail in the 10 year flood zone. Only one other section of the floodplain is traversed by a trail. This trail is very historic and heavily traveled - the wide footpath immediately adjacent to the Old North Bridge, the site of the Colonial Minutemen's encounter with British forces which initiated the American Revolution. The area surrounding this path was intensively searched. Lawn runs here from the trail to the annual flood line.

Conclusions and Recommendations.

No Britton's violets were found within Minuteman Park during 1992 despite over forty hours of intensive searching.

For the reasons described above, the search was conducted in mid-summer and early fall when the area was heavily vegetated.

Potential habitat areas have now been identified and will be checked again in May of 1993 at the beginning of the growing season before most of the herbaceous vegetation has developed.

The areas along the footpath by the Minuteman statue and along the trail on the east side of Monument Street might be managed to create better habitat. Allowing natural woody vegetation to grow along the former and removing the japanese knotweed from the latter are recommended to achieve this.

**Additional Locations**

Additional areas along the Concord River in the vicinity of the Carlisle population, including parts of Great Meadows National Wildlife Refuge, were searched for new populations. No sites were found in these areas. Time did not permit a detailed search of other parts of the Refuge.

is important - possibly for species survival by moving seeds to new sites.

3. Association with Trails. Britton's violet populations are linear in a second sense - that they occur along trails. All but the Concord2 population are found on both sides of the trail - with the vast majority of the plants on the side nearest the river. (At the Concord2 site the area on the side of the road furthest from the river has been completely landscaped. It is unknown whether plants occurred in this area prior to disturbance.) At most sites the trails are across ridges or filled areas in the 10 year flood zone. The edges of the trails differ from the surrounding forest in that they have more light, less competition for water, and shallower litter.

4. Shallow Litter. All populations grow in areas with shallow litter. Few individuals occur where litter is deeper than 1 cm. Seeds may germinate under somewhat deeper litter but be unable to penetrate it. Litter may be removed, i.e. kept shallow, by occasional inundation or being adjacent to trails.

5. Sparse Cover. There is sparse woody vegetation in the tree and shrub canopies as well as the forest floor herb layer.

6. Light Level. All populations receive some direct sunlight but the amount is highly variable. More sun leads to greater flowering though whether this translates to more recruits to the population is unknown.

**Suggested Elements for a Management Plan**

1. Protect natural areas along rivers in eastern Massachusetts, especially areas where there are historic records of Britton's violet.

2. Maintain trails as trails to keep litter down.

3. Prohibit motorized vehicles which could wipe out a population with a single pass along the trail edge.

4. Maintain a moderate canopy through selective tree and shrub removal.

5. Remove invasive plants. Both european buckthorn (Rhamnus frangula) and swamp dewberry (Rubus hispidus) have invaded Britton's violet populations. Buckthorn is widespread in most of the populations. Plants were observed to die out as Rubus invaded the Bedford population over the past 3 years. Thus Rubus should immediately be removed from the Bedford site.

6. Maintain at least 200 feet from the edge of development activity.

7. Obtain permanent conservation restrictions for the population area and a wide buffer zone around it.

8. Prohibit alterations of grade or vegetation within the buffer area.

Cook, R.E. 1978. Fragile blossoms of spring aren't shrinking violets. Smithsonian March: 65-71.
Foy, L. 1978. Breeding strategies and seed dispersal in the genus Viola. New England Wild Flower Notes Winter.
Gershoy, A. 1928. Studies in North American violets. Vermont Agricultural Experiment Station Bulletin 279.
Harper, J.L. 1974. Population biology of plants. Academic Press. London. 892pp.
Russell, N.H. 1965. Violets (Viola) of central and eastern United States: An introductory survey. Sida 2(1): 1-113.
Zielinski, S.A. 1990. Population studies of the rare species Viola brittoniana Pollard in Massachusetts.

h/report92

Appendix A

ARTICLE WHICH APPEARED IN SPRING 1991 ISSUE OF MACC NEWSLETTER

## Britton's Violet
## A Rare Plant of River Floodplains

Britton's Violet (Viola brittoniana Pollard) is a blue-purple violet which grows on or just above river floodplains. It is listed as rare and threatened by the Massachusetts Natural Heritage and Endangered Species Program (NHESP). V. brittoniana is classified as a facultative wetland plant in the Northeast region by the National Wetlands Inventory. Thus it occurs in wetlands 34-66% of the time.

Britton's Violet (also known as the Coast Violet) is a member of the genus Viola which contains over 900 species of trees, shrubs, and herbs distributed worldwide in temperate woods and fields. Thirty-five species occur in New England.

V. brittoniana is a stemless blue violet - it produces leaves and flowers directly from the rootstock, instead of branching from above ground stems. This group, the most recently evolved violets, are typically North American plants found in the east and midwest. They are the characteristic blue violets of cold swamps, deep woods and forest undergrowth.

V. brittoniana Pollard is a herbaceous perennial which dies back to a rootstock each fall. Leaves, which form a clustered rosette when they emerge in May, usually have three primary leaf segments with are each then split into several lobes. A variety 'pectinata' differs only in having long, narrow, comb-like incisions of its leaf-blade. Britton's Violet has leaves similar to the Bird's Foot Violet.

Britton's Violet produces two kinds of flowers. Showy purple chasmogamous flowers form in mid to late May. Greenish cleistogamous flowers form in June and July, appearing as inconspicuous pointed buds. Since they do not open they self-fertilize.

The seeds of many spring-flowering forest floor herbs are dispersed by ants. Most Viola species explosively eject their seeds which are then often picked up by the ants. They eat the attached fat bodies, or "eliasomes" and then deposit the intact seeds outside their nests. While the dispersal mechanism of V. brittoniana is not well understood, the species has characteristics associated with ant dispersal.

V. brittoniana is found on the coastal plain of the eastern United States from Maine to North Carolina. It appears to be rare throughout its range. While there are 14 documented occurrences prior to 1978, only a half dozen populations are known today in Massachusetts.

Historical records describe the habitat of Britton's Violet as upper flood plains and sandy river meadows. William Brewster described

Britton's Violet in 1909 as shunning wetter parts of meadows and growing on elevated ridges or benches of dry land near a river. Some known populations are linear - found along woodland trails.

Historical descriptions and observations of existing sites suggest Massachusetts V. brittoniana populations are declining, both in number and size. Tuckerman found V. brittoniana to be abundant in Concord in 1839. However, it was already sparse and localized in Massachusetts by 1909.

A species may be rare because its habitat is rare, because its requirements are very specific, or both. V. brittoniana habitat loss is clearly occurring as river floodplains become more heavily altered. Little is know about its requirements, but it appears to prefer areas where the leaf litter is very thin. Research is currently underway to clarify its population biology and ecological needs, and assist the NHESP in determining how to maximize its chances of survival.

While the known populations occur along the Concord and Neponset Rivers there may well be populations along other rivers. A thorough search for additional sites is needed.

Britton's violet flowers from mid to late May when most other violets have finished flowering, so now is the time to search for new populations. If you find a population of Britton's Violet or would like more information please call the author at MACC.

**Sally A. Zielinski, Ph.D.**
Biologist
MACC Executive Director

May 14, 1991

of barriers to hybridization among closely related species. Brainerd's (1924) studies of violet hybrids found growing in the wild showed offspring blending the characteristics of parents. Brainerd concluded that the limits to hybridization are only set by species not growing together.

Normally ecological barriers separate closely related Viola. When sympatric, species are usually found in markedly different habitats and rarely co-occur except where vegetation is changing rapidly and zones are compressed and narrow. In altered habitats, formerly separated species are now occurring together (Russell 1954).

At least 30 of the 75 North American violet species hybridize, including V. brittoniana (Brainerd 1924). Six species studied by Solbrig et al. (1980) in Bedford, Massachusetts (which did not include V. brittoniana), were all partly or fully interfertile.

## Reproduction in Viola

The genus Viola is known for its multiple reproductive mechanisms: sexual outbreeding through showy or chasmogamous (CH) flowers, sexual inbreeding via cleistogamous (CL) flowers, and asexual propagation via stolons or rhizomes (Solbrig et al. 1980).

The violets are a group of naturally inbreeding plants. In general CH flowering of violets promotes cross-pollination, but CH flowers are also often capable of selfing with or without insects. Selfing of CH flowers is common in the Nominium group which includes V. brittoniana (Gershoy 1928).

Cleistogamy occurs in at least 56 plant families (Mayers & Lord 1983) and involves obligate inbreeding with decreased variability likely in the offspring (Thompson & Beattie 1981) Most violet species have cleistogamous reproduction. A notable exception is V. pedata (Culver & Beattie 1978). Far more seed is generally produced from CL than CH flowers (Cook 1978).

Much of the vernal flora of cool temperate forests is apparently ant dispersed (Culver & Beattie 1980). Viola is basically myrmecochorous but different selective pressures, especially seed predation, have led to divergence in dispersal syndromes within the genus. Mechanisms in Viola range from autochory to diplochory to myrmecochory. Diplochory, explosive ejection followed by ant action, occurs in a majority of Viola. Pure autochory has not been found, and pure myrmecochory occurs just in a few Eurasian species (Beattie & Lyons 1975). V. pallens, V. blanda, V. pedata and V. sororia, which occur in the same geographical area in Massachusetts as V. brittoniana, are all diplochores (Newell et al. 1981; Beattie & Lyons 1975), as well as most species studied by Culver & Beattie (1978).

## Limiting Factors

Forest litter depth studies were conducted in Carlisle and Bedford. In order to profile variation in litter depth with distance from the trail center, depth was measured at .1m intervals along transects running perpendicular to the trail and extending 1.5m to either side. At the Carlisle site two transects were placed - at 2m and 5m along the trail. In Bedford, where the population extends over a considerable distance, three transects were used - at 20, 40, and 60m along the trail.

The depth of the litter layer in which each violet plant was growing was measured to the nearest .1cm in late summer before the first frost occurred or the trees shed their leaves. A depth micrometer was used to take measurements immediately adjacent to each plant without compressing the litter.

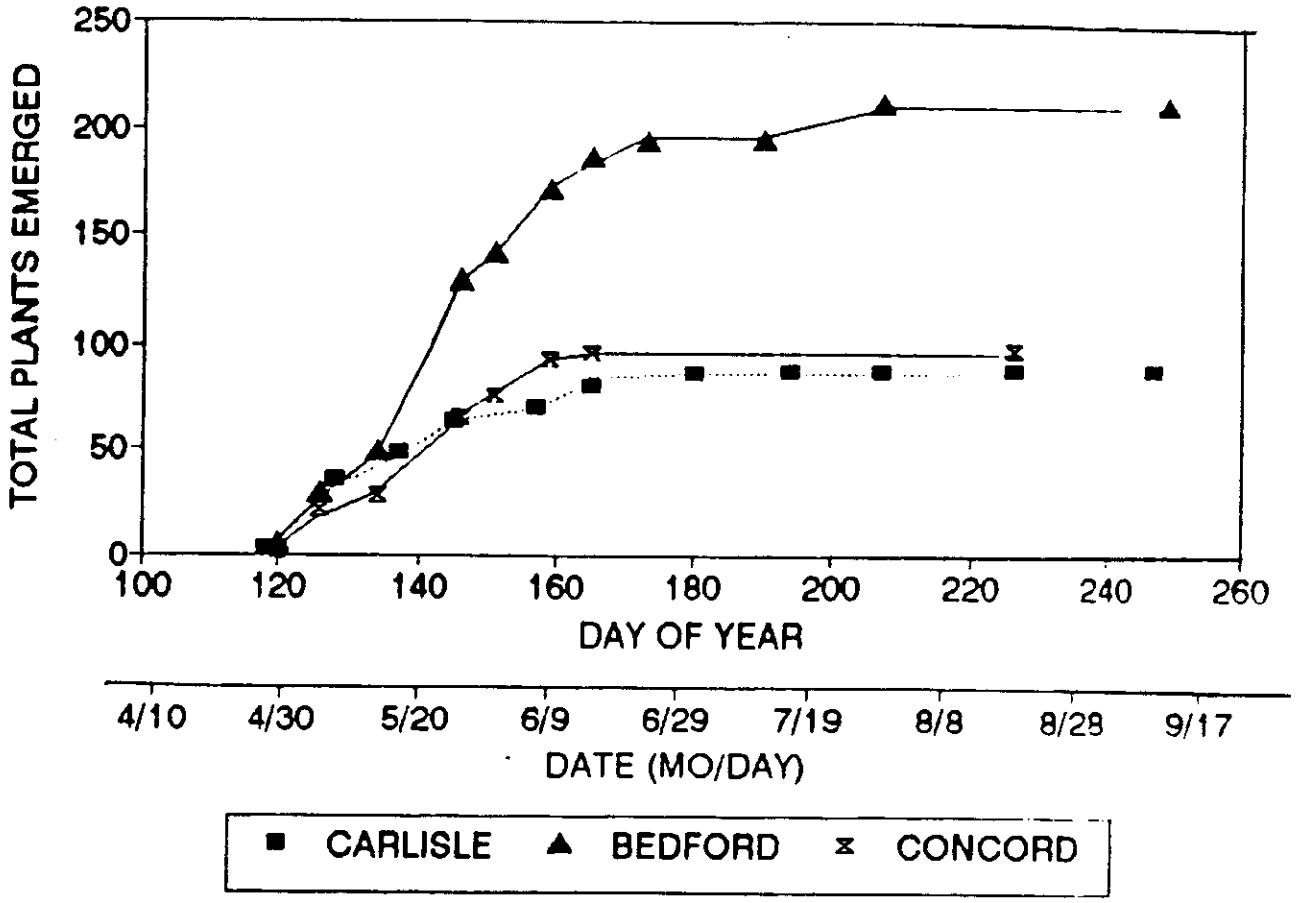
Plants at each depth interval were then compared for frequency of occurrence and flower and fruit production. Relationships were determined between litter depth and date of emergence, the distance plants were located from the trail center, and plant height (for the early emerging plants). The distribution of plants at different distances from the trail was related to the distribution of litter depths.

A litter removal project was initiated at the Carlisle and Bedford sites to test whether deep litter is a limiting factor in the distribution of V. brittoniana individuals within a population.

Strips perpendicular to the center line of the trail, extending 2.5m to one side, were selected at each site. To optimize the chance of seed dispersal to the treated areas only strips falling within a population and adjacent to V. brittoniana individuals were considered. However, to avoid disruption to existing plants no potential plots were designated within 10cm of a known plant. It was determined by observation that strips should be about 40cm wide to allow for some drift of litter from adjacent areas due to wind or water action or animal activity, and still leave a 20cm wide area in the middle with shallow litter. All possible strips meeting these requirements were determined for each population. Only four such strips existed in Carlisle and all were used. They were randomly assigned 'control' or 'removal' strips. Six strips were randomly selected in Bedford and alternately designated 'control' or 'removal' strips. Control strips remained undisturbed.

Litter was removed to leave a depth of 1cm. Removal took place June 22 in Carlisle and June 29 in Bedford. Plots were monitored

## Figure 1: PLANT EMERGENCE



over two years have been monitored thus far. Results, however, are also consistent with photoperiod as a cue. Multi-year and multi-site studies of emergence which include temperature monitoring will help identify the cue, and will be initiated in 1991.

### Population Size

The Bedford population, with over 200 individuals, is over twice the size of those in Carlisle and Concord (Tab. 1). The Carlisle and Concord populations are roughly equal in size (89 vs. 99 plants). These numbers are higher than previously reported. NHESP observations were made in late May during CH flowering. However plants continue to emerge for another month. About 3/4 of the individuals at Carlisle and Bedford had emerged by May 31 in 1990. Since plant counts before mid-June may seriously underestimate population size, counts should be made at this time or a correction factor based on the emergence curves applied to the numbers observed during the CH flowering season.

The extended period of emergence of V. brittoniana individuals indicates that population sizes recorded in a monitoring program may seriously underestimate actual size if observations are made during the CH flowering season. More reliable readings can be obtained after mid-June.

While plant counts in Carlisle in 1989 ceased June 18 and it is unknown if any more plants appeared, the presence of 68 plants on June 18, 1989 versus 81 on June 14, 1990 suggests a population size increase. Some Viola population sizes appear to be more stable than others. Newell (1983) found increases in the population sizes of three Viola species in Newfoundland, whereas Newell et al. (1981) found Massachusetts populations of these species stable over a 10 year period.

## Density, Pattern and Association

### Spatial Pattern

At both Carlisle and Bedford plants range up to roughly 2m from the trail center. However, the Carlisle population extends about 7m along the trail while the Bedford population ranges over about 65m (Figs. 2,3*; Tab. 3). While the Bedford population is twice the size of the Carlisle population, there is considerably higher density of V. brittoniana in Carlisle - 2.58 plants per square meter compared to .83 plants in Bedford.

In both populations plants are densest by far on the river side of the trail (Figs. 2,3). This is also the case at the Concord site.

* Due to their size Figures 2&3 are placed at the end.

## Table 3: POPULATION DENSITY

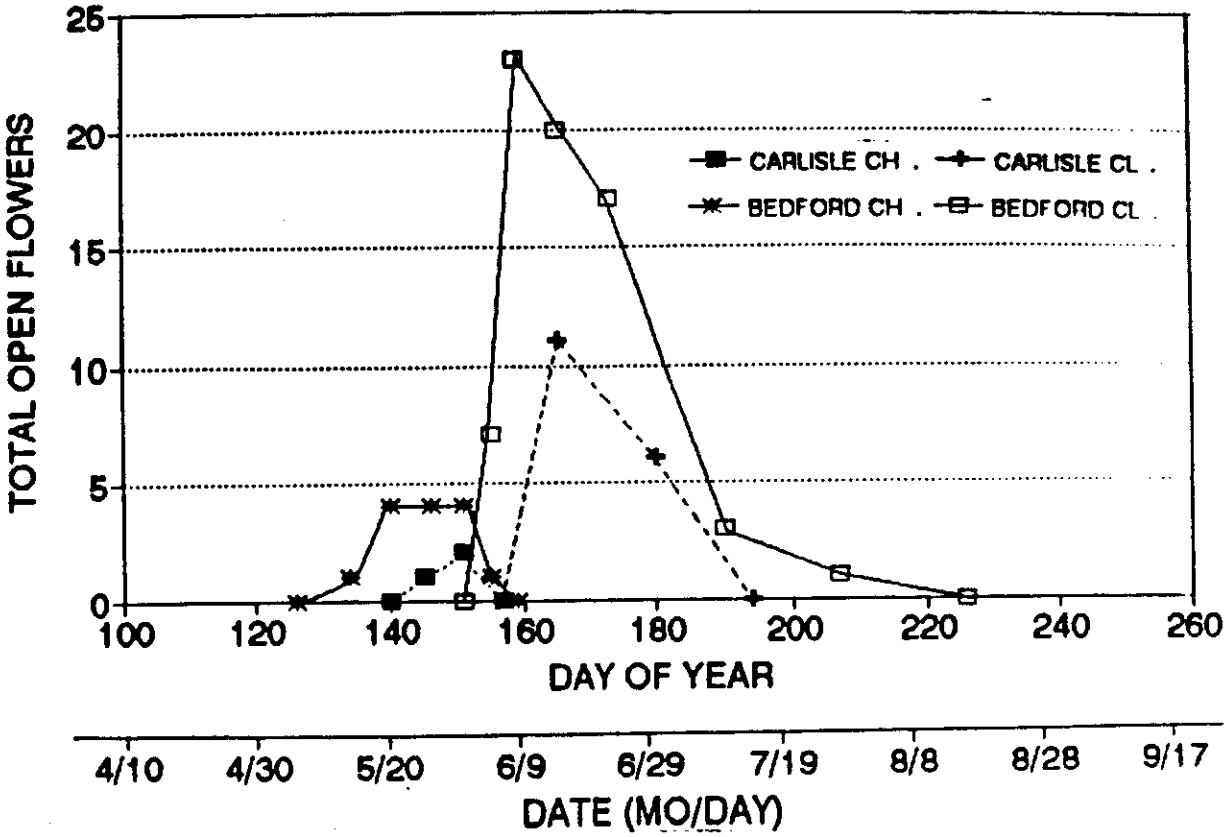
| | CARLISLE | BEDFORD |
|---|---|---|
| (a) Distance individuals extend along trail (m) | 7.35 | 64.69 |
| (b) Distance individuals extend from trail (m) | 2.35 | 1.97 |
| (c) Total area covered by population (sq. m) (a)x(b)x(2) | 34.55 | 254.88 |
| (d) Individuals in population (#) | 89 | 211 |
| (e) Population density (#/sq. m) (d)/(c) | 2.58 | 0.83 |

Table 4: SPECIES ASSOCIATED WITH *Viola brittoniana*

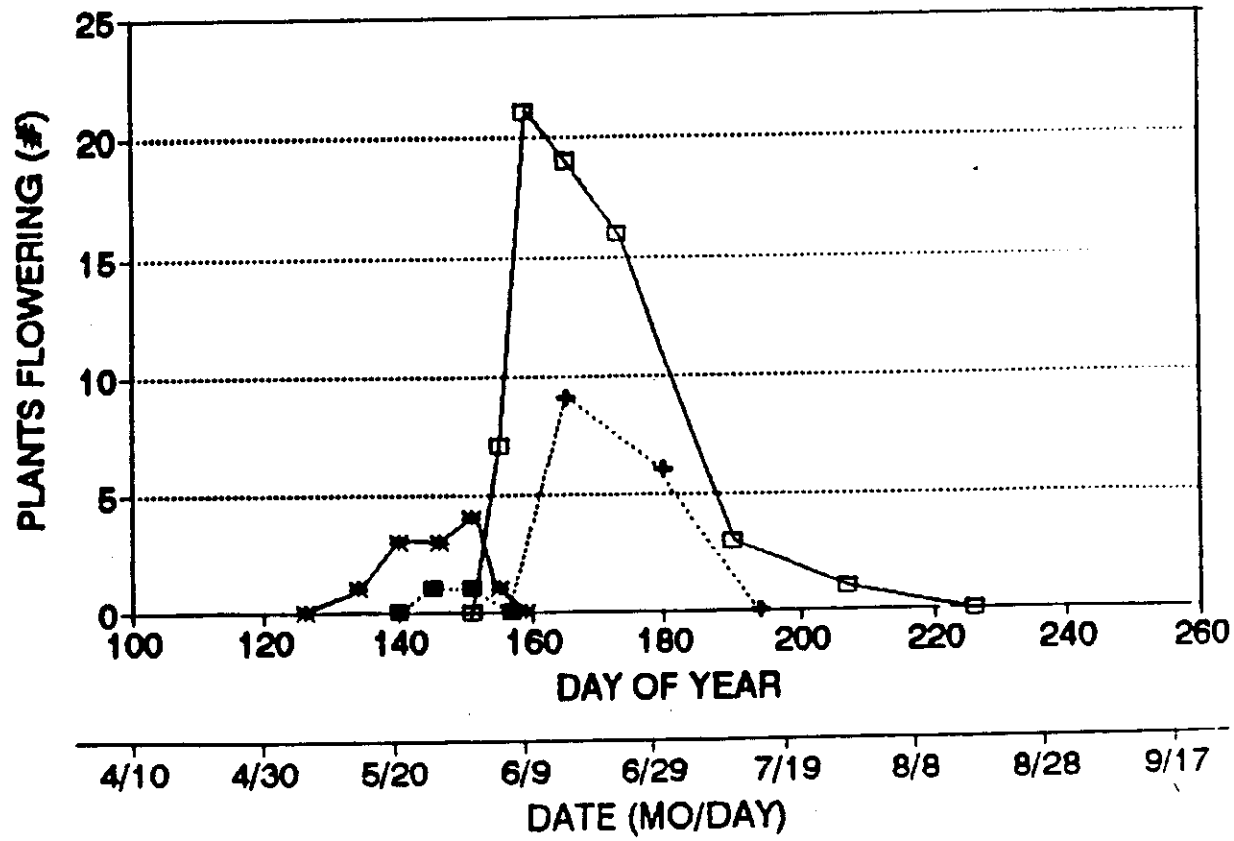
| SCIENTIFIC NAME | COMMON NAME | CARLISLE | BEDFORD |
|---|---|---|---|
| Acer rubrum | red maple | | * |
| Alnus incana | speckled alder | * | |
| Aster sp.* | aster | * | |
| Cyperaceae 1 | sedge | | * |
| Cyperaceae 2 | sedge | | * |
| Gramineae 1 | grass | * | * |
| Gramineae 2 | grass | | * |
| Gramineae 3 | grass | | * |
| Maianthemum canadense | canada mayflower | * | |
| Musci ssp.** | moss | * | * |
| Onoclea sensibilis | sensitive fern | | * |
| Pilea pumila*** | clearweed | | * |
| Pinus strobus | white pine | * | |
| Polytricum sp. | haircap moss | * | |
| Quercus alba | white oak | * | |
| Rhamnus frangula | european buckthorn | * | * |
| Rosa sp.**** | rose | * | * |
| Rubus hispidus | swamp dewberry | | * |
| Rubus occidentalis | black raspberry | | * |
| Spiraea latifolia | meadowsweet | | * |
| Thelypteris thelypteroides | marsh fern | * | |
| Uvularia sessilifolia | wild oats | | * |

