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THE PHENOLOGY AND STAND STRUCTURE OF
MYRICA FAYA AIT. IN HAWAI'I

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ABSTRACT

The objectives of this study were to observe the phenological cycles of Myrica faya in Hawaii and to sample the stand structure of sites that have been invaded by this species. Observations on the phenology of M. faya were made at 2-week intervals from March 1983 through March 1985. Data were taken at three sites and were related to the data from nearby weather stations. Data collected included information on flowering, fruiting (mature and immature), leaf flushing, leaf fall, and fruit drop. Analysis of the phenologic patterns observed showed flowering, fruiting, and fruit drop to be endogenously controlled while leaf flushing and leaf fall were influenced by environmental variables. Radial growth of nine trees at two of the sites was monitored with a microdendrometer.

Stand structure data were collected at two sites in 10 m wide belt transects. Basal diameters of all tree species were measured. One site showed M. faya to be well established and reproducing abundantly while the other site had relatively few individuals of M. faya in the two smallest size classes.

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INTRODUCTION

Myrica faya Ait. (Myricaceae), commonly known as faya or firetree in Hawai'i, is a native of the Azores, Madeira, and Canary Islands in the Atlantic Ocean. It was introduced to Hawai'i in the late 1800s by Portuguese immigrants, presumably as an ornamental (Neal 1965, Hasselwood and Motter 1983, Smathers and Gardner 1979, Fosberg 1937, Gardner and Kageler 1982). The Hawaiian Sugar Planters' Association obtained seeds of M. faya for use in reforestation, and plantings were recorded for the islands of O'ahu, Kaua'i, and Hawai'i (Fosberg 1937, Skolmen 1979). Plantings were discontinued when the noxious character of this species became apparent (Fosberg 1937, Whiteaker and Gardner 1985). Since this original introduction, M. faya has naturalized and spread to all major Hawaiian Islands except Moloka'i, Kaho'olawe, and Ni'ihau, and infests a total of 34,365 hectares (85,912 acres) over a wide variety of habitats (Whiteaker and Gardner 1985).

Because of its habit of forming multiple branches near the base of the main stem (Smathers and Gardner 1979), it has often been described as a shrub or small tree reaching heights of only 4 to 6 m (13 to 20 ft.) (Neal 1965, Haselwood and Motter 1983, Fosberg 1937). However, in the Hamakua region of the island of Hawai'i, M. faya grows to over 16 m (50 ft.) high, forming dense canopies with no understory. Even seedlings of M. faya itself are absent (Smathers and Gardner 1979, L. Whiteaker, pers. observation). The plant has narrow, pointed, smooth, shiny, dark green leaves with entire or toothed margins (Neal 1965, Haselwood and Motter 1983). Staminate flowers with four stamens each are borne on small catkins. Three pistillate flowers that may be joined and accompanied by one bract are also grouped in small catkins (Fosberg 1937, Neal 1965). Although M. faya has a strong tendency toward dioecism, a few staminate flowers may be found on pistillate plants and a few pistillate flowers may be found on staminate plants (Gardner 1985). Fruits are small, edible drupes that form dense clusters, changing from green through red to purple when ripe (Neal 1965, Fosberg 1937, Lawrence 1951).

Observations by Krauss (1964) of the flowering and fruiting of M. faya in its native habitat showed abundant male flowers and a few small fruits in June. In July most male flowers were dry and many green and a few purple fruits were seen. All stages of fruiting were observed in September, and by November many ripe and fallen fruits were reported. Gardner (1984) reported various stages of flowering with some immature fruit development during a visit to the native habitats on M. faya in April and May.

The purpose of this study was to observe the phenological cycles of M. faya in Hawai'i and to sample the stand structure of selected sites that were heavily infested by this species. These results will serve as a data base for determining the timing of the implementation of a biological control program should an appropriate agent be found, and for an assessment of the stand dynamics of a plant community infested by this species.

METHODS

Phenology data were collected from ten trees at each of three sites for a total of 30 trees that were monitored. Of the three sites, two were in Hawaii Volcanoes National Park (HAVO): Hilina Pali, 1.9 miles west of Chain of Craters Road, and Byron Ledge. The third site was on the English property (Shipman Estate), just east of HAVO (Fig. 1). These sites were chosen to represent an increasing moisture gradient (Fig. 2), in the order named above, and because each site was near a weather monitoring station. Also, these sites represent a decreasing temperature gradient (Fig. 3). Data collected included information on flowering, immature fruiting, mature fruiting, leaf flushing, leaf fall, and fruit drop. Also, maximum and minimum temperatures were recorded from maximum/minimum thermometers installed at each site. Index values revised after Lamoureux (1973) were used for quantification of the phenophases. Leaf fall and fruit drop were collected in 1 m x 1 m litter traps placed under the canopy of each M. faya tree. Material collected was sorted and the M. faya leaf fall and fruit drop weighed. Data for phenophases were collected at approximately biweekly intervals over 2 calendar years. Material was collected from litter traps on the same schedule over 1 calendar year. Subsamples of five trees at the Byron Ledge site and four trees at the English site were monitored for increases in basal diameter over 20 months using a microdendrometer (Daubenmire 1945). Only nine trees were monitored since only these trees had large enough diameters for appropriate application of this technique.

Stand structure data were collected using 10 m-wide belt transects subdivided into 5 m x 5 m subplots. Basal diameters of trees of all species within the transects were measured using calipers or a diameter tape. Sampling was continued until more than 100 individuals of M. faya had been measured. Two areas were sampled in this manner. A 250 m long belt transect was located in the upper portion of the Ainahou Ranch and a 150 m long belt transect was located in the Naulu Forest. Both sites are within HAVO (Fig. 1).