* possibly A. vimineus, small white aster
** one to three species, not Polytrichum
*** probable
**** possibly R. palustris, swamp rose

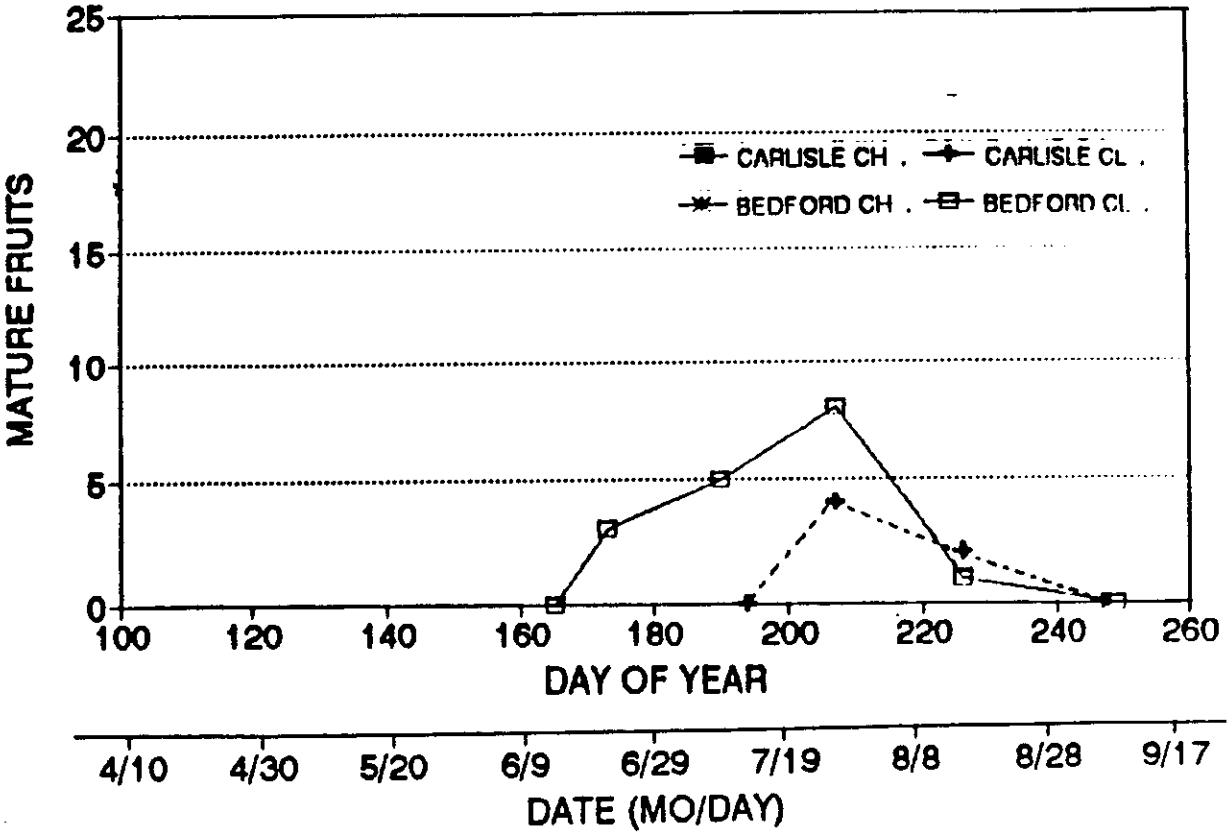
# Figure 6: TOTAL OPEN FLOWERS IN POPULATION




# Figure 7: TOTAL PLANTS FLOWERING



## Figure 8: TOTAL MATURE FRUITS IN POPULATION




## Figure 9: TOTAL PLANTS FRUITING

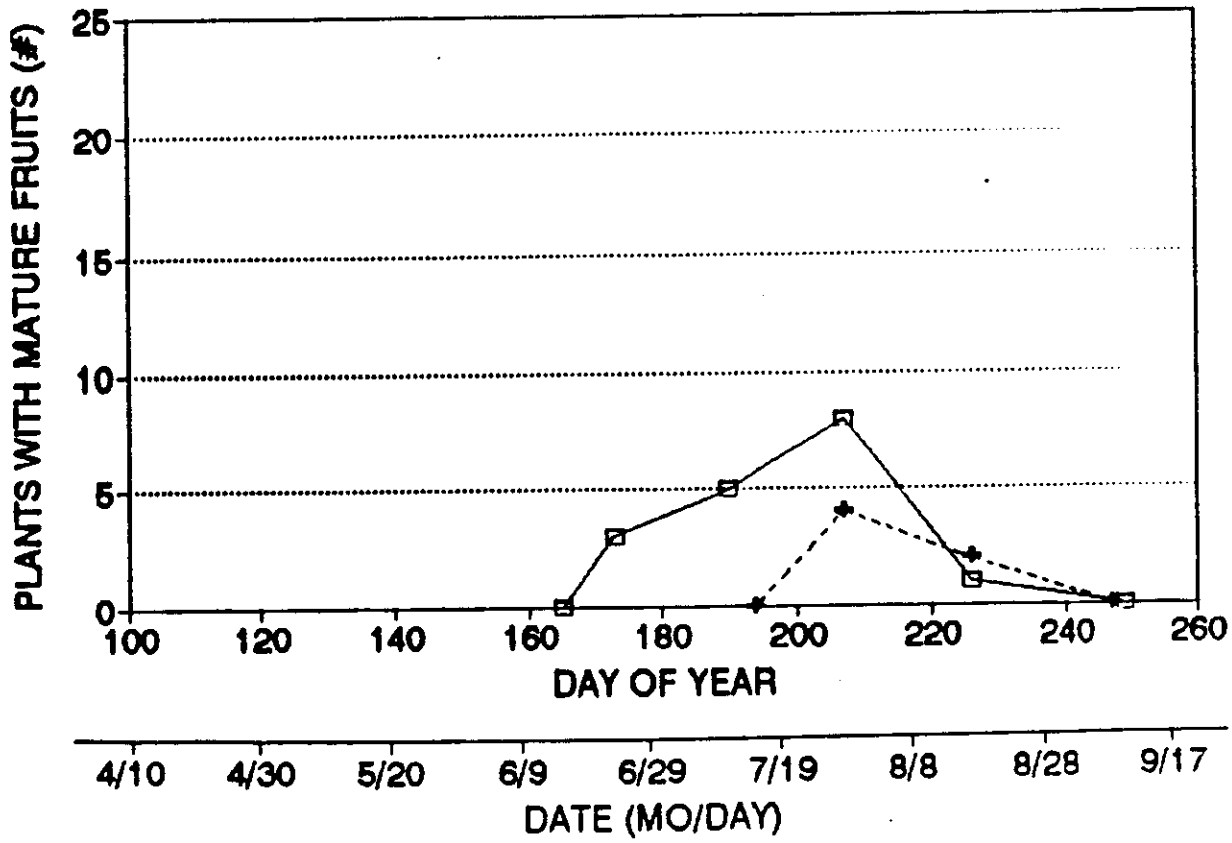


Table 5: FLOWERING AND FRUITING

| | CARLISLE | | BEDFORD | |
|---|---|---|---|---|
| | Chasmo-gamous (CH) | Cleisto-gamous (CL) | Chasmo-gamous (CH) | Cleistō-gamous (CL) |
| **Flowers** | | | | |
| Total in population | 2 | 17 | 8 | 56 |
| Total plants flowering | 1 | 13 | 7 | 38 |
| Percent plants flowering | 1.1 | 14.6 | 3.3 | 18 |
| Flowers/plant mean(sd) | .02(.21) | .19(.49) | .04(.21) | .25(.65) |
| **Initiated fruits** | | | | |
| Total in population | 0 | 13 | 2 | 44 |
| Total plants initiating fruits | 0 | 11 | 2 | 32 |
| Percent plants initiating fruits | 0 | 12.4 | 0.9 | 15.2 |
| Percent plants flowering initiating fruits | 0 | 84.6 | 28.6 | 84.2 |
| Initiated fruits/plant mean(sd) | 0 | .14(.41) | need | .20(.56) |
| **Mature fruits** | | | | |
| Total in population | 0 | 9 | 0 | 18 |
| Total plants maturing fruits | 0 | 8 | 0 | 17 |
| Percent plants maturing fruits | 0 | 9.0 | 0 | 8.1 |
| Percent plants flowering maturing fruits | 0 | 61.5 | 0 | 44.7 |
| Mature fruits/plant mean(sd) | 0 | .10(.33) | 0 | .08(.29) |
| **Total plants in population** | | 89 | | 211 |

one CH flower, which was at the Bedford site, initiated a fruit. Reproductive success, or the fraction of flowers producing mature fruits, was zero in both populations. Thus CH reproduction did not occur at either Carlisle or Bedford in 1990.

CL flowering was also low but considerably heavier than CH flowering at both sites. Thirteen plants in Carlisle (14.6%) and 38 in Bedford (18.0%) produced CL flowers.

Eighty-four percent of the plants at each site which produced CL flowers initiated fruit, reflecting the expected high success rate of obligatory self-fertilization.

Sixty-one percent of the plants which flowered in Carlisle and 45% in Bedford matured at least one fruit. All Carlisle plants matured one fruit per plant. Only one plant in Bedford produced two mature fruits; the rest had one.

**Emergence Time and Reproductive Success**

Early emergence was related to greater flowering and reproductive success. In Carlisle all flower production was by early emerged plants (Tab. 6). The one plant which produced CH flowers emerged early - prior to May 25. It failed to initiate or mature fruit. Similarly, in Carlisle during 1989 only the two tallest and earliest emerging plants produced CH flowers but both of these developed capsules. A much higher proportion of the population produced CL flowers (Tab. 2).

All of the plants which produced CL flowers (13 plants) had emerged by May 25. The mean height of flowering plants which emerged early was 6.76cm compared to 4.52cm for those which did not flower (50 plants). Thus in Carlisle the plants which flowered were 50% taller.

In Bedford only early emerged plants flowered. Three of the seven plants which produced CH flowers had emerged by May 14, and the other four by June 8 (Tab. 6). Only one in each group initiated fruit but none matured.

Of the 38 plants which produced CL flowers in Bedford over half (20) had emerged by May 14. A total of 35 plants emerged by June 8 and all 38 by June 22. Though open flowers were produced through July 27 no plant which emerged after June 22 flowered.

Early emerging plants had greater reproductive success. Sixty percent of plants which emerged by May 14 matured fruits compared with only 33% of plants emerging later.

Table 6: EMERGENCE TIME AND REPRODUCTION

| CARLISLE | EMERGENCE DATE May 25 1 | Jun 14 2 | Jun 29 3 | Aug 14 4 |
|---|---|---|---|---|
| CHASMOGAMOUS FLOWERING | | | | |
| Plants flowering (#) | 1 | 0 | 0 | 0 |
| Plants initiating fruits(#) | 0 | 0 | 0 | 0 |
| Plants maturing fruits (#) | 0 | 0 | 0 | 0 |
| Plants flowering which matured fruits (%) | 0 | 0 | 0 | 0 |
| CLEISTOGAMOUS FLOWERING | | | | |
| Plants flowering (#) | 13 | 0 | 0 | 0 |
| Plants initiating fruits(#) | 11 | 0 | 0 | 0 |
| Plants maturing fruits (#) | 8 | 0 | 0 | 0 |
| Plants flowering which matured fruits (%) | 0.62 | 0 | 0 | 0 |

| BEDFORD | May 14 1 | Jun 8 2 | Jun 22 3 | Jul 9 4 | Aug 14 5 |
|---|---|---|---|---|---|
| CHASMOGAMOUS FLOWERING | | | | | |
| Plants flowering (#) | 3 | 4 | 0 | 0 | 0 |
| Plants initiating fruits(#) | 1 | 1 | 0 | 0 | 0 |
| Plants maturing fruits (#) | 0 | 0 | 0 | 0 | 0 |
| Plants flowering which matured fruits (%) | 0 | 0 | 0 | 0 | 0 |
| CLEISTOGAMOUS FLOWERING | | | | | |
| Plants flowering (#) | 20 | 15 | 3 | 0 | 0 |
| Plants initiating fruits(#) | 18 | 11 | 2 | 0 | 0 |
| Plants maturing fruits (#) #) | 11 | 5 | 1 | 0 | 0 |
| Plants flowering which matured fruits (%) | 0.55 | 33.3 | 33.3 | 0 | 0 |

Early emerging plants which flowered were no larger than those which did not. The mean height of plants which flowered by May 14 (20 plants) was 3.4cm compared to 3.3cm for those which did not flower (31 plants).

**Flowering Time and Reproductive Success**

There is no relationship between reproduction and flowering time (Tab. 7). While more plants flowered early than late in both Carlisle and Bedford, the percent of early and late flowering plants which produced fruits is about the same in both populations. (The dates defined as early and late are based on dates with detailed observations.)

**Multiple Flowers and Reproductive Success**

There was no difference in reproductive success between early and late flowers on a given plant (Tab. 8). Four of the 13 plants in Carlisle which produced CL flowers had more than one flower, as did nine of 38 in Bedford.

All four Carlisle plants produced two flowers each. None developed two fruits, but three of the four developed one. Of these three, in two cases the earlier flower matured the fruit. In Bedford five of the nine plants which had multiple flowers produced three flowers, the rest two. Eight of the nine plants initiated at least one fruit. No plant matured three fruits; one matured two fruits (from the later two of the three flowers). Four plants matured one fruit. Two matured the middle of three flowers, one matured the later of two flowers, and one matured the earlier of two flowers.

**Plants with Both Chasmogamous and Cleistogamous Flowers**

Most plants which produced CH flowers also produced CL flowers. In Carlisle the only plant which produced CH flowers also produced two CL flowers (Fig. 10) but only one of the CL flowers matured a fruit. In Bedford five of seven plants with CH flowers produced CL flowers, and three of these matured fruits - one each (Fig. 11).

**Population Structure**

Most plants in the Carlisle and Bedford populations did not reproduce in 1990 (Tab. 9). Individuals within the populations were classified as: producing CH flowers; producing CL flowers (but not CH flowers); or non-reproductive. The profiles of the two sites were similar. About 85% of the Carlisle population and 81%

Table 7: REPRODUCTIVE SUCCESS OF EARLY AND LATE FLOWERING PLANTS

| | EARLY | LATE |
|---|---|---|
| **CARLISLE** | | |
| | By May 25 | After May 25 |
| **CHASMOGAMOUS FLOWERS** | | |
| Plants which had begun flowering (#) | 1 | 0 |
| Plants developing fruits (#) | 0 | 0 |
| Plants maturing fruits (#) | 0 | 0 |
| Plants flowering which matured fruits (%) | 0 | 0 |
| | By Jun 14 | After Jun 14 |
| **CLEISTOGAMOUS FLOWERS** | | |
| Plants which had begun flowering (#) | 10 | 3 |
| Plants developing fruits (#) | 8 | 3 |
| Plants maturing fruits (#) | 6 | 2 |
| Plants flowering which matured fruits (%) | 60.0 | 66.7 |
| **BEDFORD** | | |
| | By May 20 | After May 20 |
| **CHASMOGAMOUS FLOWERS** | | |
| Plants which had begun flowering (#) | 3 | 4 |
| Plants developing fruits (#) | 1 | 1 |
| Plants maturing fruits (#) | 0 | 0 |
| Plants flowering which matured fruits (%) | 0 | 0 |
| | By Jun 8 | After Jun 8 |
| **CLEISTOGAMOUS FLOWERS** | | |
| Plants which had begun flowering (#) | 22 | 16 |
| Plants developing fruits (#) | 16 | 16 |
| Plants maturing fruits (#) | 10 | 7 |
| Plants flowering which matured fruits (%) | 45.5 | 43.8 |

Table 8: PLANTS WITH MULTIPLE CLEISTOGAMOUS FLOWERS

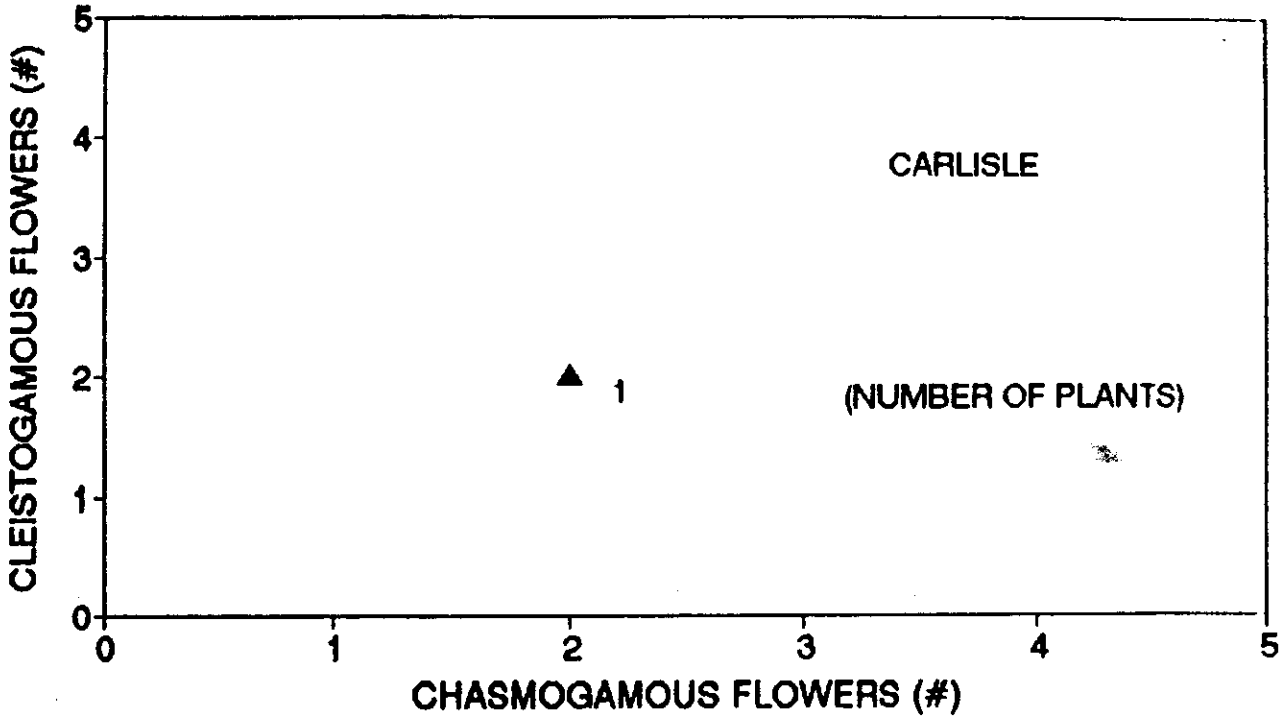
| Site | Plant Number | Fate of Flower | | |
|---|---|---|---|---|
| | | First | Second | Third |
| **CARLISLE** | | | | |
| | 4 | Matured | Aborted | |
| | 31 | Initiated | Initiated | |
| | 46 | Matured | Aborted | |
| | 61 | Initiated | Matured | |
| **BEDFORD** | | | | |
| | 1 | Initiated | Matured | Initiated |
| | 3 | Initiated | Initiated | Initiated |
| | 64 | Initiated | Matured | Matured |
| | 17 | Aborted | Matured | Initiated |
| | 19 | Initiated | Matured | |
| | 33 | Initiated | Initiated | Initiated |
| | 36 | Matured | Initiated | |
| | 37 | Aborted | Initiated | |
| | 44 | Aborted | Aborted | |

Aborted: Flower failed to initiate fruit
Initiated: Flower pollinated, fruit began to develop
Matured: Capsule matured

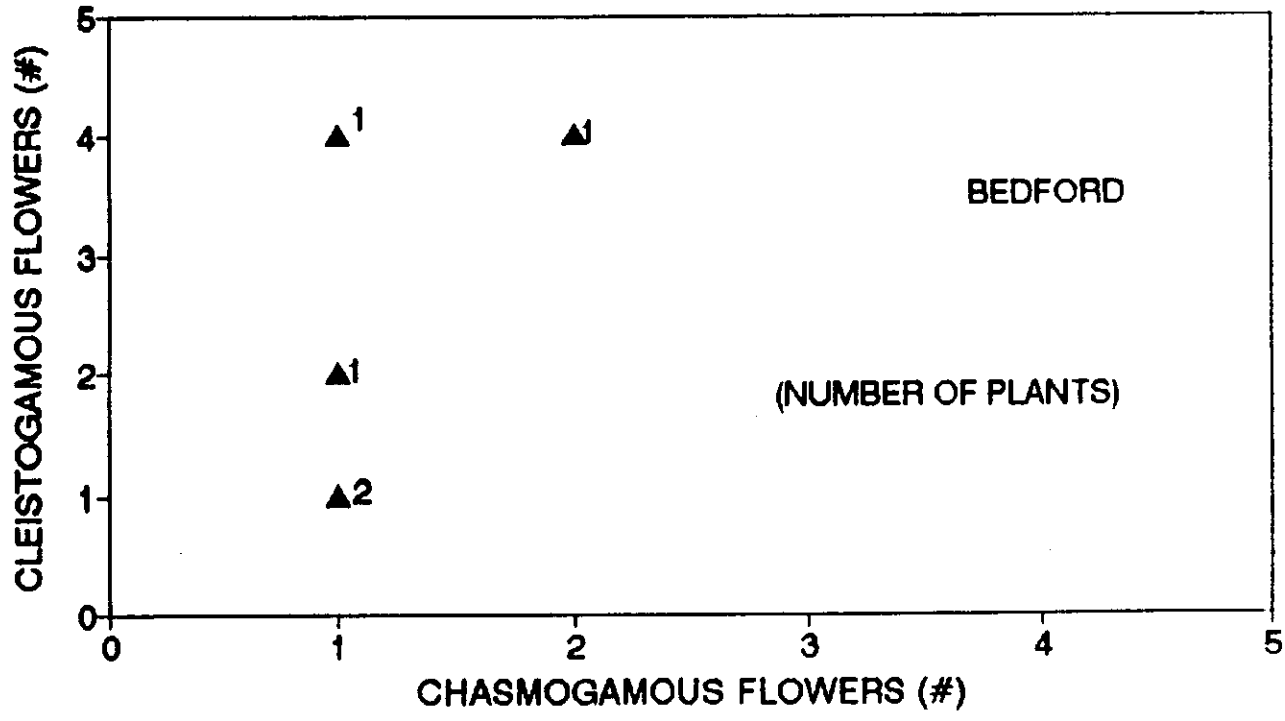
Table 9: POPULATION STRUCTURE

| | CARLISLE | BEDFORD |
|---|---|---|
| Total plants | 89 | 211 |
| Plants with CH flowers | 1 | 7 |
| Plants with CL flowers (but no CH flowers) | 12 | 33 |
| Plants with no flowers | 76 | 171 |
| Percent with flowers | 14.6 | 19.0 |
| Percent with CH flowers | 1.1 | 3.3 |
| Percent with CL flowers (but no CH flowers) | 13.5 | 15.6 |
| Percent with no flowers | 85.4 | 81.0 |

## Figure 10: PLANTS WITH BOTH CHASMOGAMOUS AND CLEISTOGAMOUS FLOWERS




## Figure 11: PLANTS WITH BOTH CHASMOGAMOUS AND CLEISTOGAMOUS FLOWERS



of the Bedford population were non-reproductive. Very few individuals produced CH flowers (1% in Carlisle; 3% in Bedford). Roughly similar proportions had CL flowers (13% in Carlisle; 16% in Bedford). Thus a small proportion of the individuals flowered and most of these produced CL flowers.

## Discussion of Reproduction

Results of these reproductive studies suggest a difference in flowering and fruiting time between Carlisle and Bedford. Additional observations are needed to assess whether this site-to-site variation occurs annually, and whether year-to-year variation occurs at each site. If emergence is triggered by temperature year-to-year variation might be expected. A second season's data, along with temperature measurements, will be gathered in 1991. Temperature data will also be collected.

Since V. brittoniana does not reproduce via stolons or rhizomes these results suggest most reproduction is occurring through CL flowers. However, while it is likely that many more seeds are produced by cleistogamy, it is unknown whether this translates into more new individuals. For example, if ants are a factor in dispersal and recruitment, it is unknown whether they are selective in taking V. brittoniana seeds. CH seeds of some Viola are more frequently taken than CL (Culver & Beattie 1978).

New individuals are clearly entering the Carlisle population from seed. Two individuals were found growing on a fallen tree.

Plants do not flower until they reach a certain size (Harper 1974). Thompson & Beattie (1981) found that V. blanda and V. rostrata plants only produce seeds or stolons once a threshold weight is reached. Cook (1978) found that, in their first season, violets usually produce only two or three small leaves and certainly no flowers. The second year there are generally five or six strong leaves, but no flowers. The third year CL flowers are produced, with CH in the fourth. This study partly confirms earlier results - at one site flowering was concentrated in larger plants.

Culver & Beattie (1980) found that populations of V. odorata and V. hirta contain a small number of dominant reproductive individuals and a large number of subdominant non-reproductives which sometimes die without reproducing. Solbrig (1981) found all individuals of V. sororia have the potential for both kinds of flowers but don't necessarily produce both every year. He also found a positive correlation between time to first reproduction and lifespan which implies a tradeoff between growth and reproduction. Solbrig et al. (1980) estimated the time for a complete turnover of individuals in populations of V. sororia at 10.5 years. Nearly 50% of tagged ramets were alive six years later. Cook (1978) suggested it is not unusual for violets to live 10 years.

Photoperiod is the dominant factor controlling flower type in Viola. Mayers & Lord (1983) found V. egglestonii produced entire leaves during short days and palmately lobed leaves during longer days. Mayers & Lord (1983) found that CH flowers in V. odorata were formed in response to 11 hours or less of daylight, and CL flowers in response to 14 hours or more. V. brittoniana similarly produces its CH flowers in the shorter days of spring and CL flowers in early summer when daylength is longer. This suggests a triggering by photoperiod. If production of CH and CL flowers is controlled by daylength plants emerging after days reach a critical length cannot produce CH flowers.

Overall early emerging plants may have a reproductive advantage. The reason may be related to resource availability and specifically to canopy closure. Solbrig et al. (1980) found that active growth slowed considerably following canopy closure between the end of May and the end of June. Zielinski (1986) reported that leaves of canopy trees in Carlisle (red maple, oak and white pine) began to expand during the first half of May and leaves of deciduous trees were fully expanded by June 13. Thus, by the time Britton's violet flowers at the end of May light reaching the forest floor has considerably diminished. The large variation in percent of the population with CH flowers suggests light level may affect the amount of flower production. Few plants at wooded sites produced CH flowers in contrast with 100% of the individuals at the only site which is in full sun.

## Limiting Factors in Plant Distribution

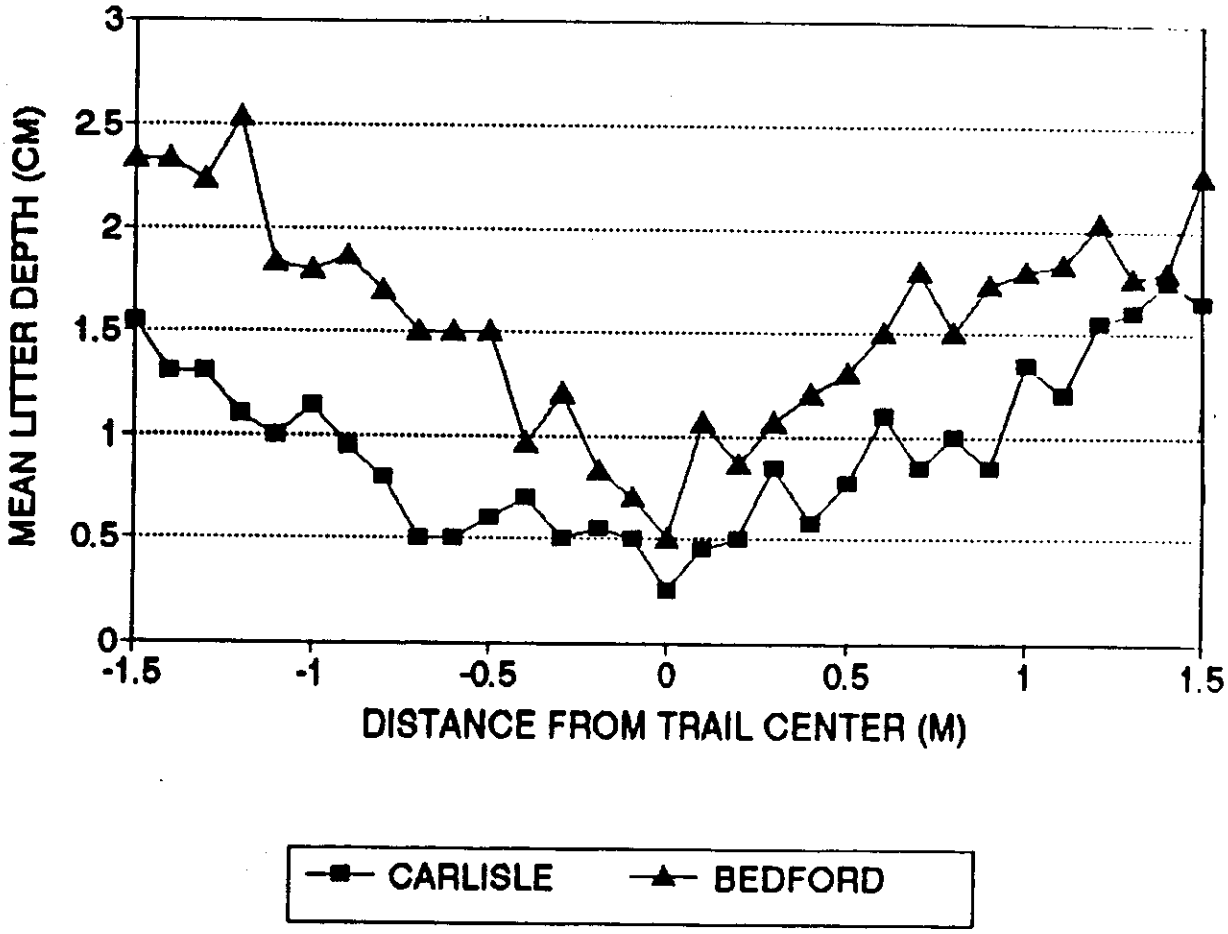
### Forest Litter Depth

The depth of litter on the forest floor increases away from the trail at both Carlisle and Bedford. Averages of measurements along transects perpendicular to the trail indicate that at any given distance from the trail litter is somewhat deeper in Bedford (Fig. 12).

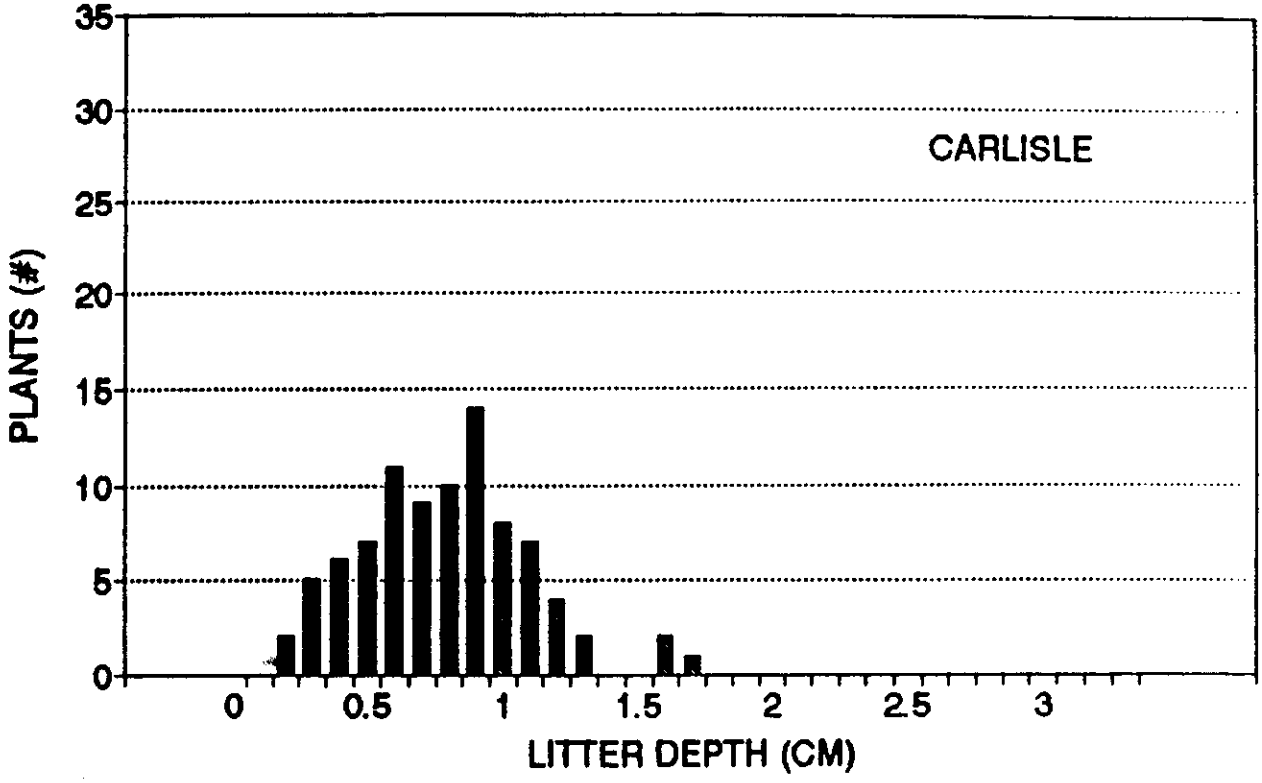
Mean litter depth beneath V. brittoniana plants is similarly less in Carlisle (.8cm) than in Bedford (1.0cm). There is a thin covering of litter in the trail at both sites. In Carlisle litter depth ranges from about .3cm in the trail to 1.6-1.7cm at 1.5m from the trail. In Bedford depth in the trail is about .5cm in the trail and 2.3cm at 1.5m.

The largest number of plants at both sites are found at a litter depth of .9cm (Figs. 13,14). Frequency plots show a roughly normal distribution around this value. While some individuals grow at a litter depth a shallow as 1cm, no plants in Carlisle and few in Bedford occur at a depth greater than 1.7cm. Over 2/3 of the

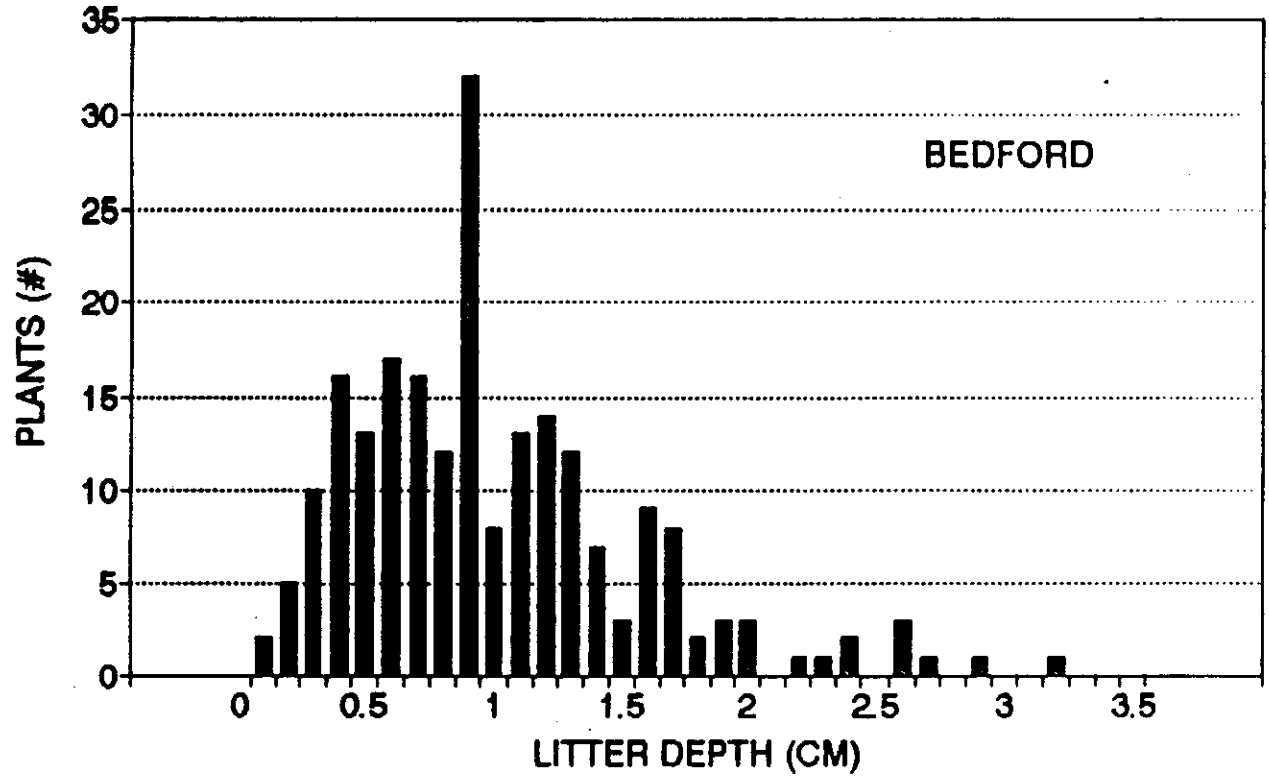
## Figure 12: LITTER DEPTH PROFILE



## Figure 13: DISTRIBUTION OF VIOLA BRITTONIANA AT DIFFERENT LITTER DEPTHS




## Figure 14: DISTRIBUTION OF VIOLA BRITTONIANA AT DIFFERENT LITTER DEPTHS



plants in Carlisle and over 1/2 those in Bedford are found between .6 and 1.2cm.

Frequency plots of plants at different distances from the trail center (Figs. 15,16) show the greatest concentration of V. brittoniana individuals is between .2m and .5m from the center at both sites. This is essentially just beyond the trail edge.

The litter in which plants are growing is generally deeper further from the trail (Figs. 17,18). However, beyond .5m from the trail many of the plants present are in pockets of shallower litter, again in the .6 to 1.2cm range.

**Litter Depth vs. Plant Emergence and Size**

There is no obvious relationship at either site between the depth of litter in which a plant is growing and the date it emerged (Figs. 19,20). Plants at a range of depths emerged during each emergence interval. There is also little relationship between the litter depth in which plants are growing and the height of the plants in May (Figs. 21,22). R=.28 in Carlisle and R=.21 in Bedford. (This comparison was made only for early emerging plants.)

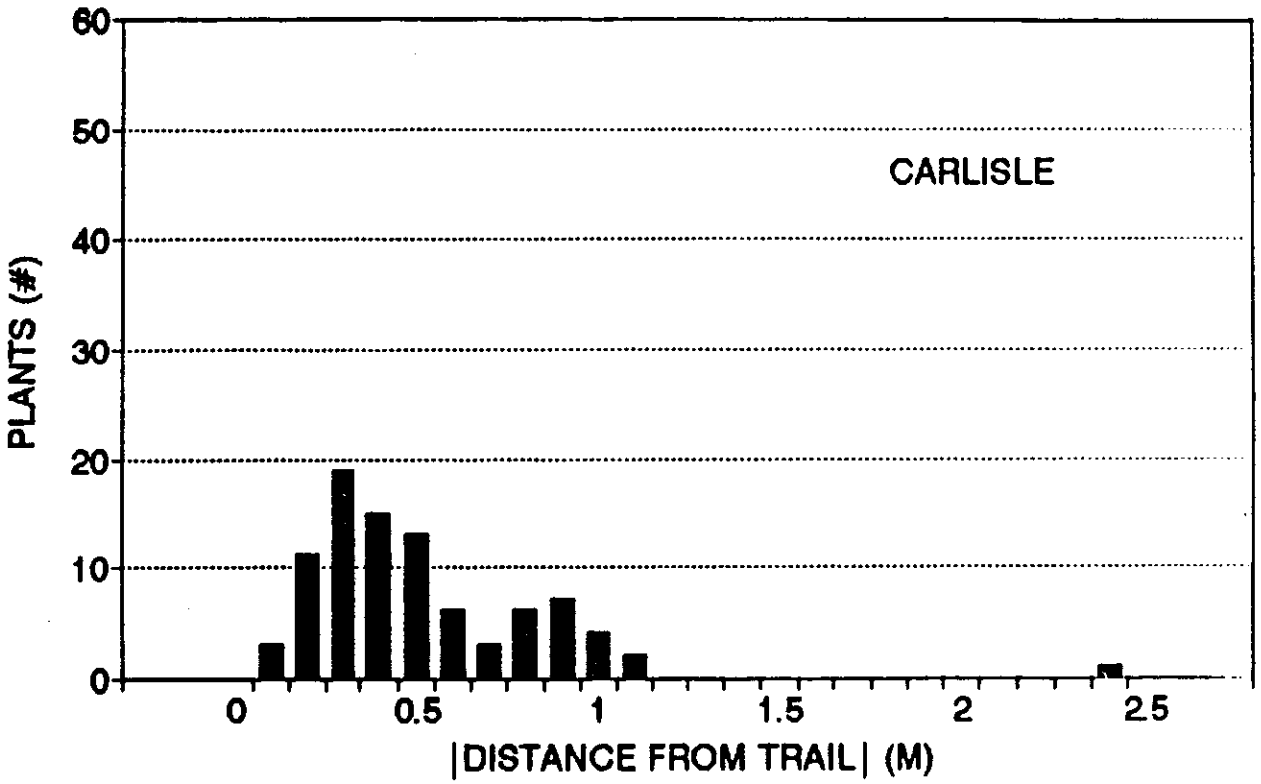
**Litter Depth and Reproduction**

While very few plants produced CH flowers, (one in Carlisle, seven in Bedford) all but one were found in litter depths between .6cm and 1.2cm (Figs. 23,24). No plants in extremely shallow or deep litter flowered. There were no CH fruits produced.

Plants with CL flowers showed a similar pattern (Figs. 25,26). Only plants near the center of the litter depth distribution flowered. The peak in Bedford was very close to the peak of the plant distribution.

In Carlisle CL fruits were produced on plants across the range of litter depths at which flowering occurred (Figs. 27,28). However, in Bedford only flowering plants in litter depths near .9cm produced fruits.