RESULTS

Flowering, immature fruiting, mature fruiting, and fruit drop showed similar patterns at all three sites. Flowering showed maximum activity in June and minimum activity in December and January in the 2 years during which observations were made (Fig. 4). Peaks of immature fruiting followed in August and September with minimum activity in February and March (Fig. 5). Maximum mature fruiting was observed in November and minimum mature fruiting was seen in May (Fig. 6). Fruit drop followed a similar pattern to mature fruiting in the 1 year observed (Fig. 7). Leaf flushing showed similar patterns at the Byron Ledge and English sites with maximum activity in June (Fig. 8). At the Hilina Pali site, leaf flushing also had peaks in June, but the pattern over the entire observation period differed somewhat from the other two sites (Fig. 9). The Byron Ledge and English sites also had similar patterns in the amounts of leaf fall, but the amounts of leaf fall at Hilina Pali showed a different pattern than at the other two sites (Figs. 10-11).

The mean radial growth of the nine trees that were monitored was 6.7 mm per year. The means of radial growth at each site did not differ significantly from each other as determined by a two-tailed t-test.

Stand structure data from the Ainahou Ranch site generally show decreasing numbers of individuals with increasing size class for both M. faya and Metrosideros polymorpha (ohia) (Fig. 12). At the Naulu site, the population data for ohia show a similar pattern to that at the Ainahou Ranch site. However, the population data for Myrica faya show relatively low numbers of individuals in the two smallest size classes (Fig. 12). Density of M. faya was 536 individuals per hectare at the Ainahou Ranch site and 733 individuals per hectare at the Naulu Forest site.

DISCUSSION

Flowering, immature fruiting, mature fruiting, and fruit drop seem to follow an annual cycle that is endogenously controlled and/or initiated by consistent annual environmental cycles, such as daylength. The timing of these phenophases in Hawai'i seems to be similar to that observed in the native habitat of M. faya (Krauss 1964, Gardner 1984). Fruiting was heaviest at the warmest and driest site (Hilina Pali) and lightest at the coolest and wettest site (English) as illustrated by the mature fruit and fruit drop graphs (Figs. 6-7). This indicates that M. faya may not be well adapted to reproducing in cold and/or extremely wet habitats. Also, these data show that while these phenophases have definite maximum and minimum

activity periods, at no time during the course of this study were any of these phenophases completely absent.

Leaf flushing may also have a generally consistent annual cycle as illustrated by the similar patterns at the Byron Ledge and English sites, and by the peak of activity occurring in June of each year at all three sites (Figs. 8-9). However, when the slightly different overall pattern of leaf flushing at the driest site, Hilina Pali, is correlated with precipitation, maximum flushing seems to follow periods of high precipitation, and minimum flushing seems to follow periods of low precipitation (Fig. 9). Thus, flushing of M. faya may be sensitive to variations in precipitation where total annual precipitation is relatively low. Flushing was only absent at one site for one observation (Fig. 8). Thus, although the amount of flushing may vary, this phenophase of M. faya is also almost never absent.

The variation between sites in the pattern of the amount of leaf fall is shown by large peaks of leaf fall occurring at different times of the year at the Hilina Pali site relative to the Byron Ledge and English sites (Figs. 10-11). This may be due to the sites' geographical positions relative to the then active Pu'u O'o vent of Kilauea Volcano and the corresponding incidence of high levels of SO₂ in the atmosphere. Thus, the large peaks in the amount of leaf fall may reflect the response of M. faya to high SO₂ concentrations superimposed on the otherwise relatively steady rate of leaf fall of an evergreen species.

Since the means of radial growth rates were not significantly different between the two sites that were monitored, growth of M. faya may not be affected by the differences in temperature and precipitation observed for these two sites (Figs. 2-3). However, since both sites probably have adequate water available to plants under normal conditions, it cannot be concluded that growth would not be affected by drier conditions. Also, since the distribution of M. faya in Hawai'i does not reach much below 545 m (1,800 ft.) or much above 940 m (6,400 ft.) elevation (Whiteaker and Gardner 1985), the small differences in temperature between these two sites cannot lead to the conclusion that growth would not be affected by more extreme temperature conditions. In the native habitat of M. faya, it seems that as latitude decreases the upper elevational limit of M. faya increases and an apparent lower elevational limit develops in the most southerly of these areas (Hodges and Gardner 1985). This may indicate that M. faya is not adapted to extremes of temperature beyond its limits of distribution. The distribution in Hawai'i may indicate similar environmental limits for this species (Whiteaker and Gardner 1985).

The mean growth rate reported here is about half the rate observed for M. faya trees on which dendrometer bands were installed (L. Walker, pers. communication). Thus, the growth rate of M. faya may be determined to be somewhat higher than found in this study if a larger sample is monitored using a more appropriate technique for measurement of long term growth.

Stand structure at the Ainahou Ranch site shows that both M. faya and Metrosideros polymorpha are well established in the area and are maintaining themselves with abundant reproduction (Fig. 12) (Daubenmire 1968), Mueller-Dombois and Ellenberg 1974, Barbour et al. 1980). This pattern can be interpreted to represent an established, self-maintaining stand of numerous individuals (Metrosideros) being successfully invaded by a currently less numerous weedy species that is reproducing well (Myrica). However, at the Naulu site the stand structure departs from this pattern in that the two smallest size classes of M. faya contain relatively small numbers of individuals. Thus, although M. faya is established at the Naulu site, it does not have the population structure usually associated with a species that is maintaining itself within the stand (Daubenmire 1968, Mueller-Dombois and Ellenberg 1974, Barbour et al. 1980). However, since these two size classes probably represent only the current and previous seasons' reproduction, this unexpected shape of the population structure of M. faya represents the failure of only 1 year of reproduction. This may be explained by environmental conditions at this site that may not have been favorable for peak germination at a critical period required for optimum reproduction of M. faya. Alternatively, the bird species that are the primary dispersal agents of M. faya (Walker et al. 1986, LaRosa et al. 1985) may not have visited this site during the peak fruiting period of the previous season. Also to be considered are stands of M. faya in Hamakua, Hawai'i and elsewhere in HAVO that are considerably more dense than the density at this site (Smathers and Gardner 1979; Whiteaker and Gardner 1985; L. Whiteaker, unpubl. data). Therefore, it cannot be concluded from these data that M. faya is not maintaining itself on this site. Rather, M. faya may have particular environmental and/or dispersal requirements for abundant reproduction in a particular year. Thus, further data collection at this or other sites and experimental study of the dispersal and germination requirements and seedling mortality of M. faya are needed to fully elucidate the population biology of this species.