## Figure 15: DISTRIBUTION OF VIOLA BRITTONIANA AROUND TRAIL




## Figure 16: DISTRIBUTION OF VIOLA BRITTONIANA AROUND TRAIL

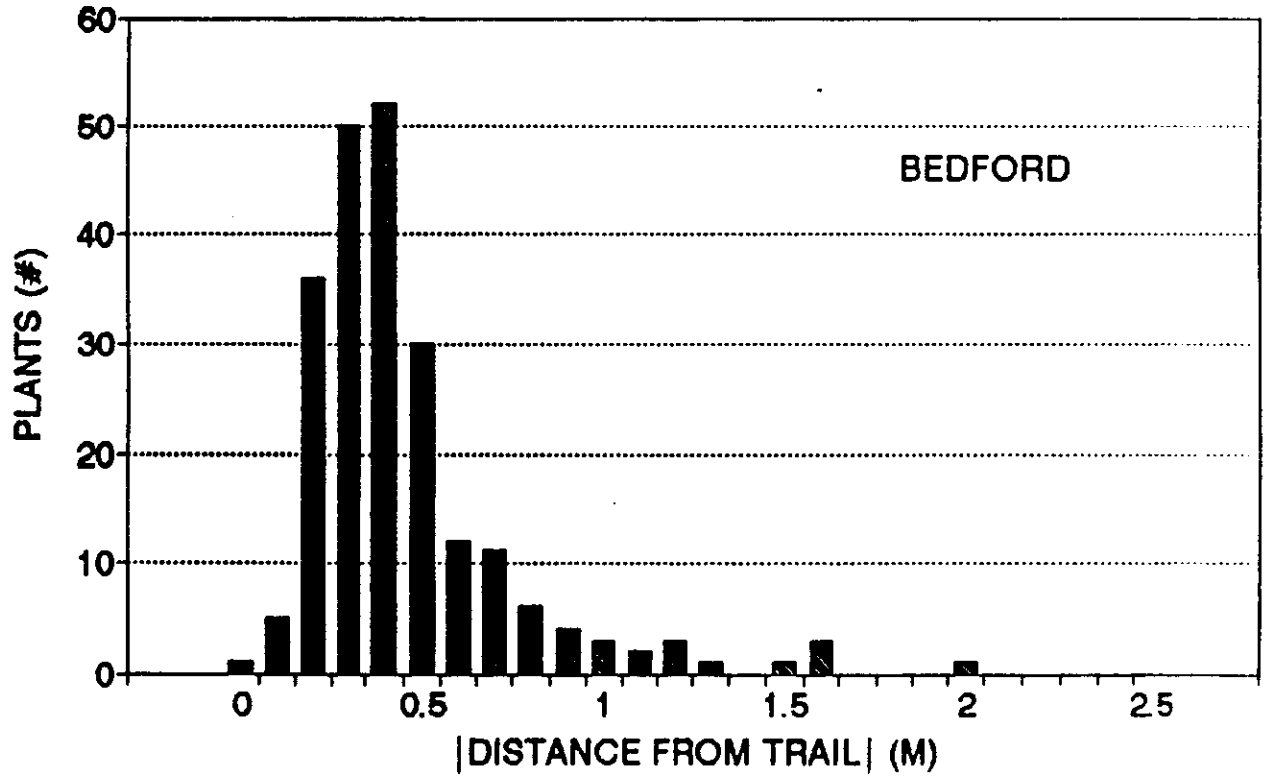


Figure 17: LITTER DEPTH BENEATH VIOLA BRITTONIANA PLANTS VS DISTANCE FROM TRAIL CENTER

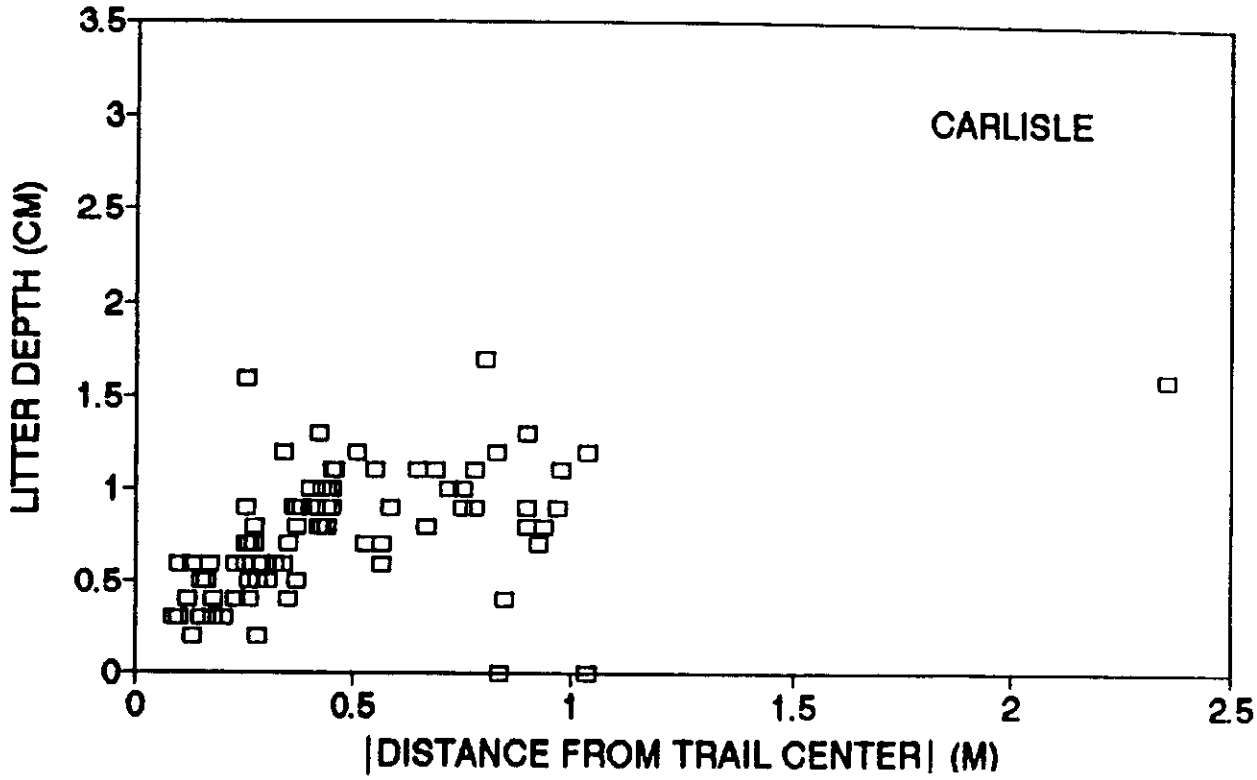
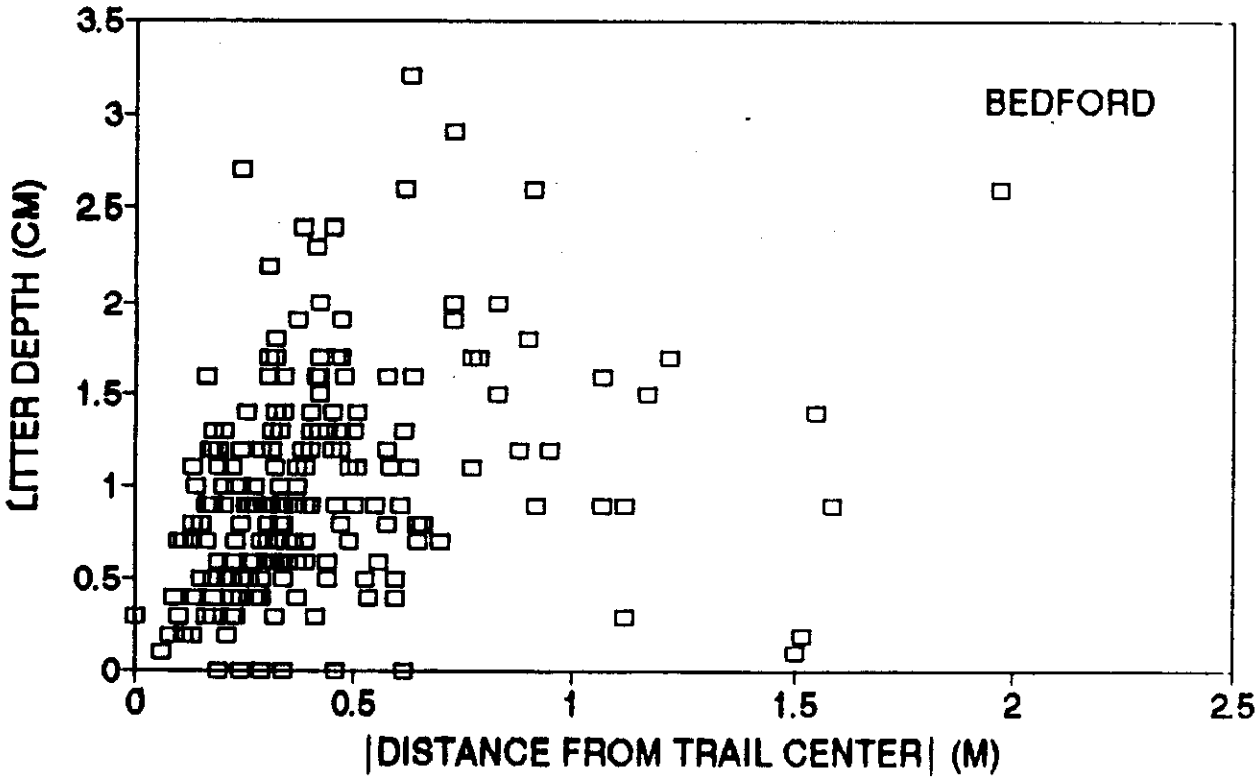
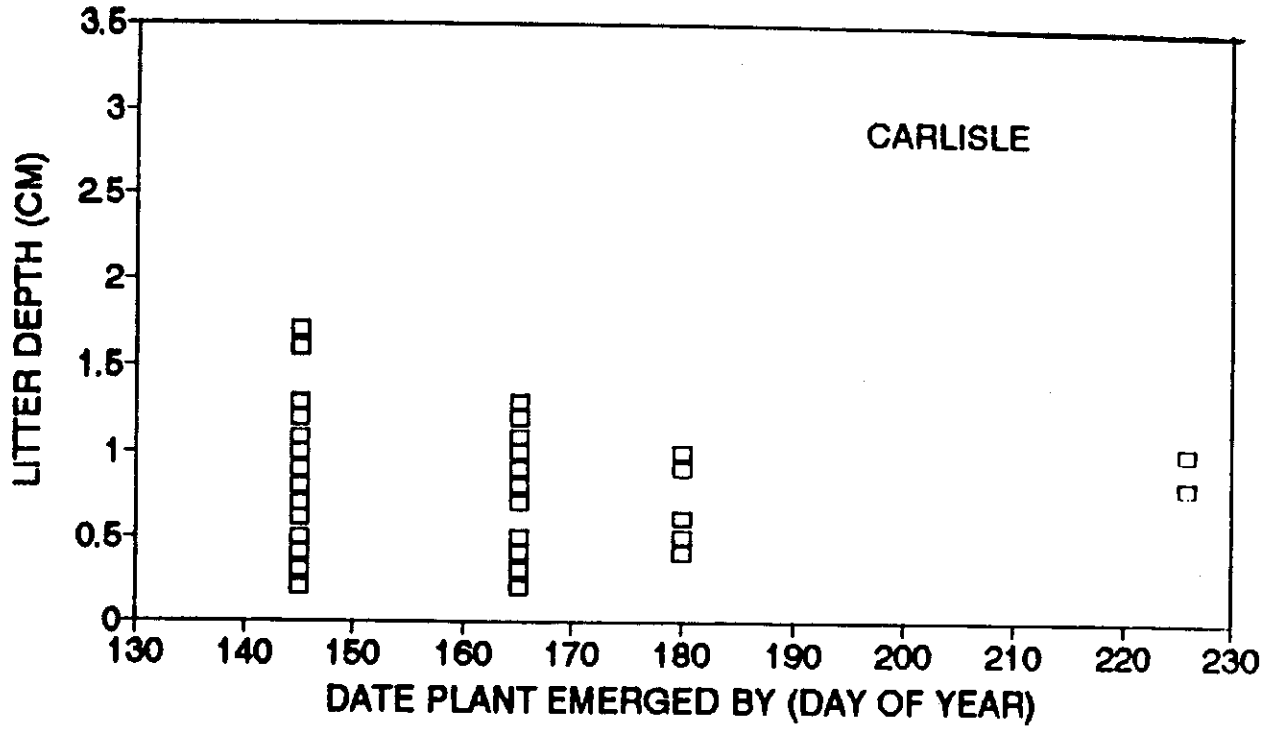


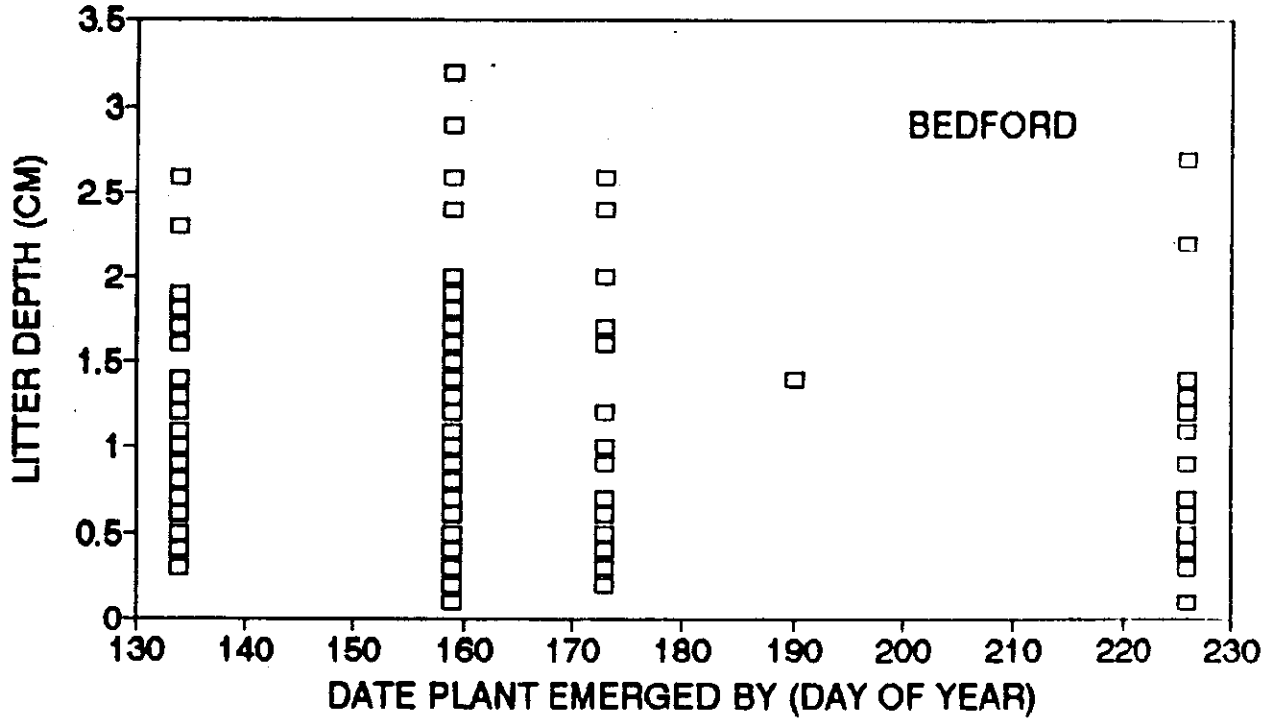

Figure 18: LITTER DEPTH BENEATH VIOLA BRITTONIANA PLANTS VS DISTANCE FROM TRAIL CENTER



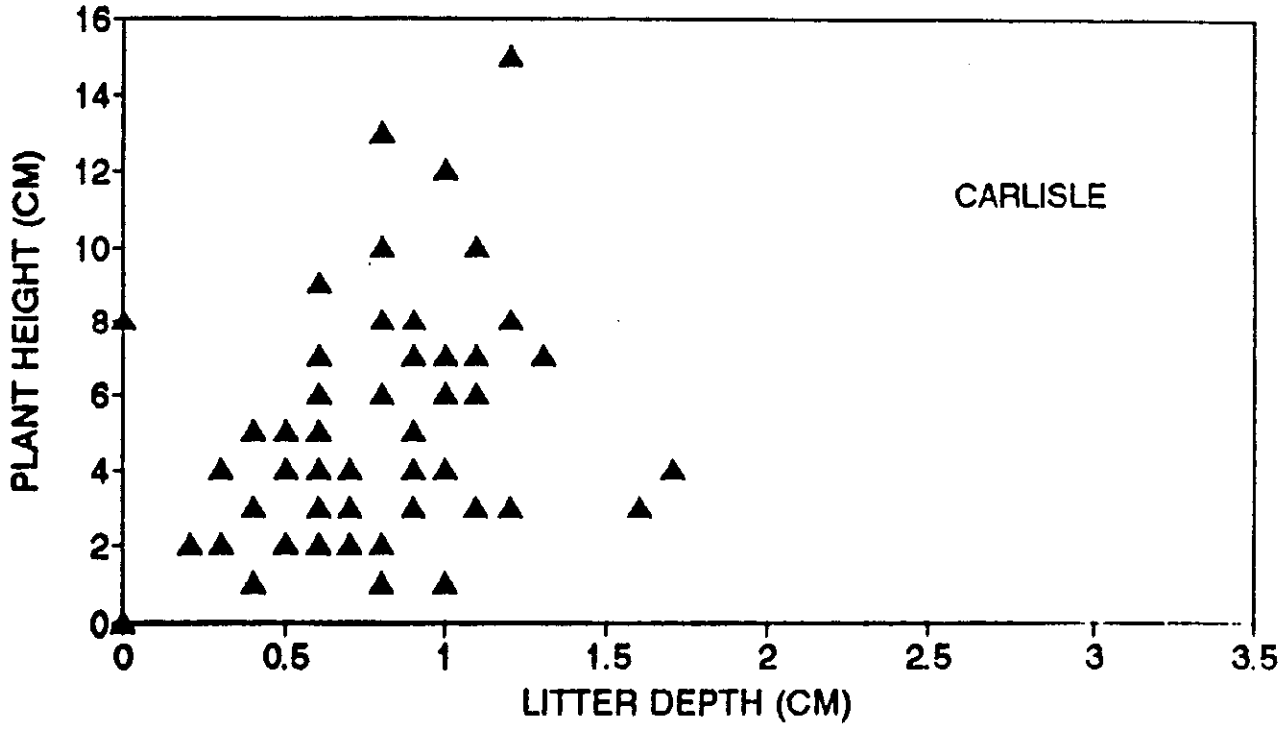
## Figure 19: PLANT EMERGENCE VS LITTER DEPTH



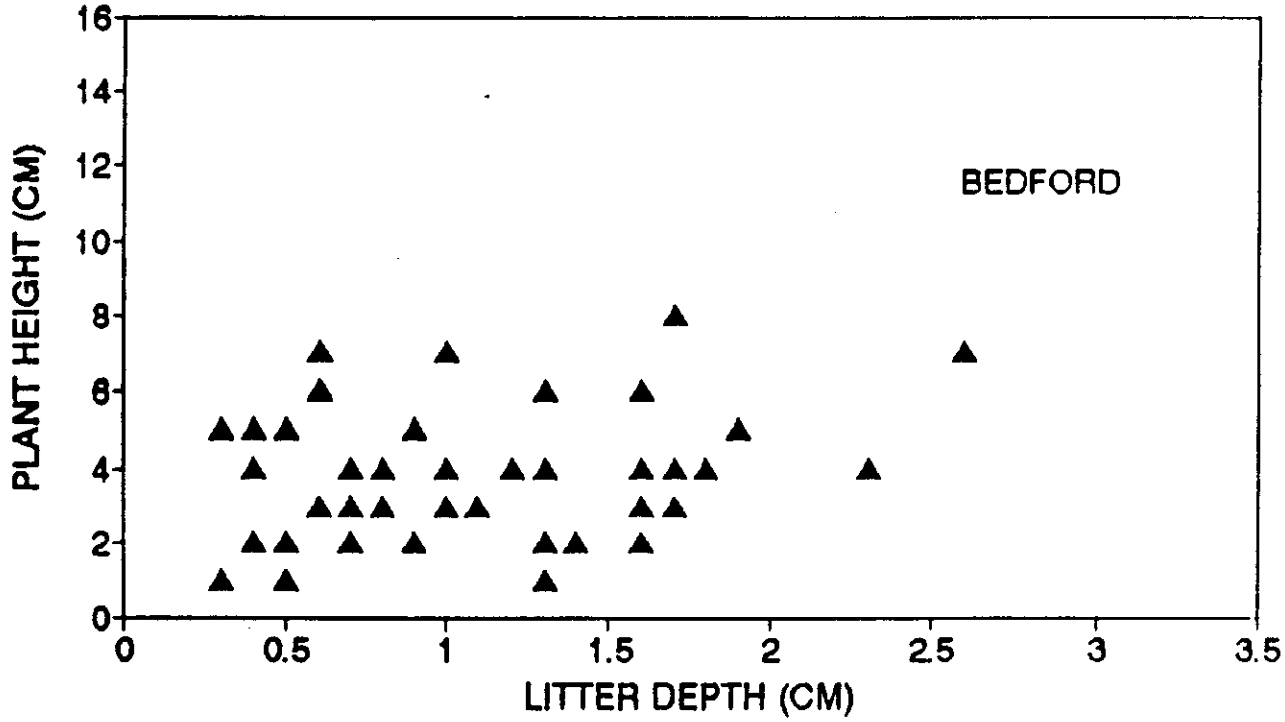

## Figure 20: PLANT EMERGENCE VS LITTER DEPTH



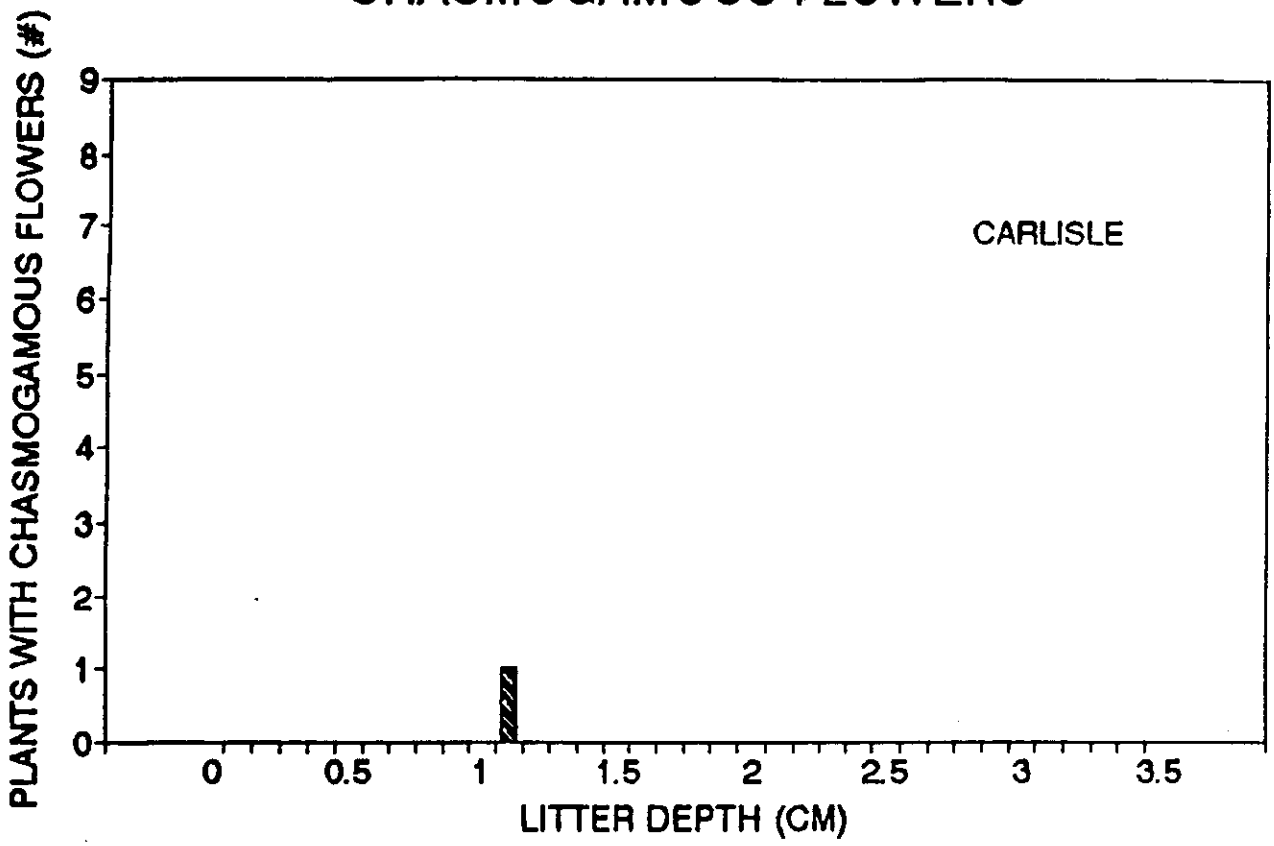
## Figure 21: PLANT HEIGHT VS LITTER DEPTH - EARLY EMERGED PLANTS



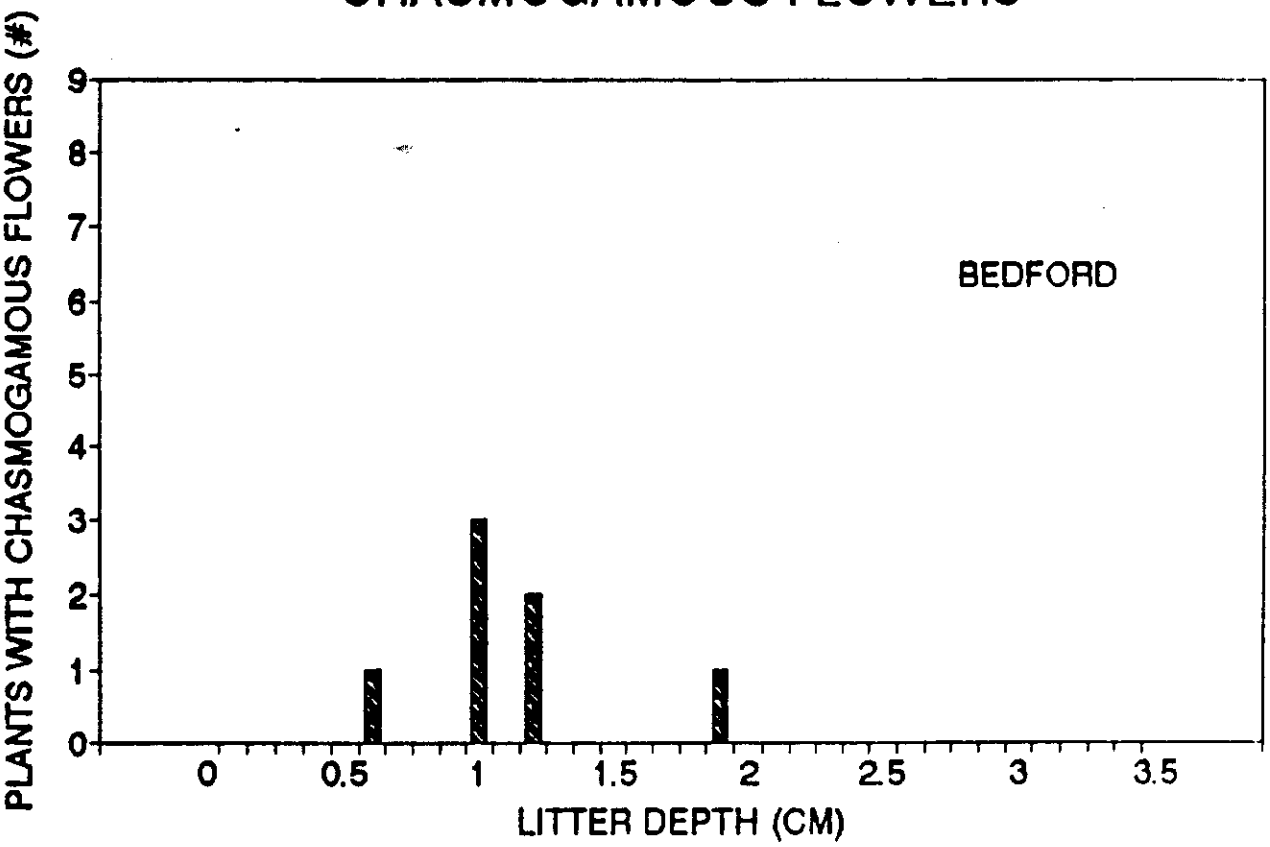

## Figure 22: PLANT HEIGHT VS LITTER DEPTH - EARLY EMERGED PLANTS



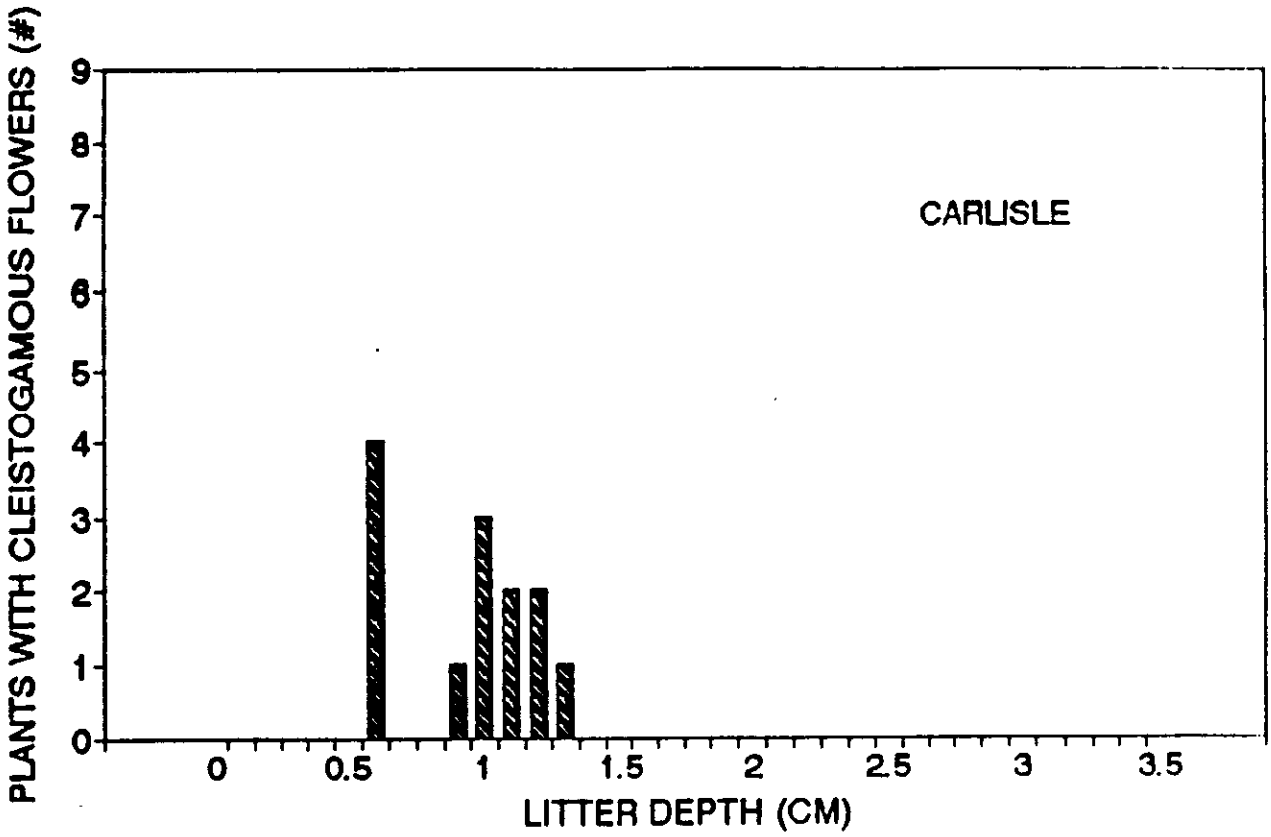
## Figure 23: LITTER DEPTH AND CHASMOGAMOUS FLOWERS



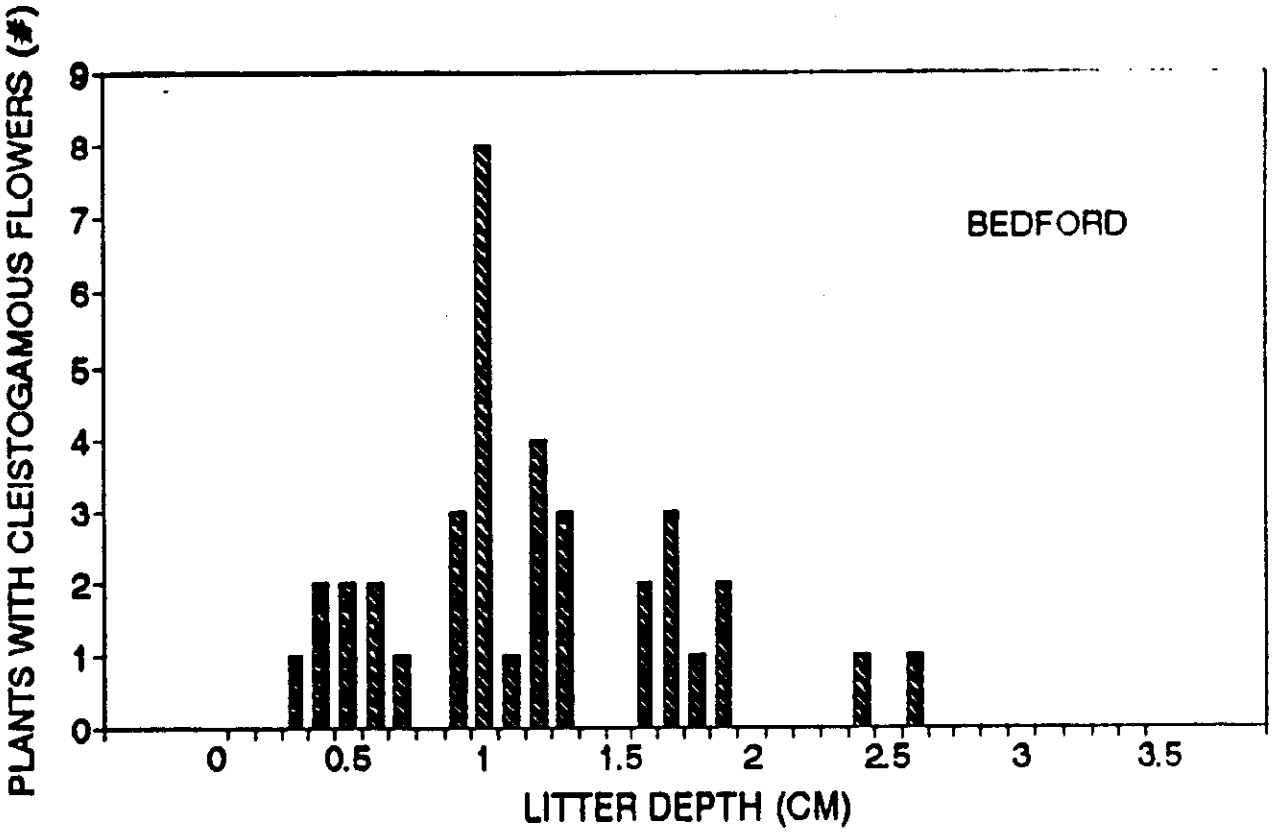

## Figure 24: LITTER DEPTH AND CHASMOGAMOUS FLOWERS



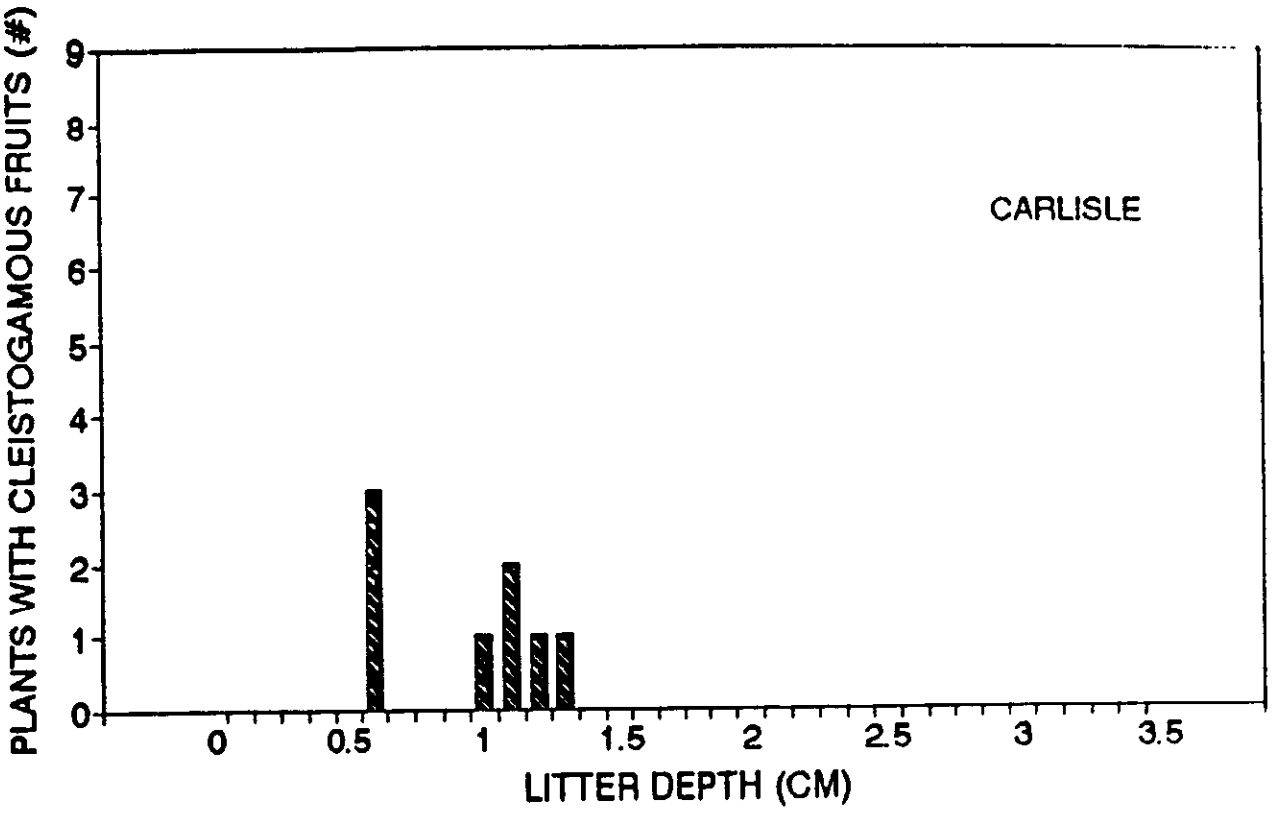
## Figure 25: LITTER DEPTH AND CLEISTOGAMOUS FLOWERS



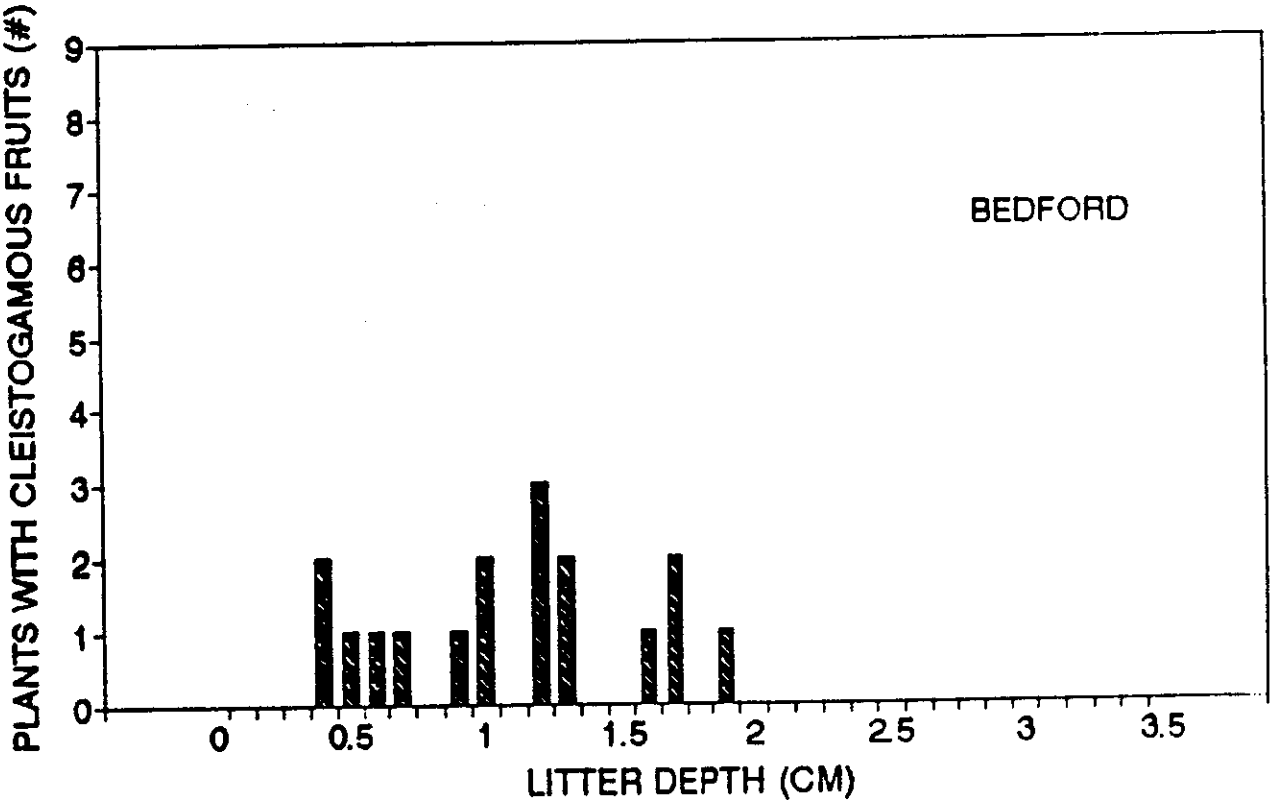

## Figure 26: LITTER DEPTH AND CLEISTOGAMOUS FLOWERS



## Figure 27: LITTER DEPTH AND CLEISTOGAMOUS FRUITS




## Figure 28: LITTER DEPTH AND CLEISTOGAMOUS FRUITS



## Litter Removal

The location of litter removal strips is shown in Figs. 2 & 3. During the process of litter removal one V. brittoniana plant was found beneath the litter in Treatment Plot 1 in Bedford. At the end of the 1990 growing season no new plants had emerged in either the strips where litter depth had been decreased to 1cm or any of the controls.

## Discussion of Litter Depth

Results of these litter depth studies suggest that there is an optimum depth at which V. brittoniana plants grow, flower and fruit, and there is a range of depths beyond which the species is not found. This optimum is .9cm in both Carlisle and Bedford.

Thus plants at these sites are concentrated in shallow litter. The results are consistent with informal observations made at other Britton's violet sites. The Concord population is growing in thin litter. The Concord2 site has little litter - plants are growing in a mowed field. Plants in Milton grow not only along a trail but in a red maple swamp with a thin layer of litter.

The fact that many populations are found immediately adjacent to trails reflects the shallow litter at the edges and suggests that continued use and maintenance by humans and animals may be essential to the populations' survival. Increased soil fertility from animal use of the trail, decreased competition from other plants, or increased light may also be important.

The shallower litter in Carlisle may explain the higher population density at that site.

If V. brittoniana is in fact a species adapted primarily to open areas with little litter it may only be able to survive in forested areas if the litter is shallow. Studies of light intensity and saturation and compensation points would help determine the sun or shade tolerance of the species.

Results were not expected from the litter removal experiment in 1990. Litter removal occurred after most plants in the populations had emerged. The failure of new plants to appear in the areas from which litter was removed suggests one of the following: no viable seeds were present, litter removal was not sufficient to allow seeds present to germinate, or the time at which germination occurs had passed. It is unknown whether viable seeds were present. Litter removal to 1cm led to a litter depth very close to the optimum of .9cm which was found in the litter depth analysis project.

It is currently unknown when seedlings germinate. Newly dispersed seeds might require a chilling period prior to germination, or have a light requirement, or require a specific daylength or temperature. This was designed as a long term project. Litter depth will be adjusted in early April 1991 if necessary and the plots followed through the growing season.

The reason(s) V. brittoniana plants seldom occur at depths far from .9cm may be that at such depths: (1) seeds seldom are present; (2) seeds seldom germinate; or (3) young plants seldom survive.

(1) This can probably be rejected. A few V. brittoniana plants are found in litter deeper than 1.2cm, suggesting some seeds reach the area. While no information is available on seed dispersal of V. brittoniana it does have characteristics of diplochorous species, and seeds of other local Viola species are ant dispersed. If the final location of Britton's violet seeds is determined by ants the depth of litter in which ant nests are found may be important.

(2) V. brittoniana seeds in deep litter may not germinate if they have a light requirement, if predators are more common or if seeds in damp dark litter are subject to decay pathogens. On the other hand seeds in extremely shallow litter or on bare ground may be more easily visible to predators or found and moved by ants.

(3) Mortality of seedlings away from the optimum litter depth might be increased due to nutritional deficiency, increased herbivore action in deep litter, difficulty in reaching sunlight or inability to penetrate the thick layer. The fact that one small plant was found beneath the litter in the removal experiment supports this hypothesis. Drought and herbivore grazing are major causes of seedling death in Viola (Newell et al. 1981). Culver & Beattie (1980) showed recruitment into a population was more a function of germination site than number of seeds.

The fact that plants near the optimum had a much greater chance of flowering and fruiting suggests that once plants become established near this depth they have the additional advantage of greater reproductive capacity. This could be the result of increased vigor, possibly due to better resource availability, or the decrease in predators which consume reproductive parts or pathogens. The concentration of fruit production in plants near the optimum litter depth is unlikely to be due to difference in pollinator availability since both CH and CL flowering display the same pattern.

The lack of relationship between the date a plant emerges and depth of litter in which it is growing suggests, if temperature is the cue to emergence, any temperature variation with litter depth may be small.

The above discussion assumes the relative depth of litter is the same from year to year. This might not be the case. Further research on litter depth might include formal investigation of whether the same optimum occurs at other V. brittoniana sites and whether the depth beneath a given plant varies from year to year.

Litter depth may not be the only factor limiting suitable sites for establishment, growth and reproduction of Britton's violet. The high proportion of plants growing in an open field which produced CH flowers suggests that light may play an important role in level of flowering, and could affect the balance of CH and CL flowers.

**Ground Water Level**

The trail in Carlisle is roughly level and plants furthest from the trail and parallel to it are at the lowest elevation. During the spring of 1989 the water table at the Carlisle site came within 12cm of the Britton's violet individuals at the lowest elevation but complete inundation did not occur. From April 17 to May 26 the water table varied in a rough sinusoid with a period of 30 days and a peak to peak variation of 36cm.

In 1990 there was again no inundation in Carlisle, nor did inundation occur in Bedford. However at Bedford one end of the trail is somewhat lower than the other. May 26 was preceded by a week of heavy rain and the highest water levels of the season were observed at that time. At Bedford the ground was saturated on the portion of the site from meter 10 onward. The Concord site never flooded except possibly by runoff after a heavy storm.

**Search for Additional Populations**

About 50% of the upper floodplain of the Concord River was searched in 1989 - in the portion of Carlisle running from Billerica to Route 225.

While no new populations were found in 1989 or 1990 publicity led to heightened public awareness of Britton's violet. A newspaper article (press release) (Fig. 29) and flyer described the species, its importance and where to search. A field workshop was held during the CH flowering season. The field workshop during the CH flowering season attracted seven people, most of whom have some expertise and a long standing interest in plant conservation. A number of other individuals who had learned of the project through the flyer, newspaper or word of mouth, indicated they were searching for populations.

# Figure 29: PRESS RELEASE

H E L P  F I N D  A  R A R E  V I O L E T

ATTEND MONDAY WORKSHOP

Britton's Violet (Viola brittoniana Pollard) is a rare and threatened plant in Massachusetts. It grows in river floodplains along the east coast of the United States. This purple-flowered violet was very common here one hundred years ago, but much of its habitat has now been altered for agriculture or development.

Only five populations of Britton's Violet are now known in Massachusetts. Four are along the Concord River. One of these is in Carlisle. Most populations are found along woodland trails through the floodplain.

Dr. Sally Zielinski, a Carlisle botanist, has begun a long term research project which will involve both the study of known populations and a search for additional ones. The study will include following the size and reproduction of populations, assessing factors which may be causing their decline, and developing a management plan to help protect them from likely extinction.

The project is funded by a grant from the Massachusetts Natural Heritage and Endangered Species Program and sponsored by the Carlisle Conservation Commission. (However, no town funds are involved.)

There are probably many undiscovered sites along rivers in Massachusetts, including in Carlisle. You can help find them by walking the floodplain along the Concord, Merrimac and Assabet Rivers in Carlisle, Concord, Bedford, Billerica, Acton and other local towns.

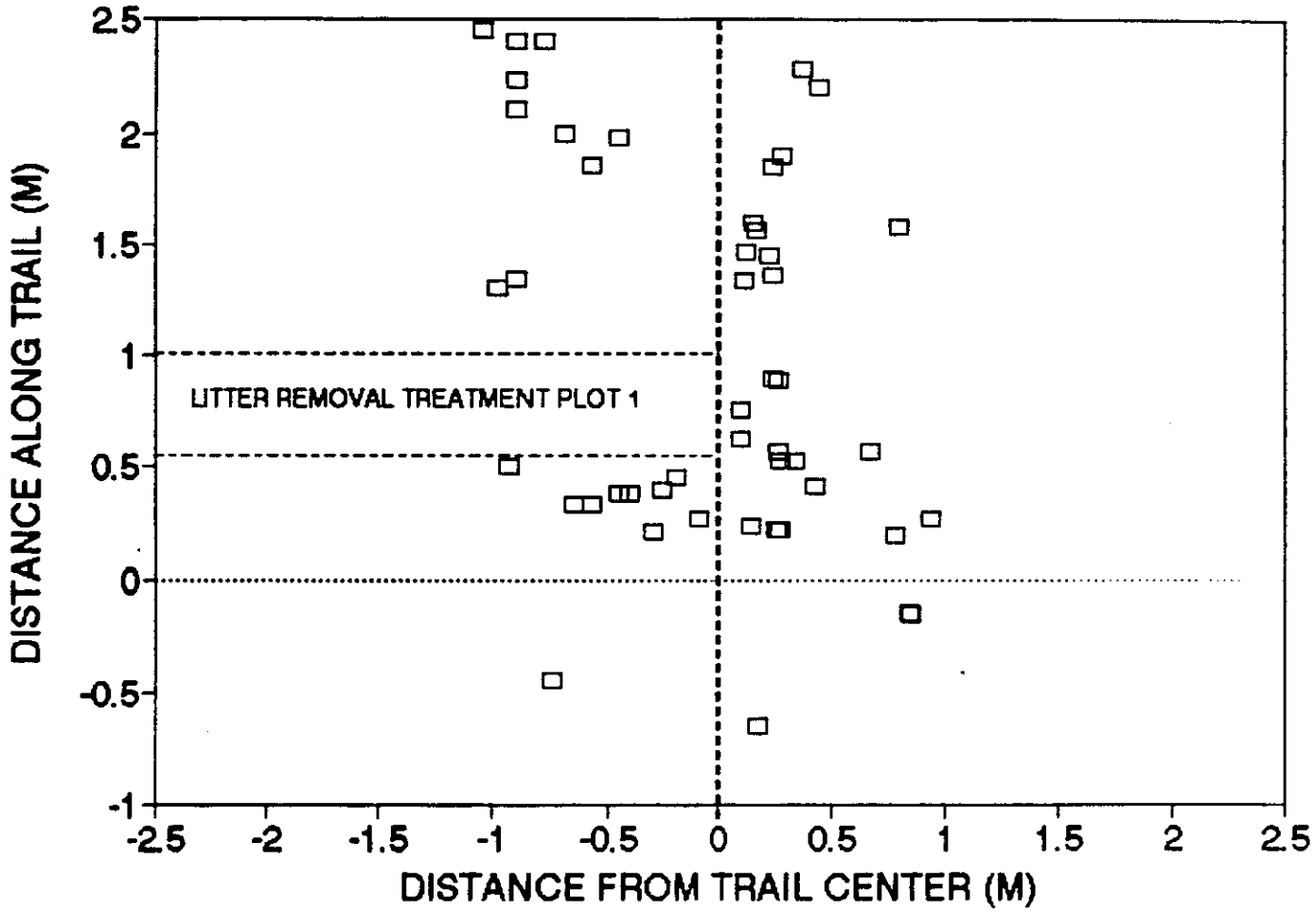
Britton's differs from most violets because its leaves do not generally have the usual heart shape, but rather resemble a foot with toes. The only other violet in our area with this leaf shape is the Bird's Foot Violet (Viola pedata), which mostly grows in dry open areas. The time to search is now while the plants are in flower, and throughout summer and early fall, looking for the distinctive leaves.