ACKNOWLEDGEMENTS

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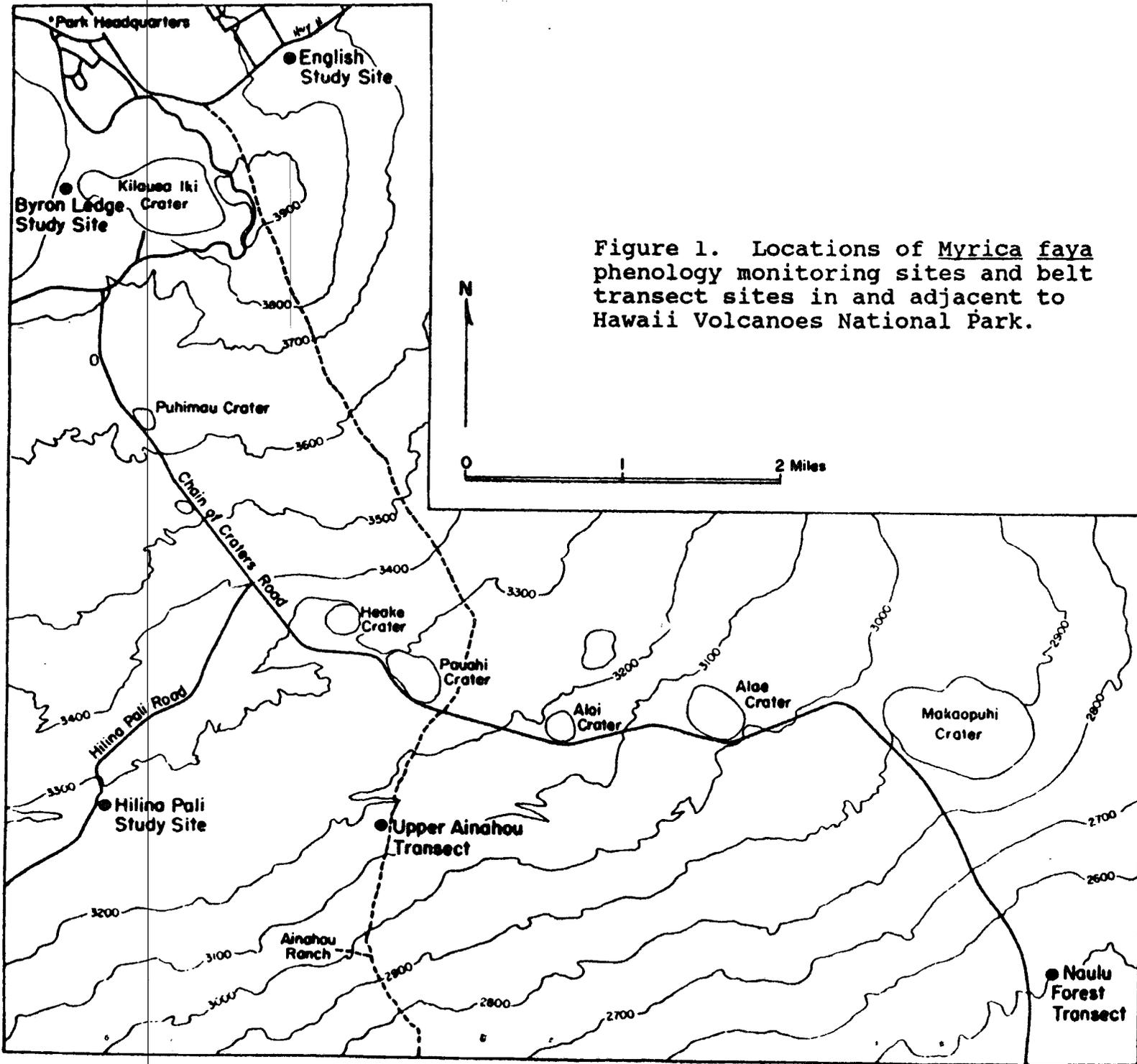


Figure 1. Locations of *Myrica faya* phenology monitoring sites and belt transect sites in and adjacent to Hawaii Volcanoes National Park.

PRECIPITATION

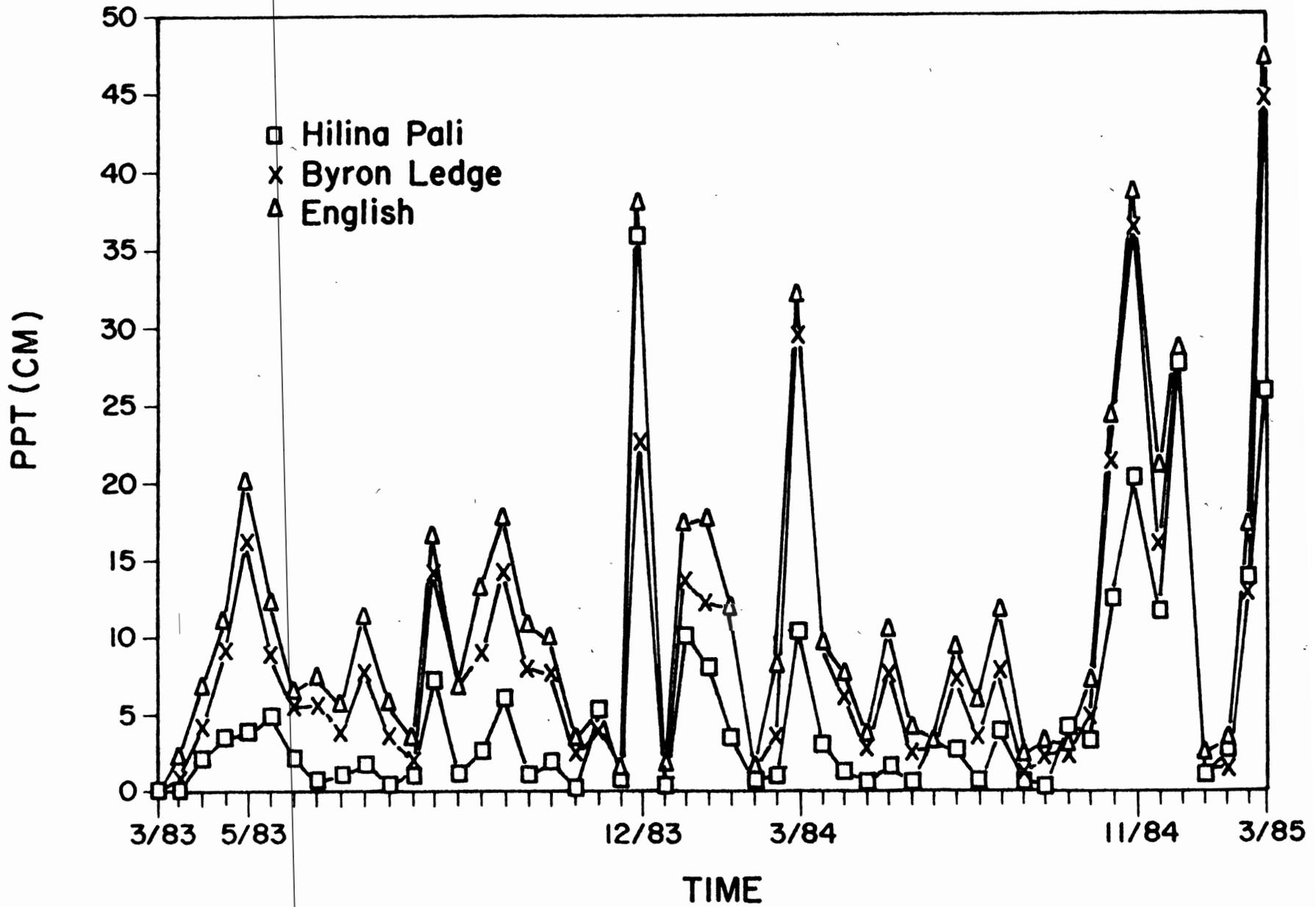


Figure 2. Precipitation recorded at weather stations near the phenology monitoring sites during the 2-year data collection period.

MAXIMUM TEMPERATURE

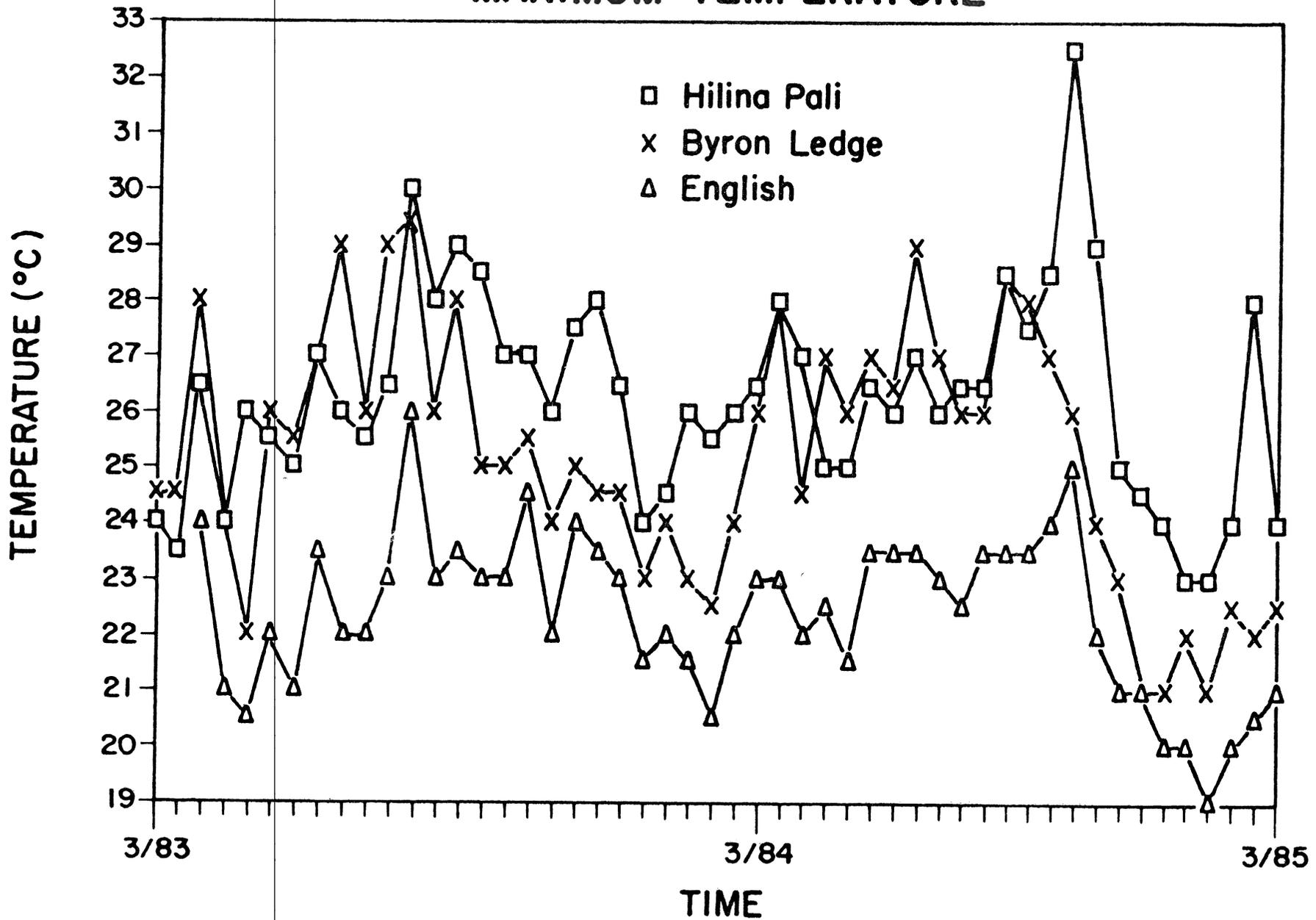


Figure 3. Maximum temperatures recorded from maximum/minimum thermometers installed at each phenology monitoring site.