There will be an evening field workshop next Monday, June 4. If you would like to attend and help in the search call: Sally Zielinski at 369-6958 or the Conservation Commission at 369-0336.

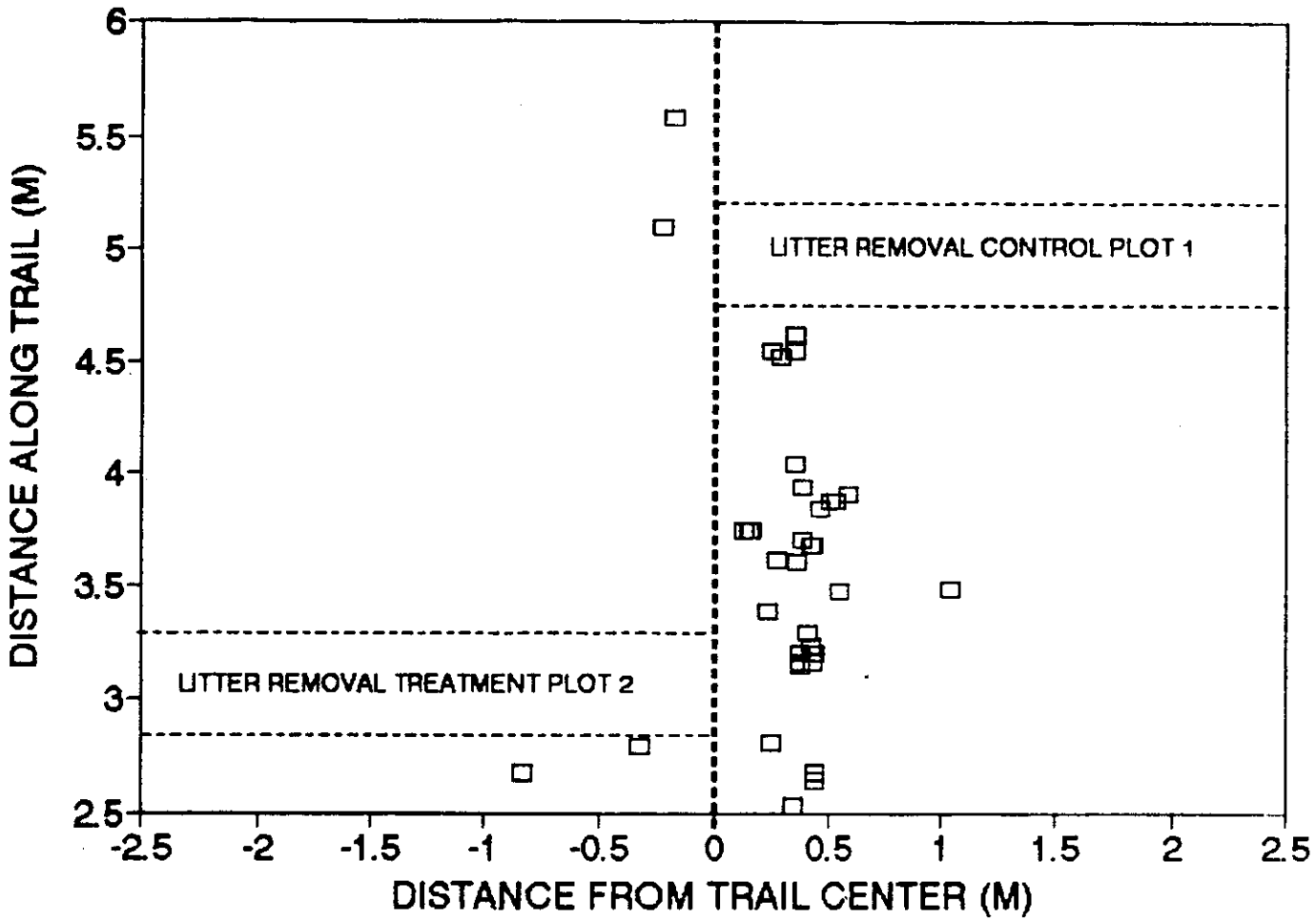
**PRESS RELEASE**
Carlisle Conservation Commission
May 28, 1990

Thus a group of about 15 people in the area are currently knowledgeable about Britton's Violet and actively looking for new populations along the floodplain of the Concord River in sections of Carlisle, Bedford and Concord.

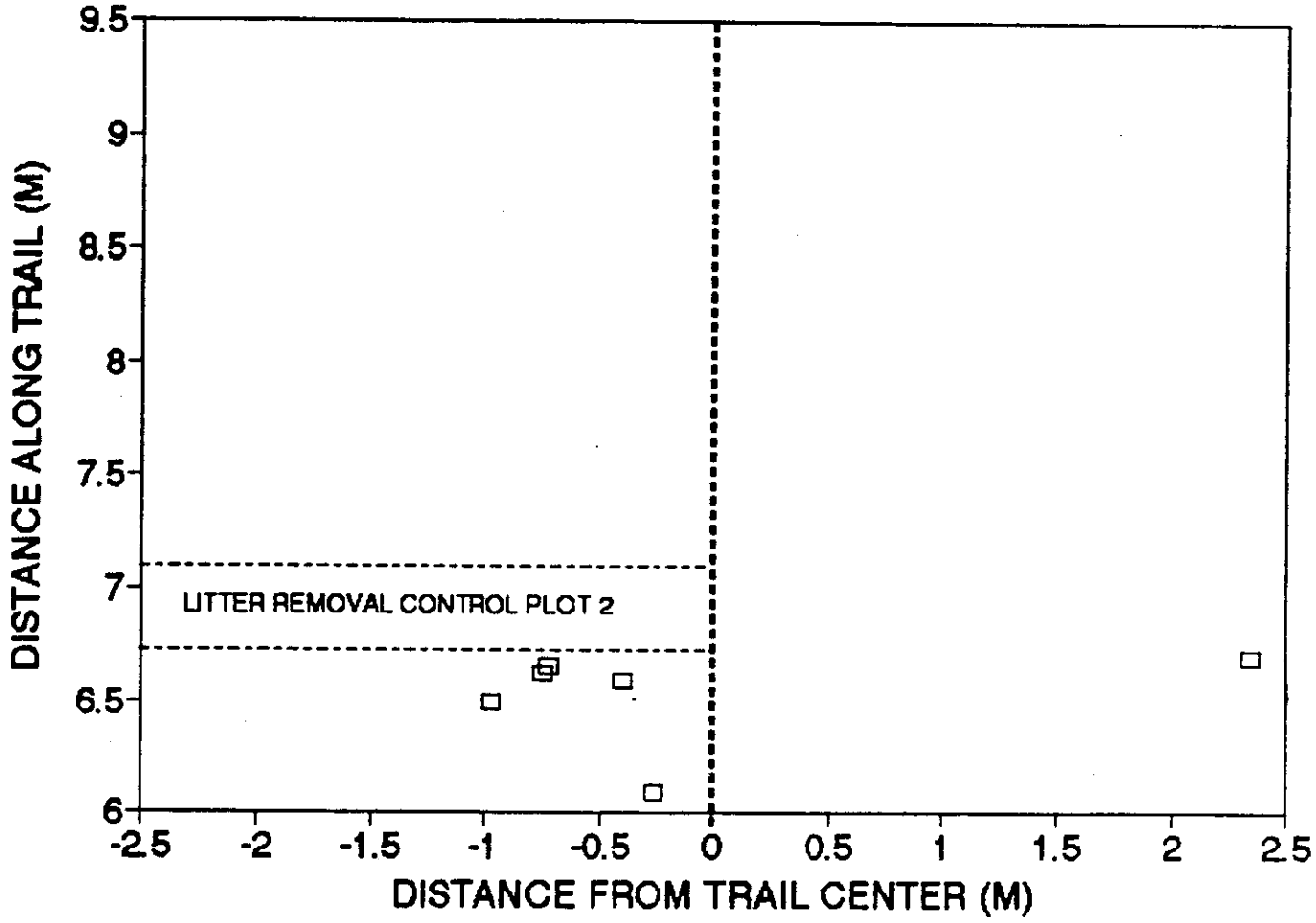
# Figure 2: POPULATION MAP - CARLISLE



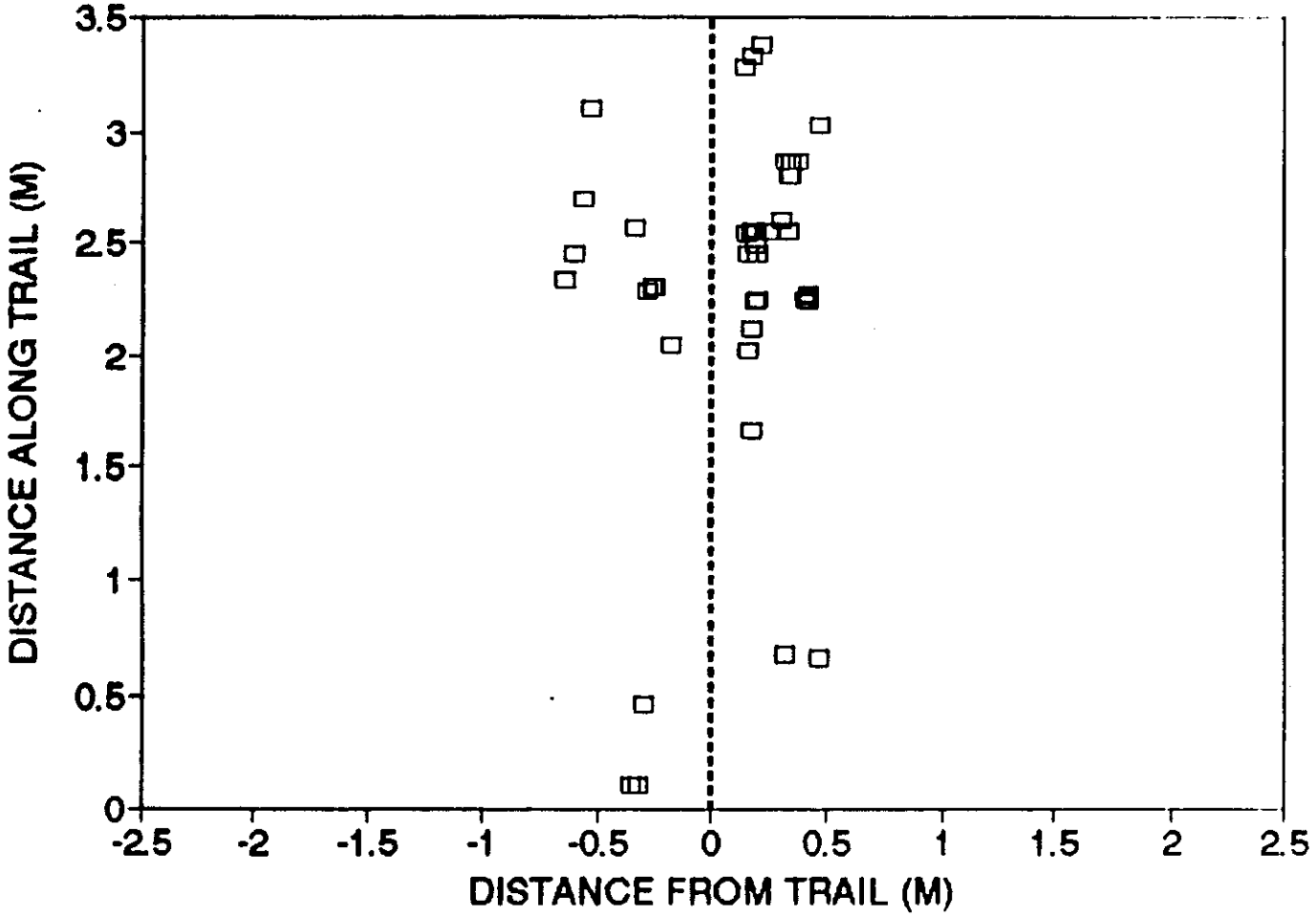
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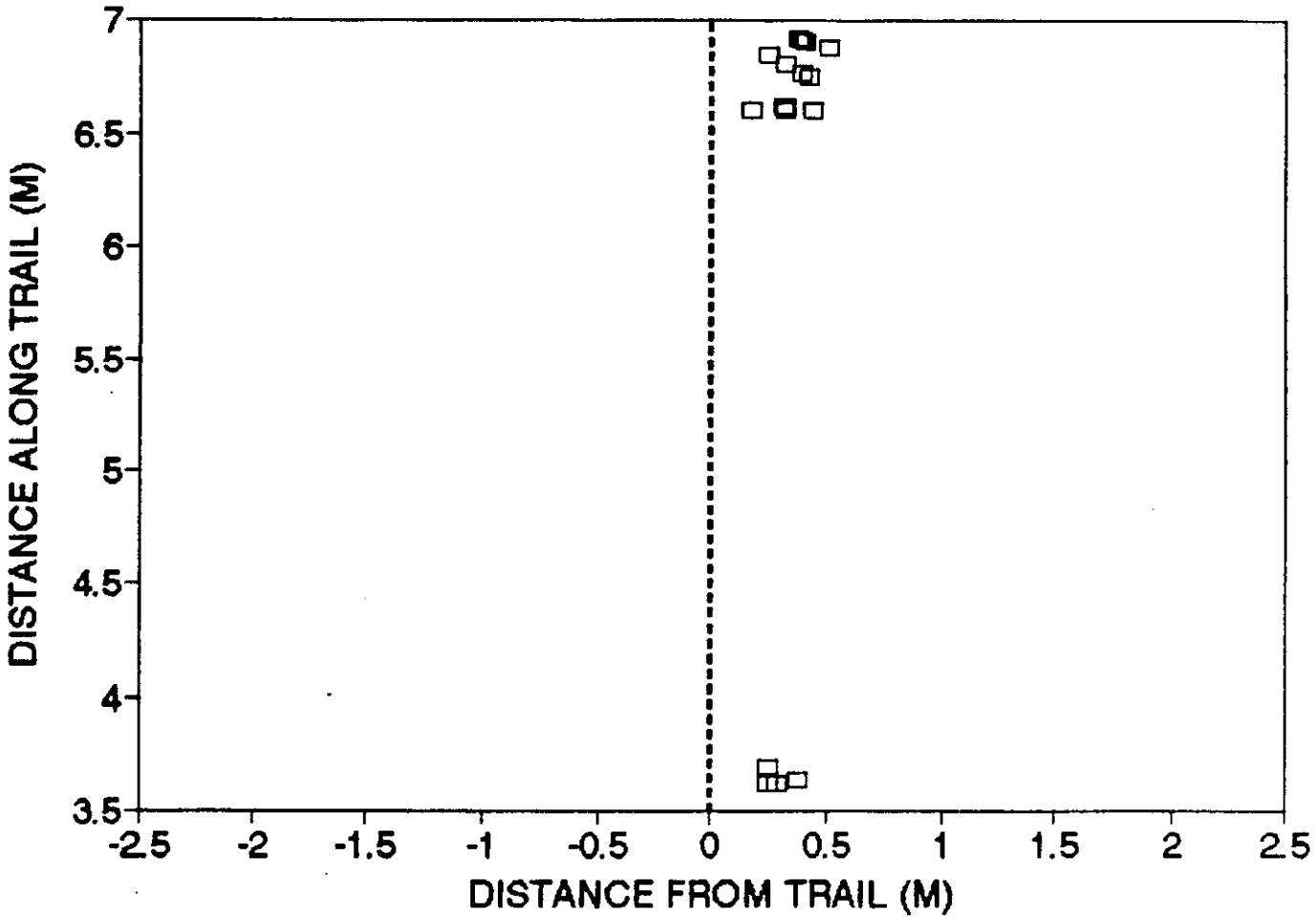
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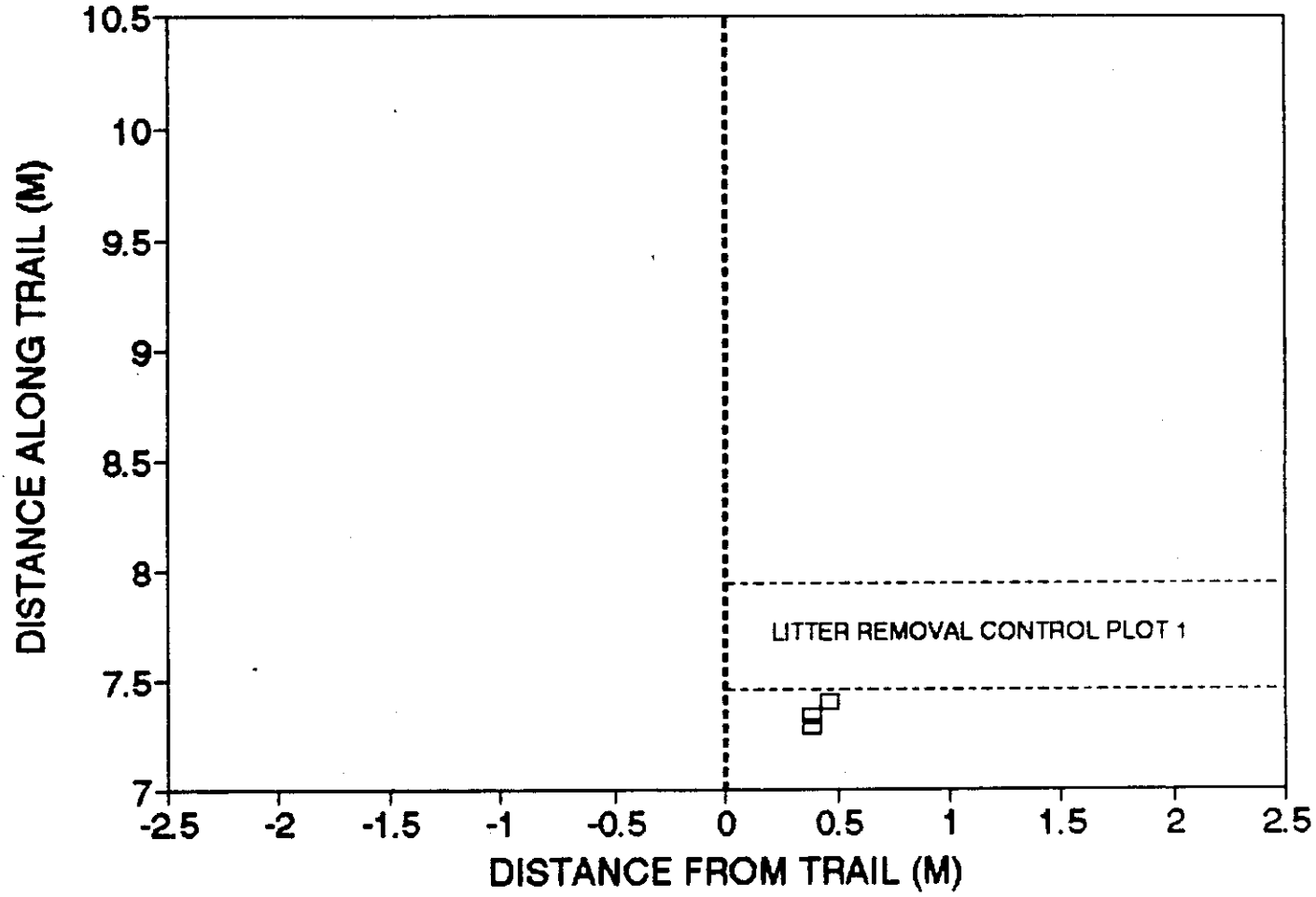
# Figure 3: POPULATION MAP - BEDFORD