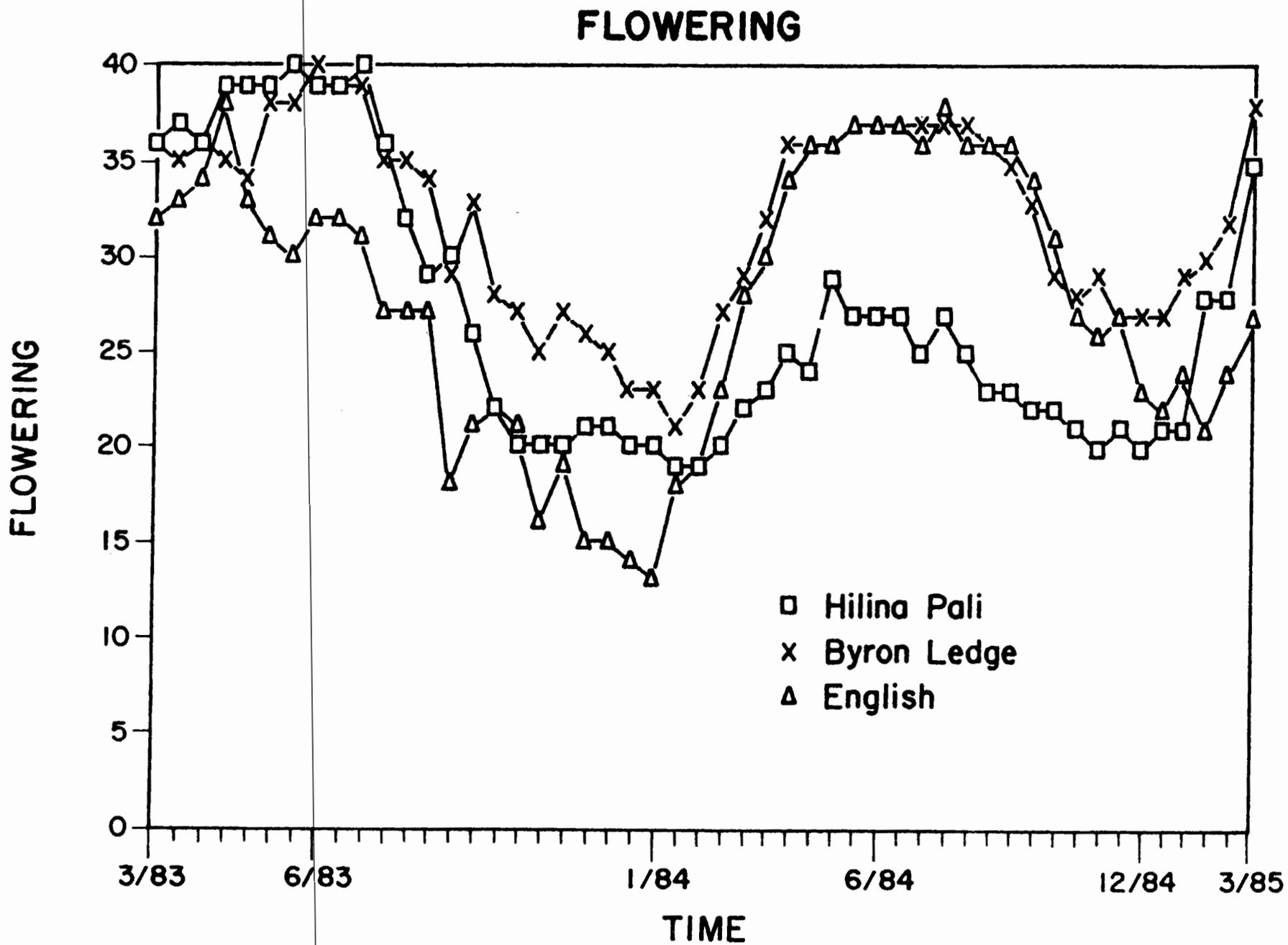


Figure 4. Index values for flowering for each phenology monitoring site.

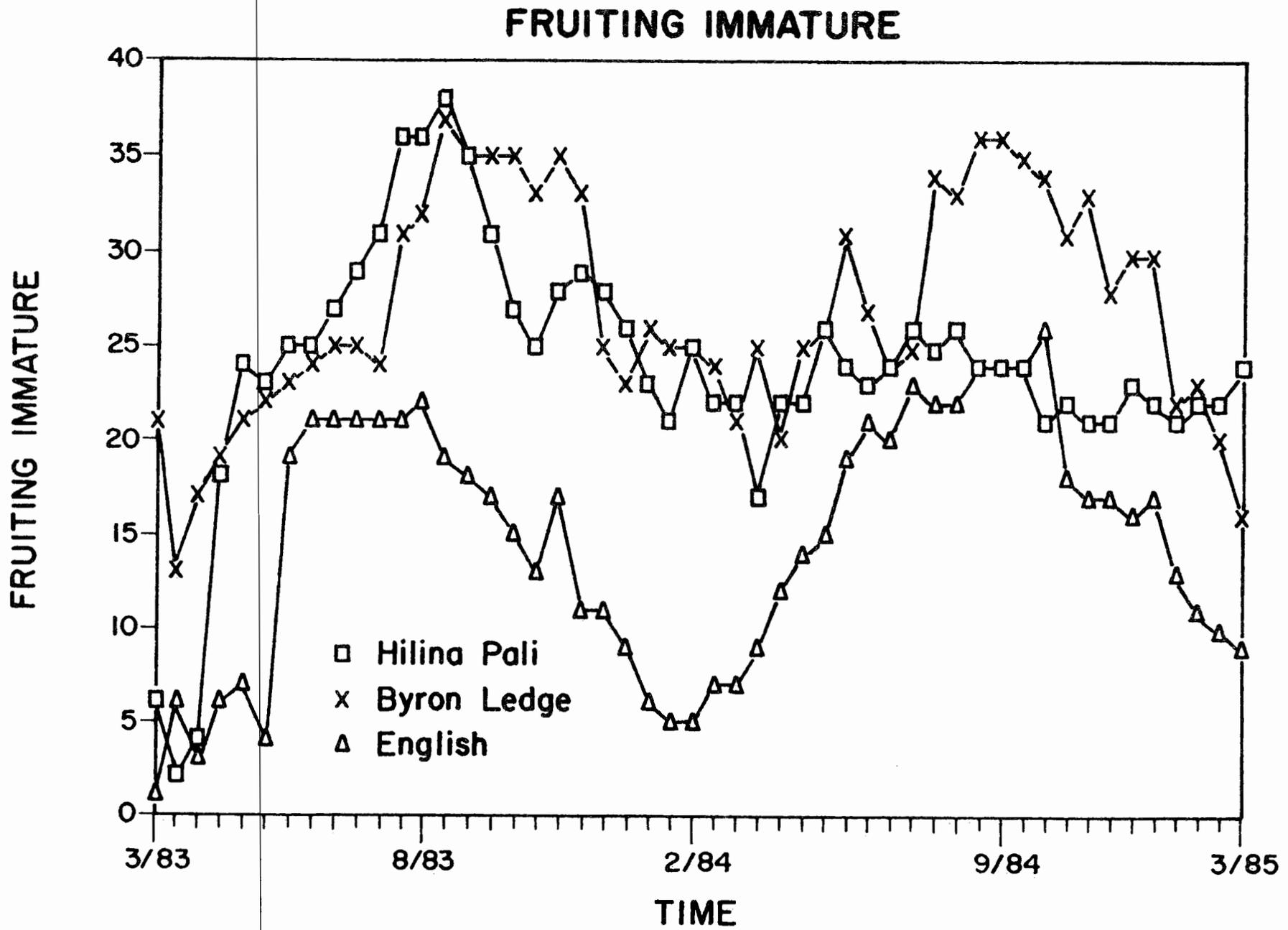


Figure 5. Index values for immature fruiting for each phenology monitoring site.

FRUITING MATURE

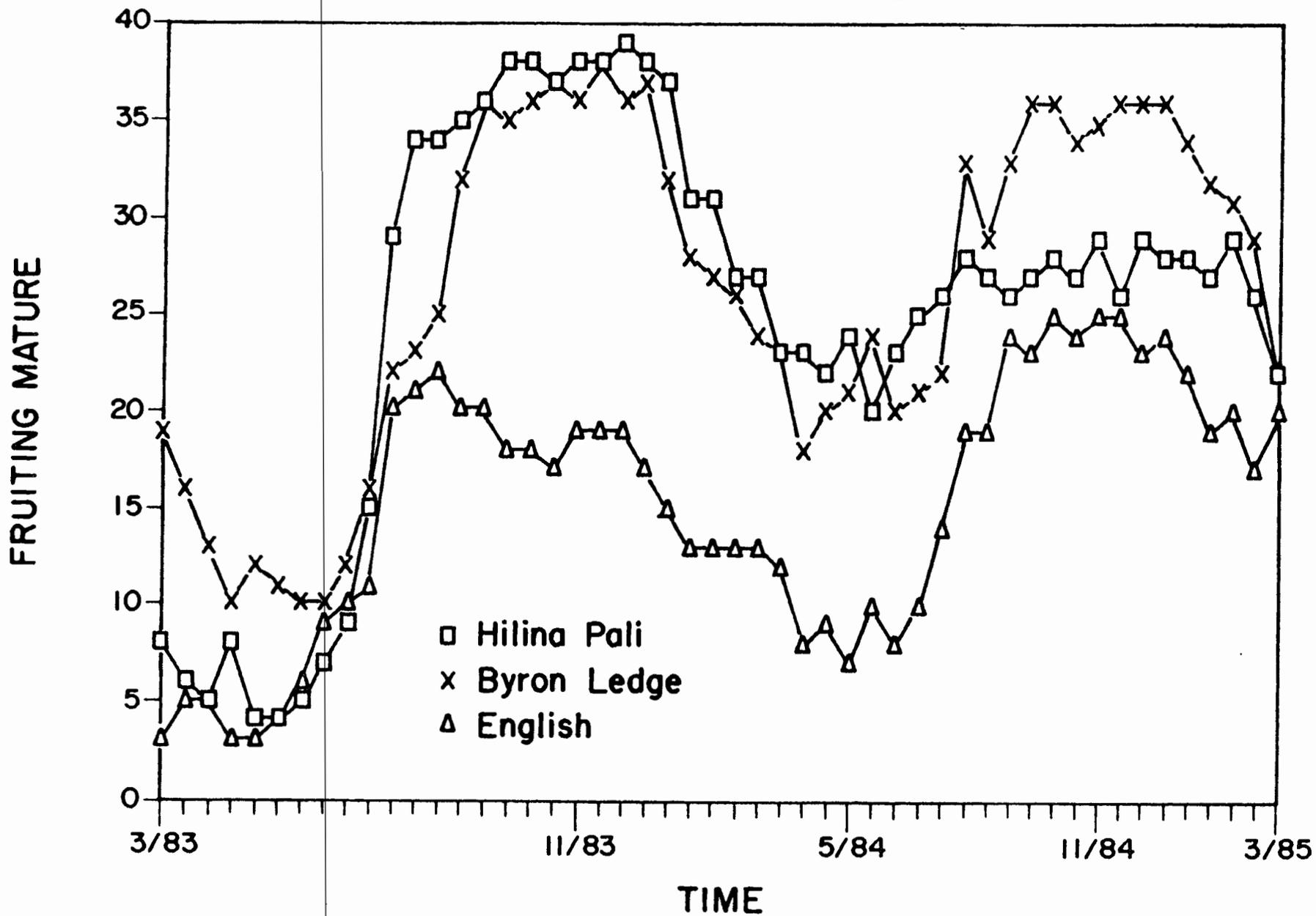


Figure 6. Index values for mature fruiting for each phenology monitoring site.