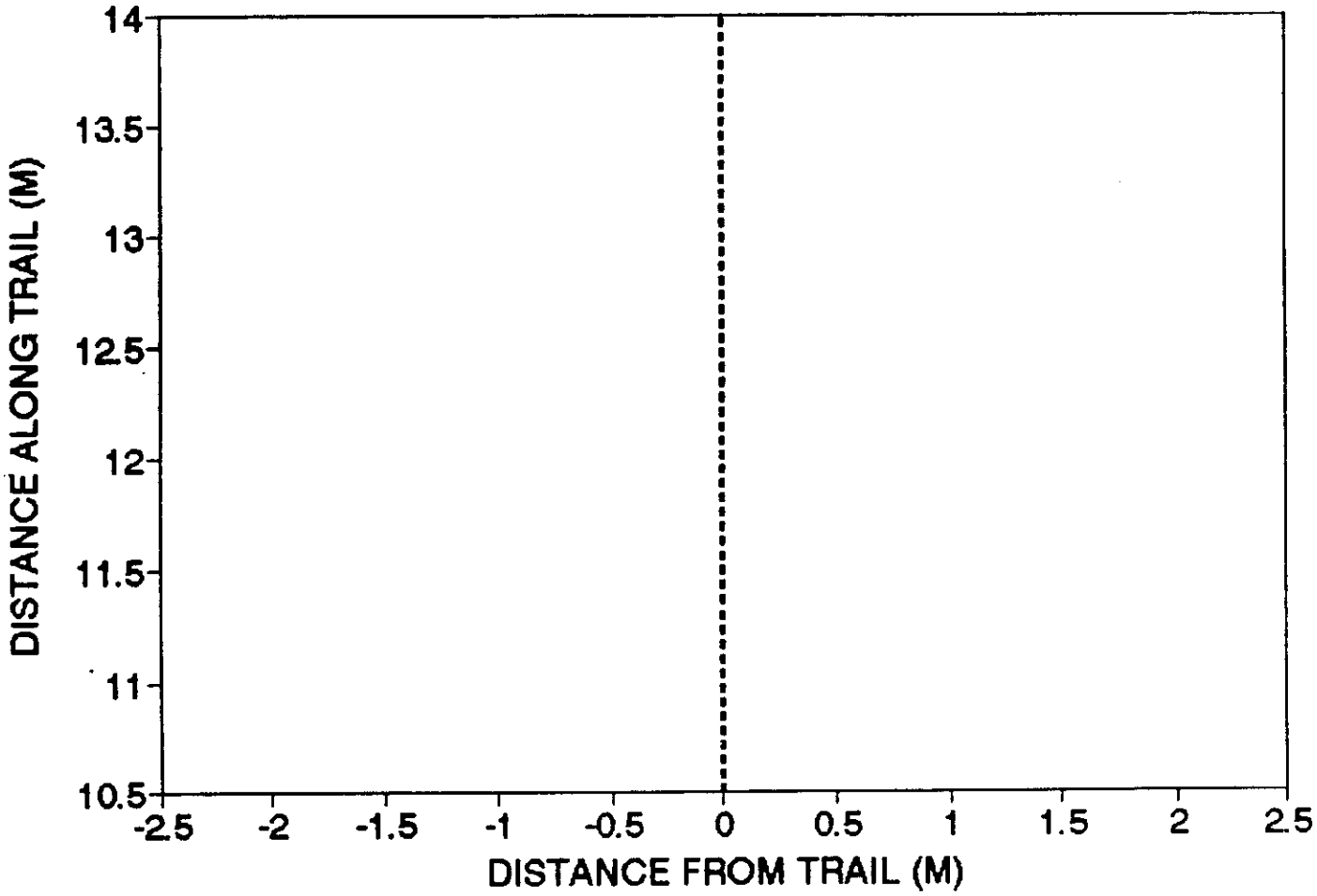
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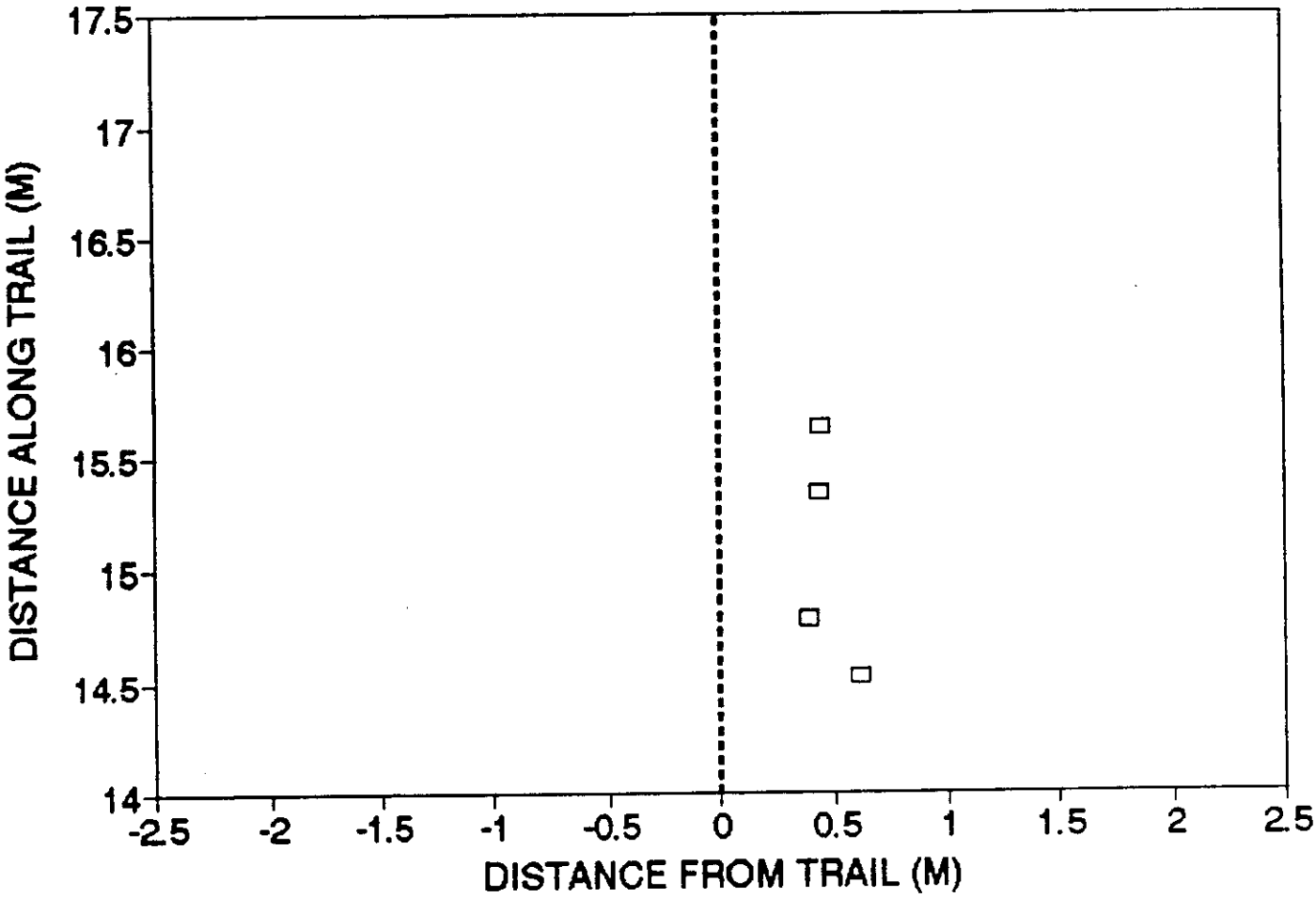
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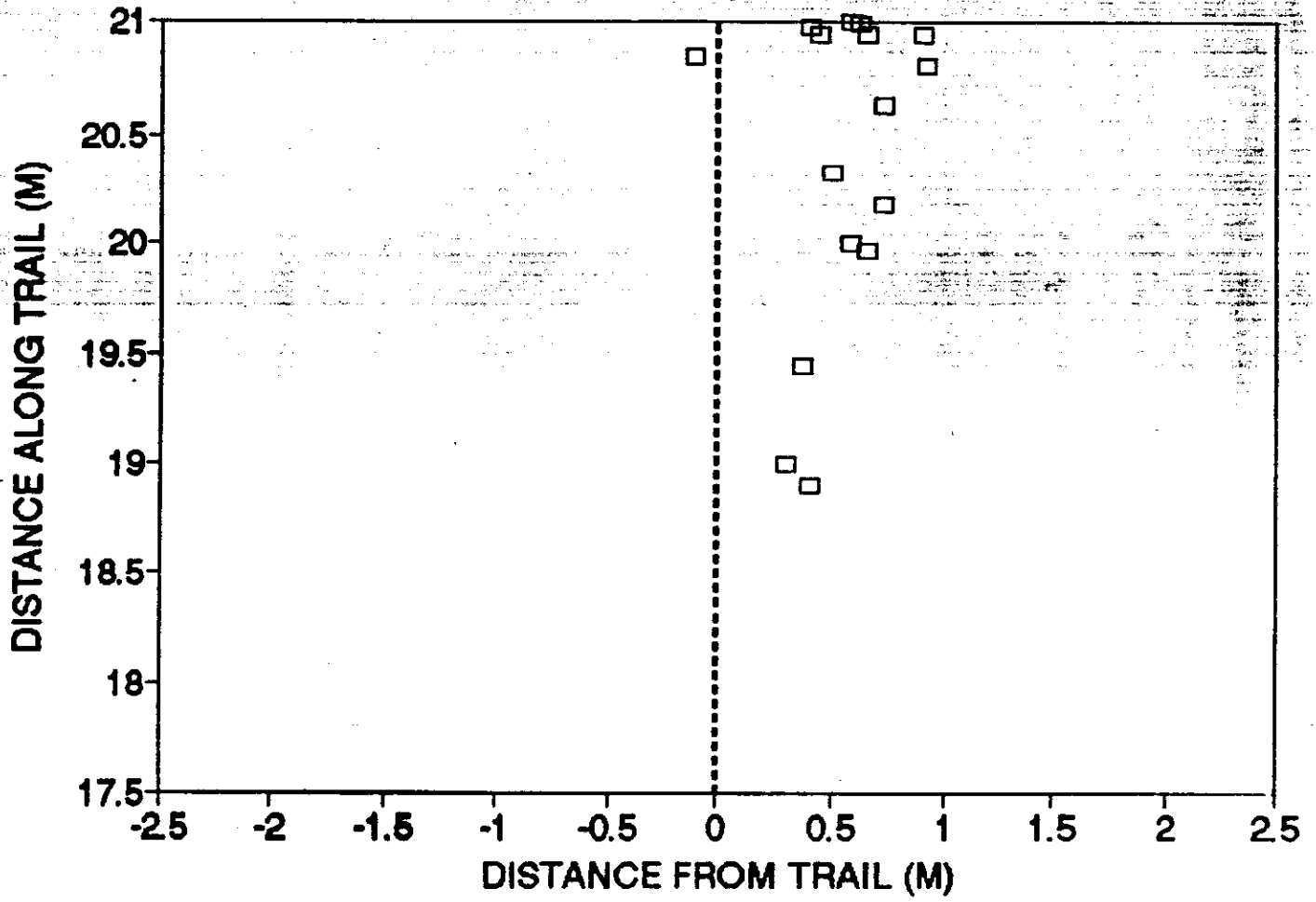
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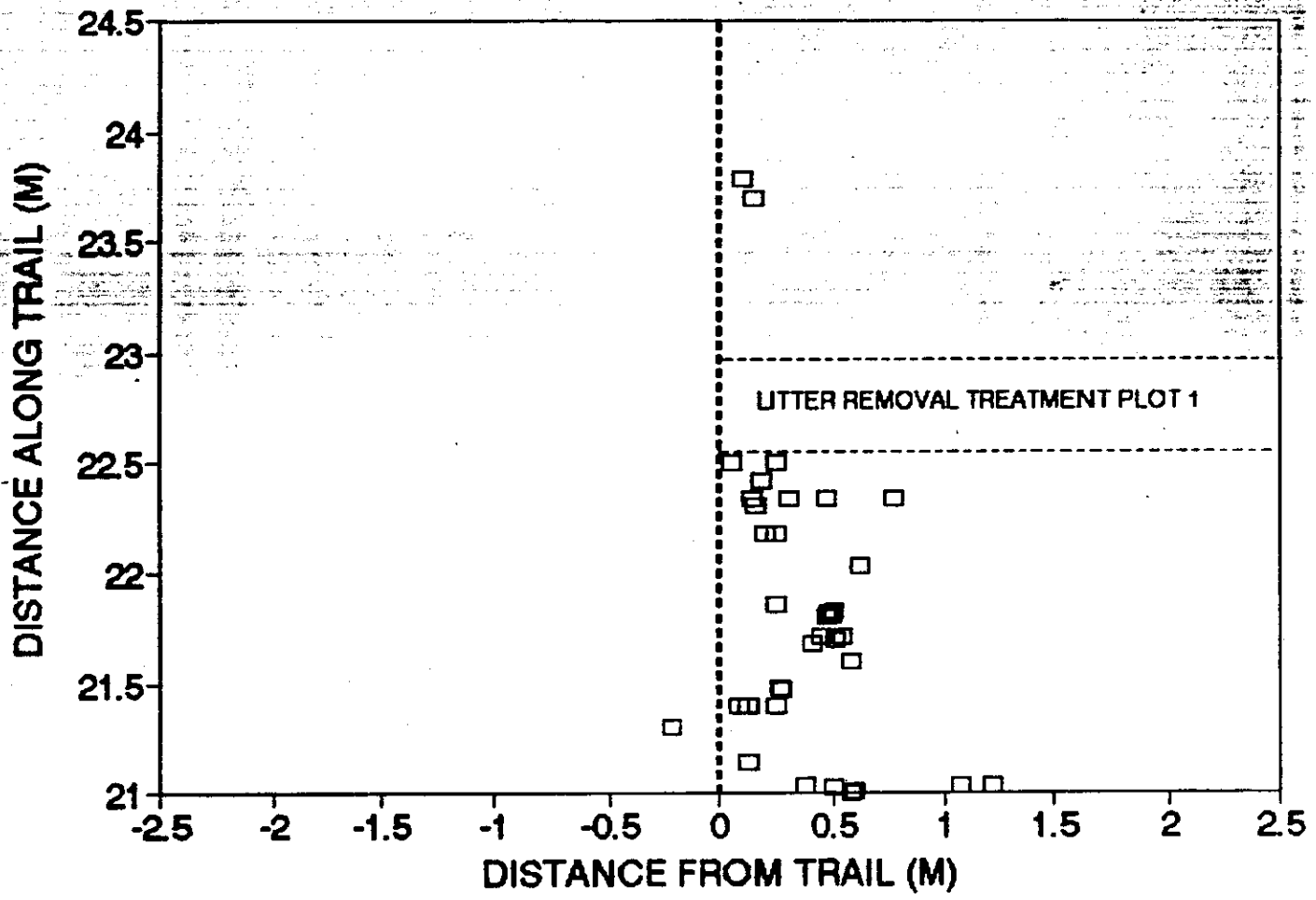
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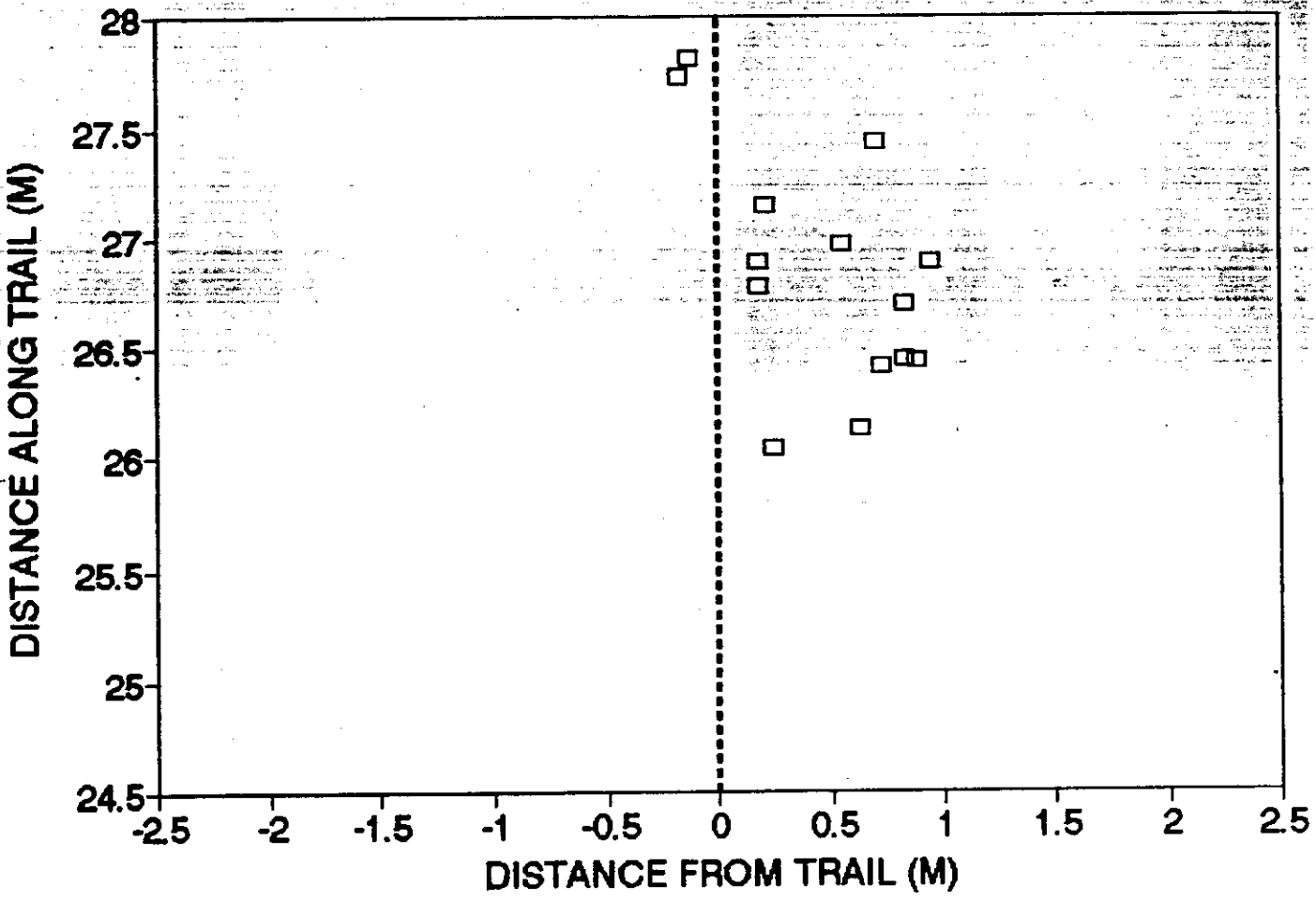
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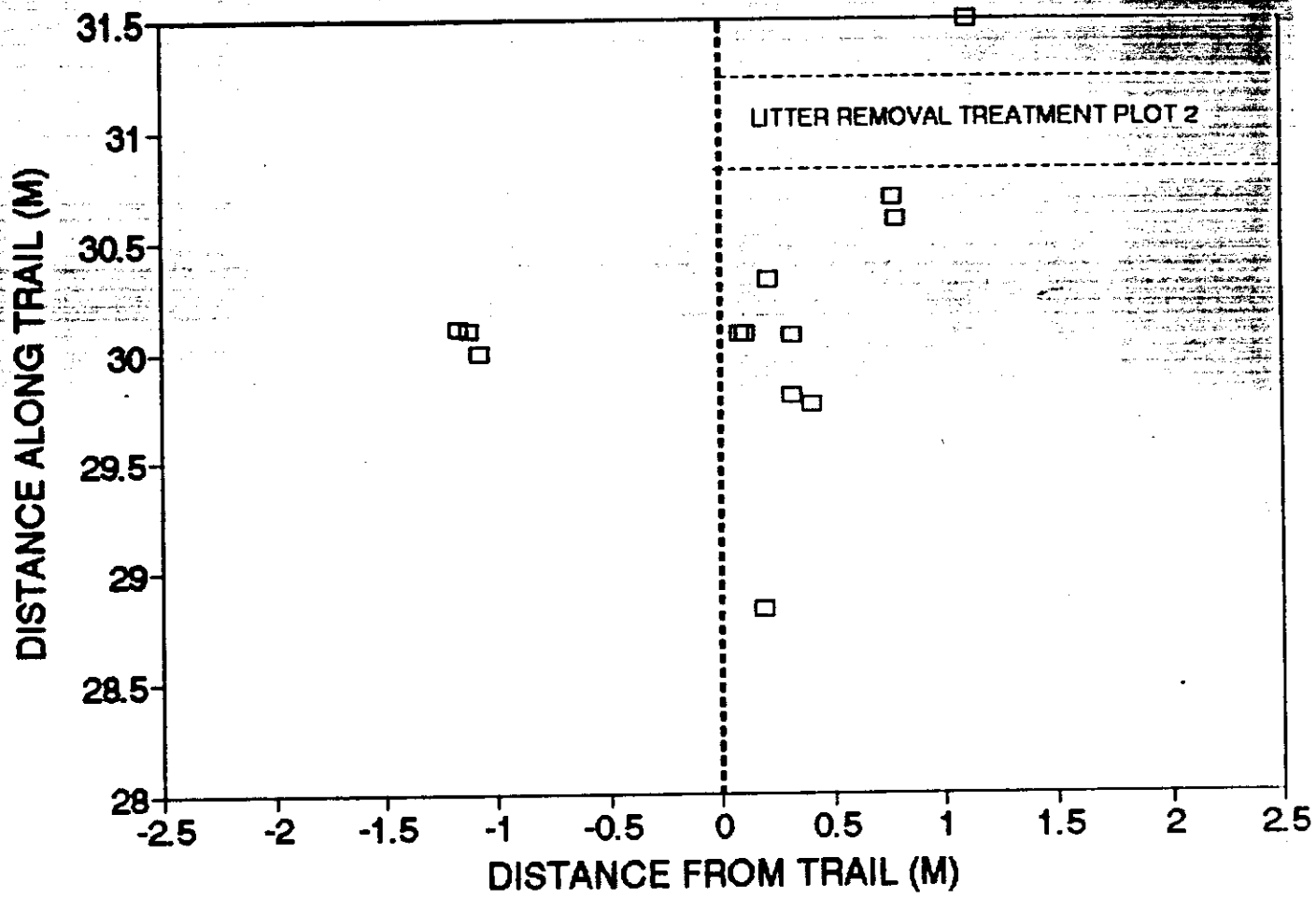
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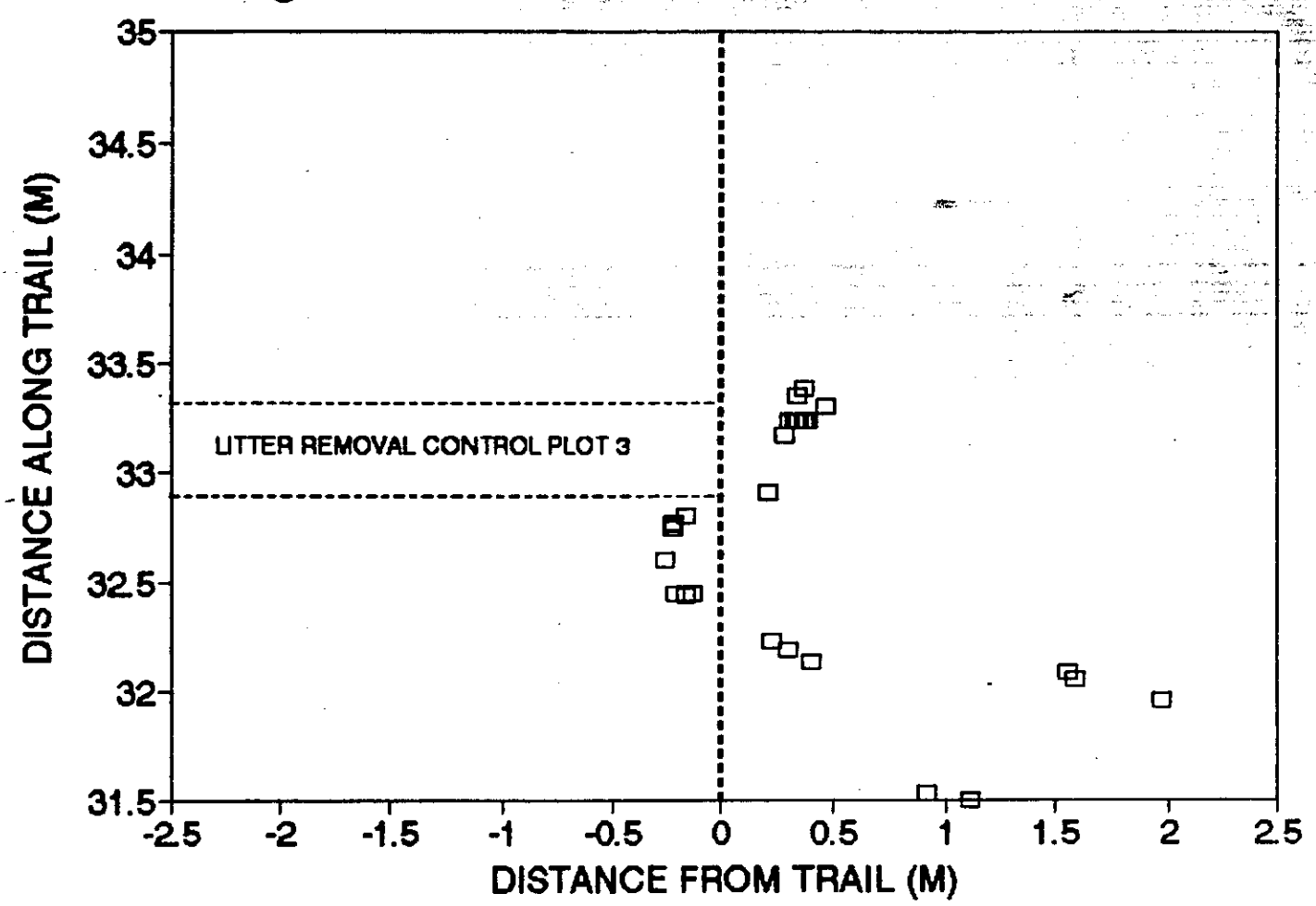
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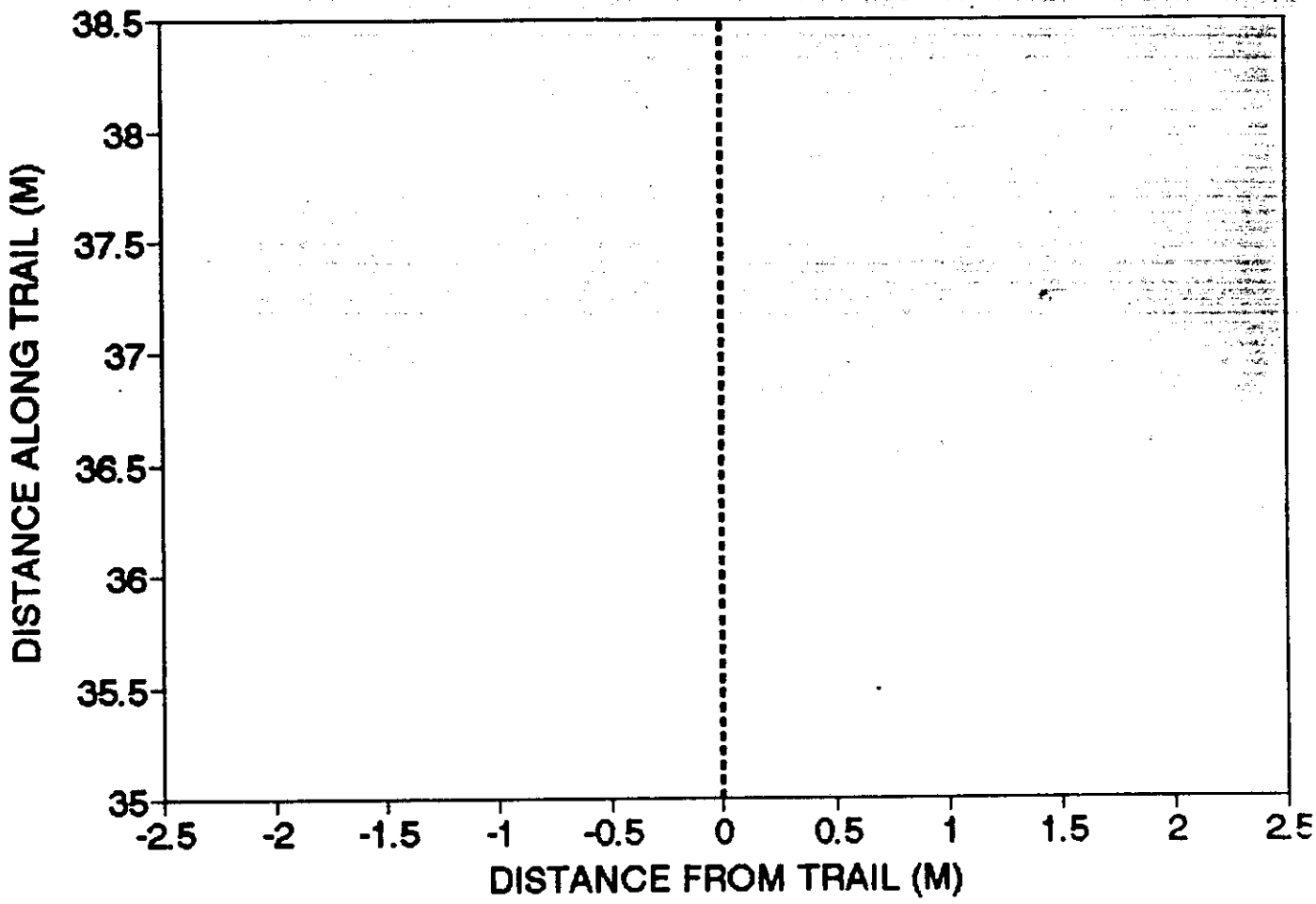
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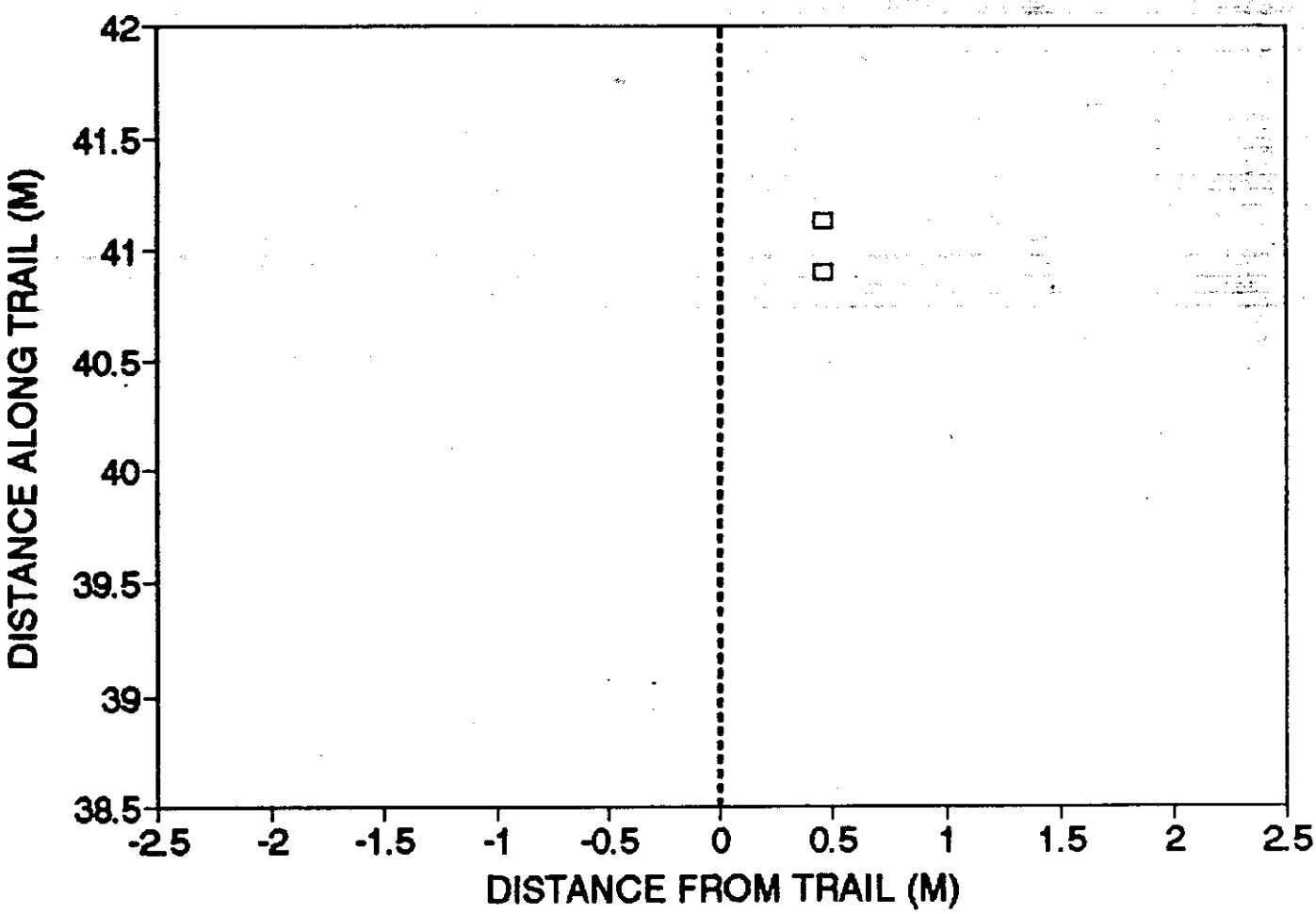
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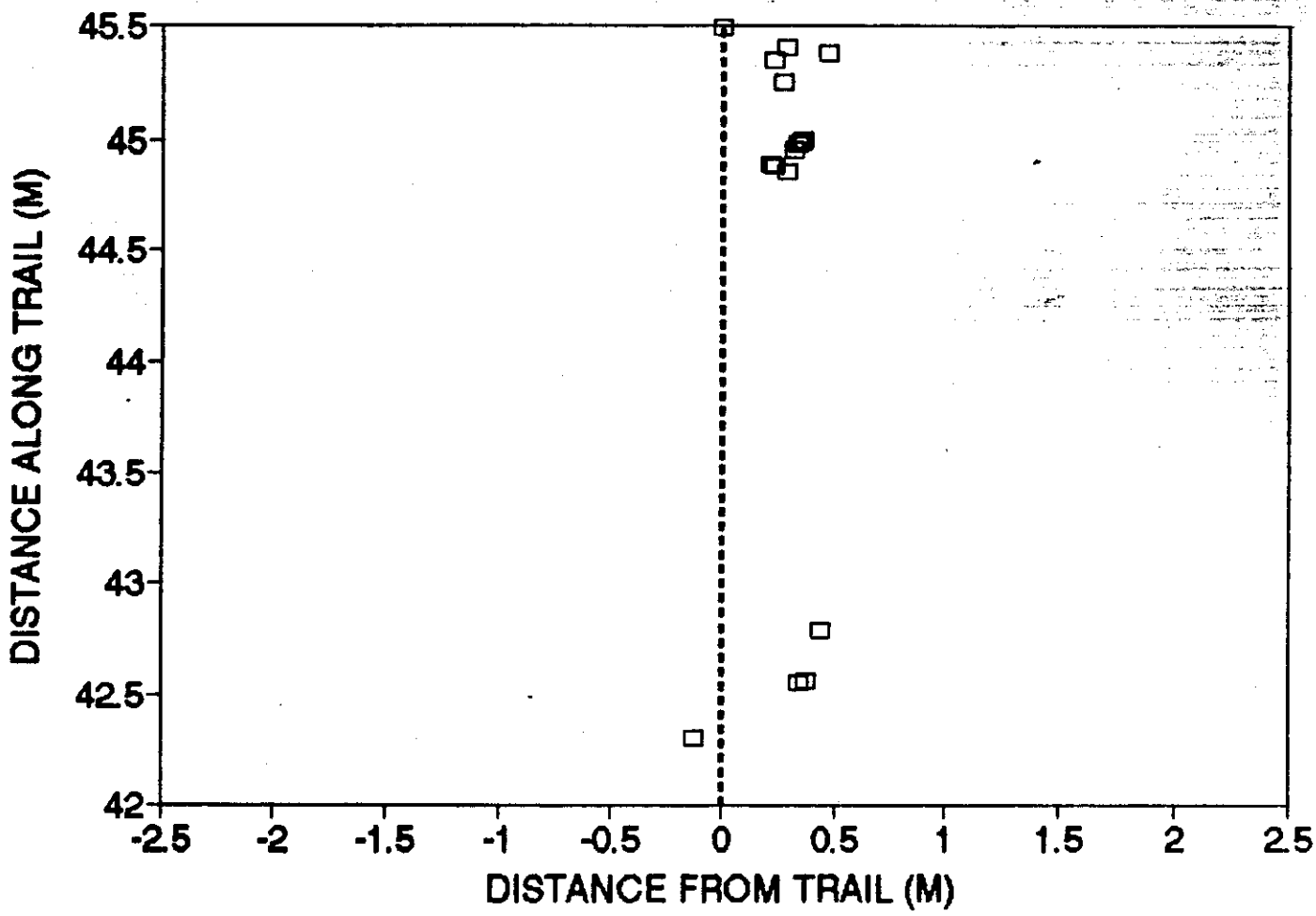
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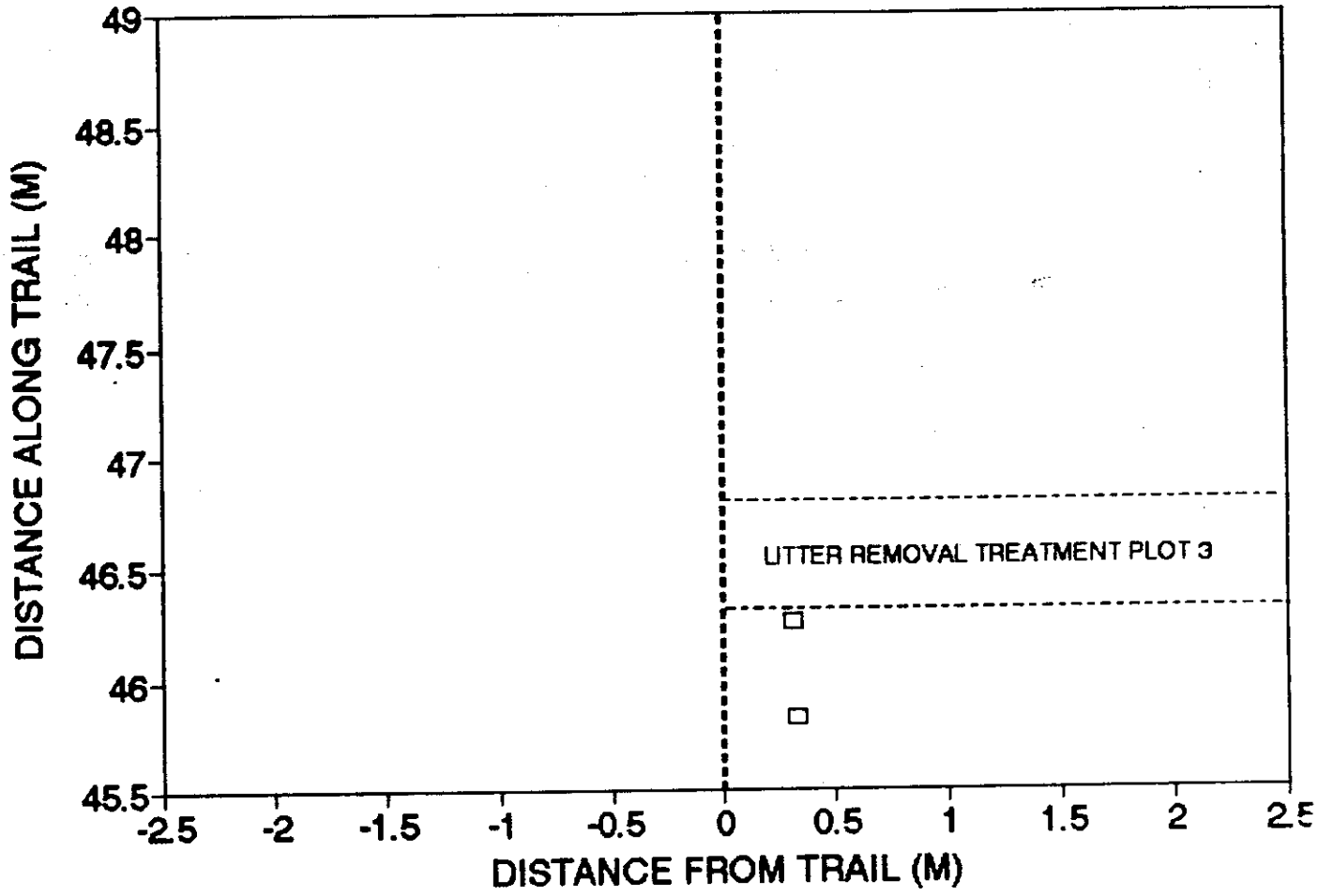
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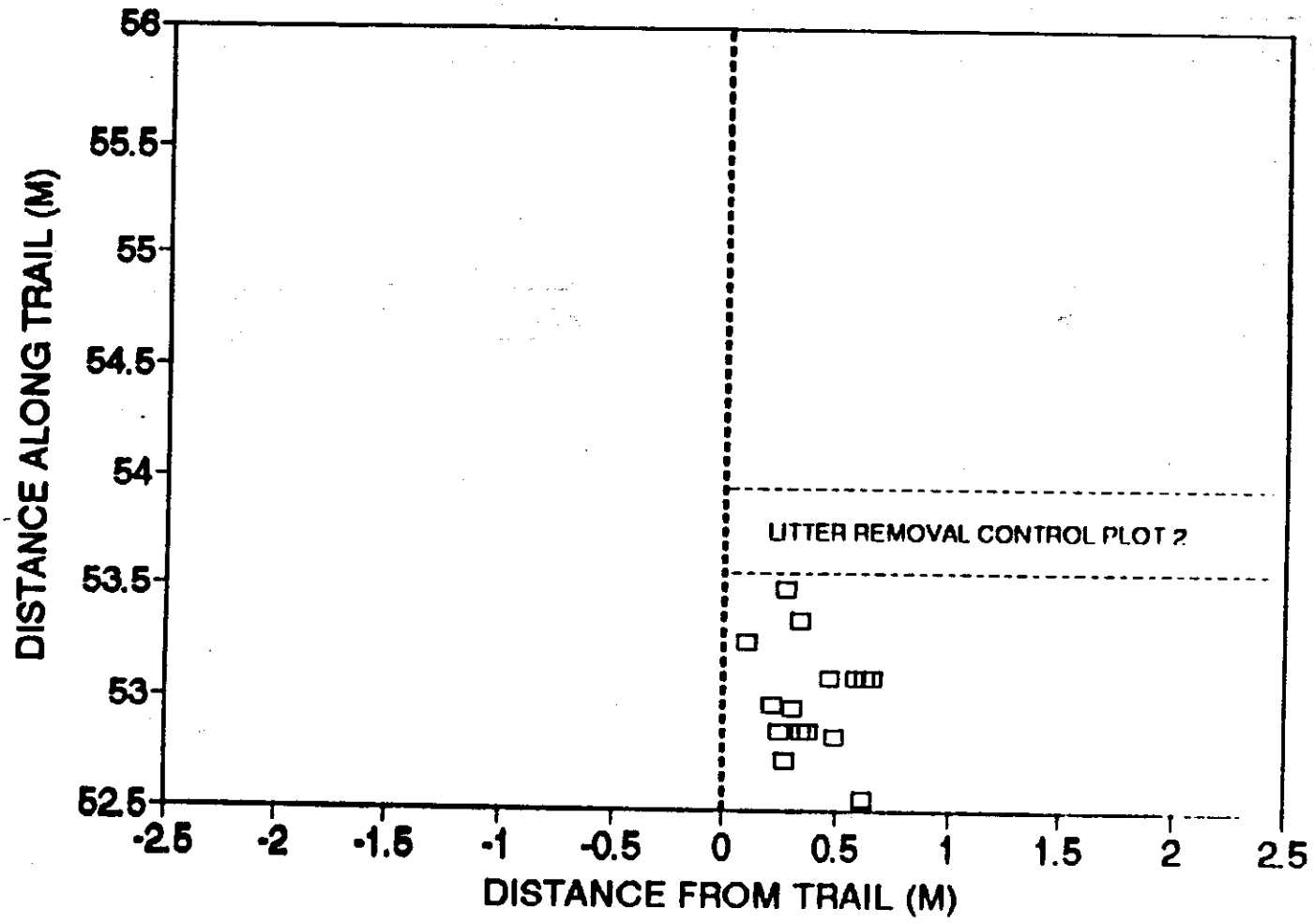
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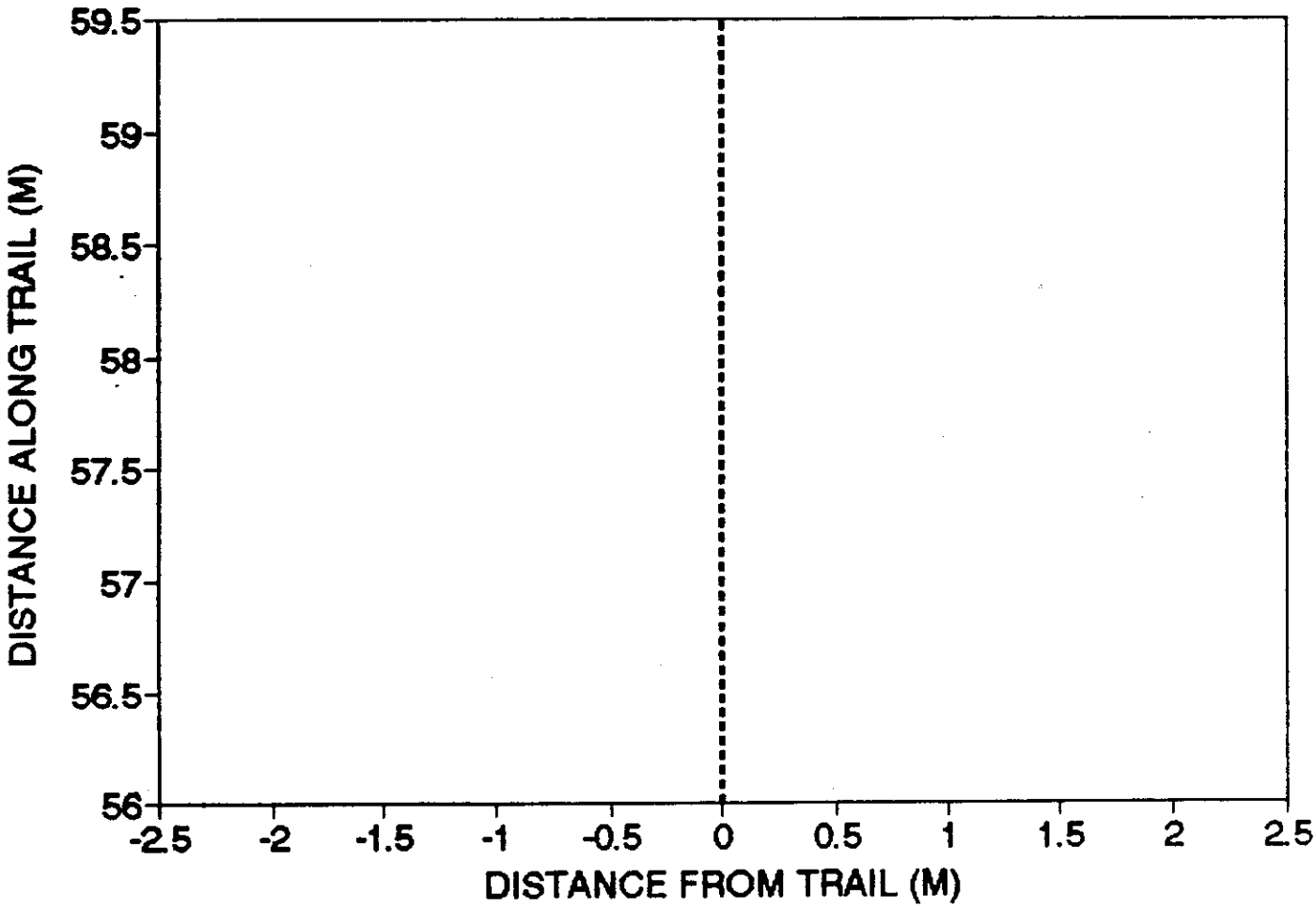
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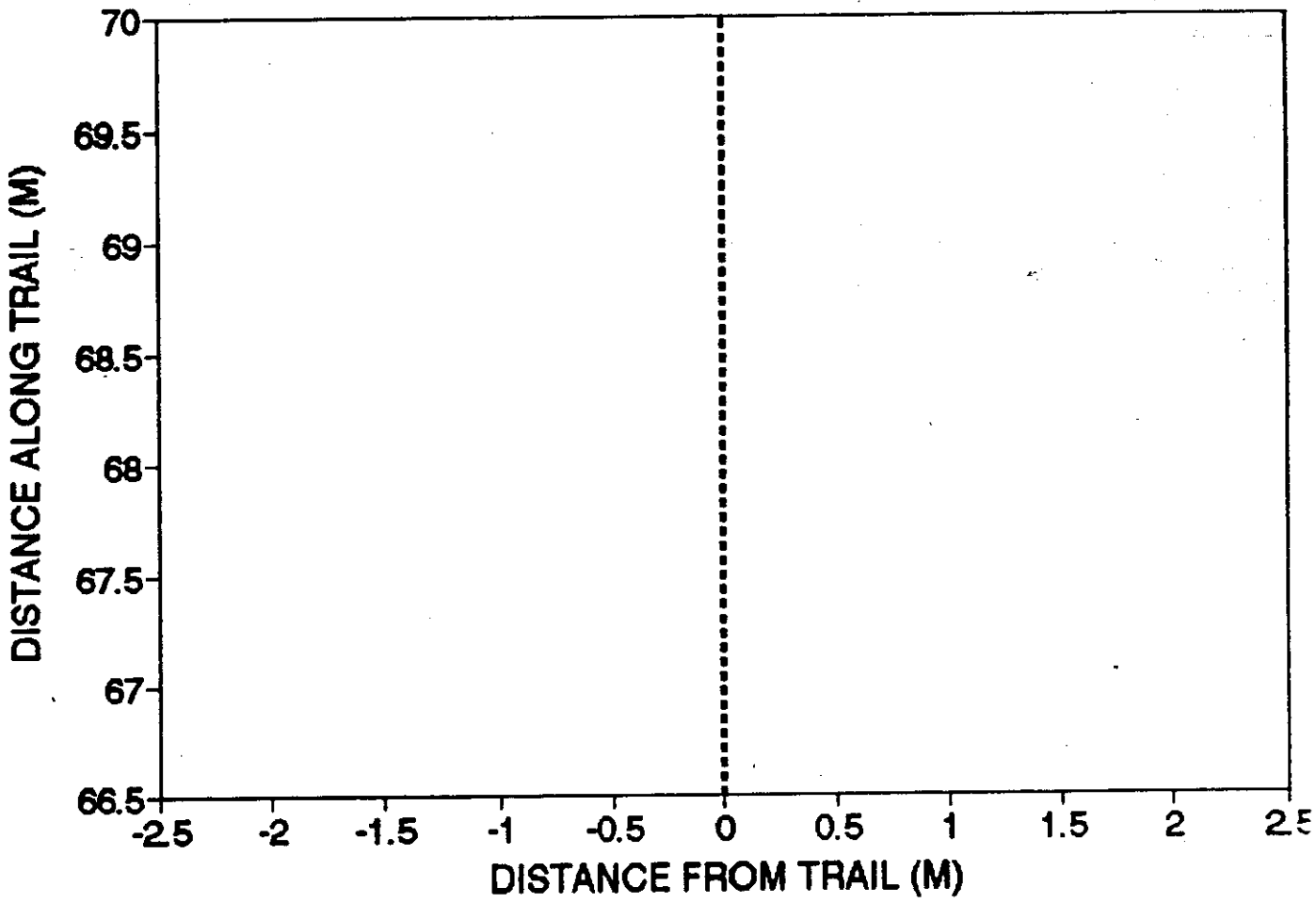
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