FRUIT DROP

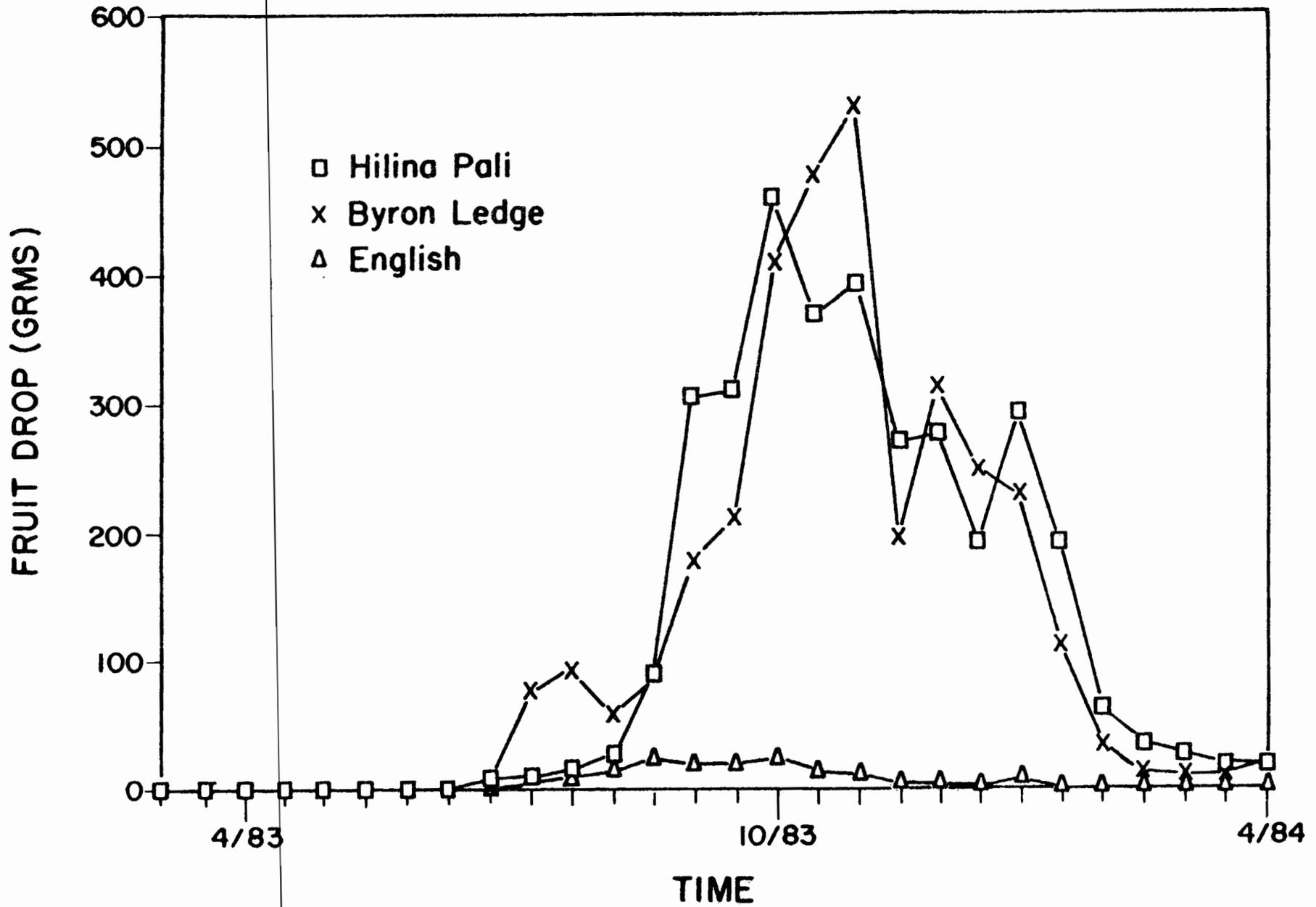


Figure 7. Grams of fruit collected in ten litter traps for each phenology monitoring site.

FLUSHING

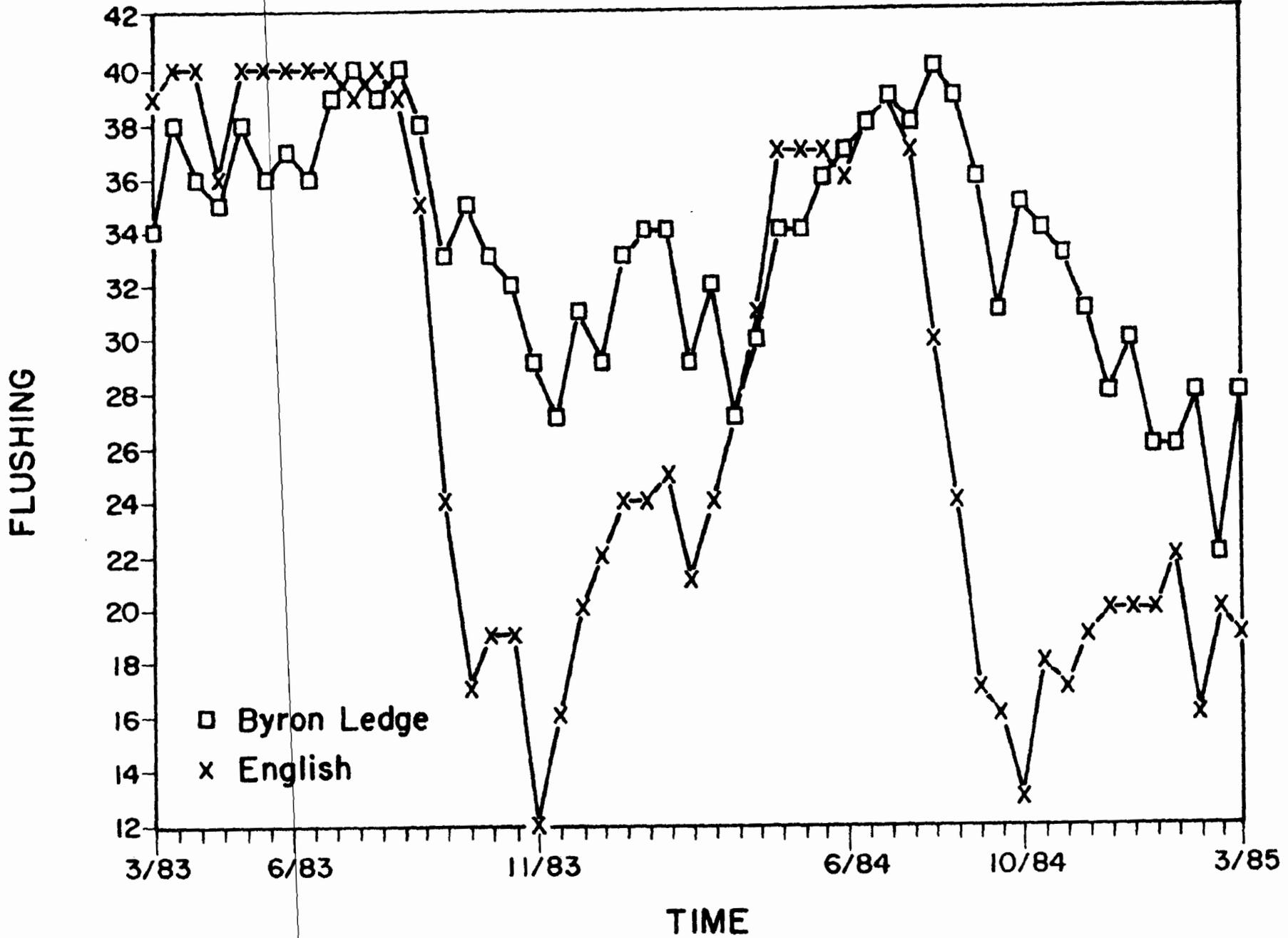


Figure 8. Index values for leaf flushing for the Byron Ledge and English phenology monitoring sites.

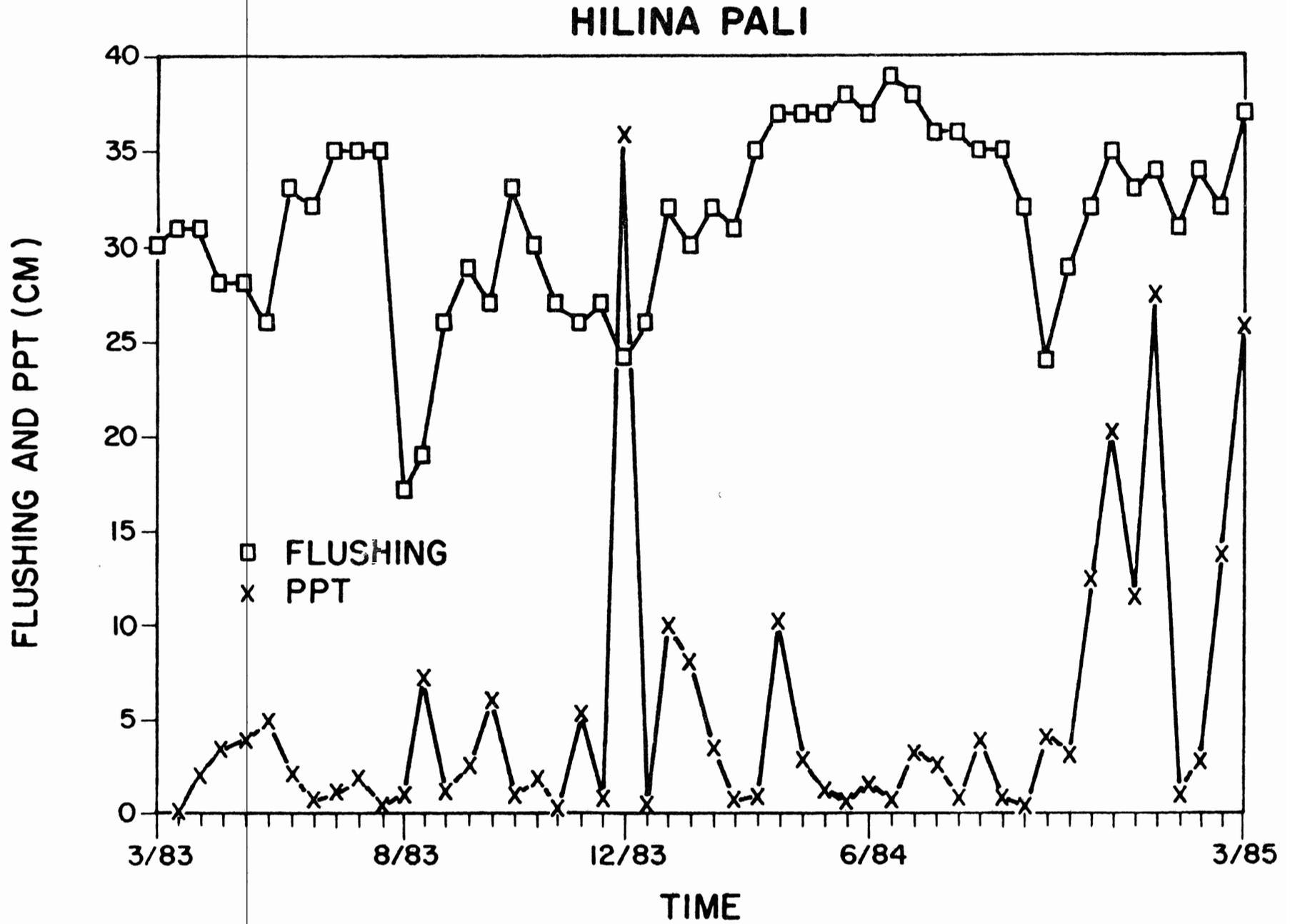


Figure 9. Precipitation and index values for leaf flushing for the Hilina Pali phenology monitoring site.

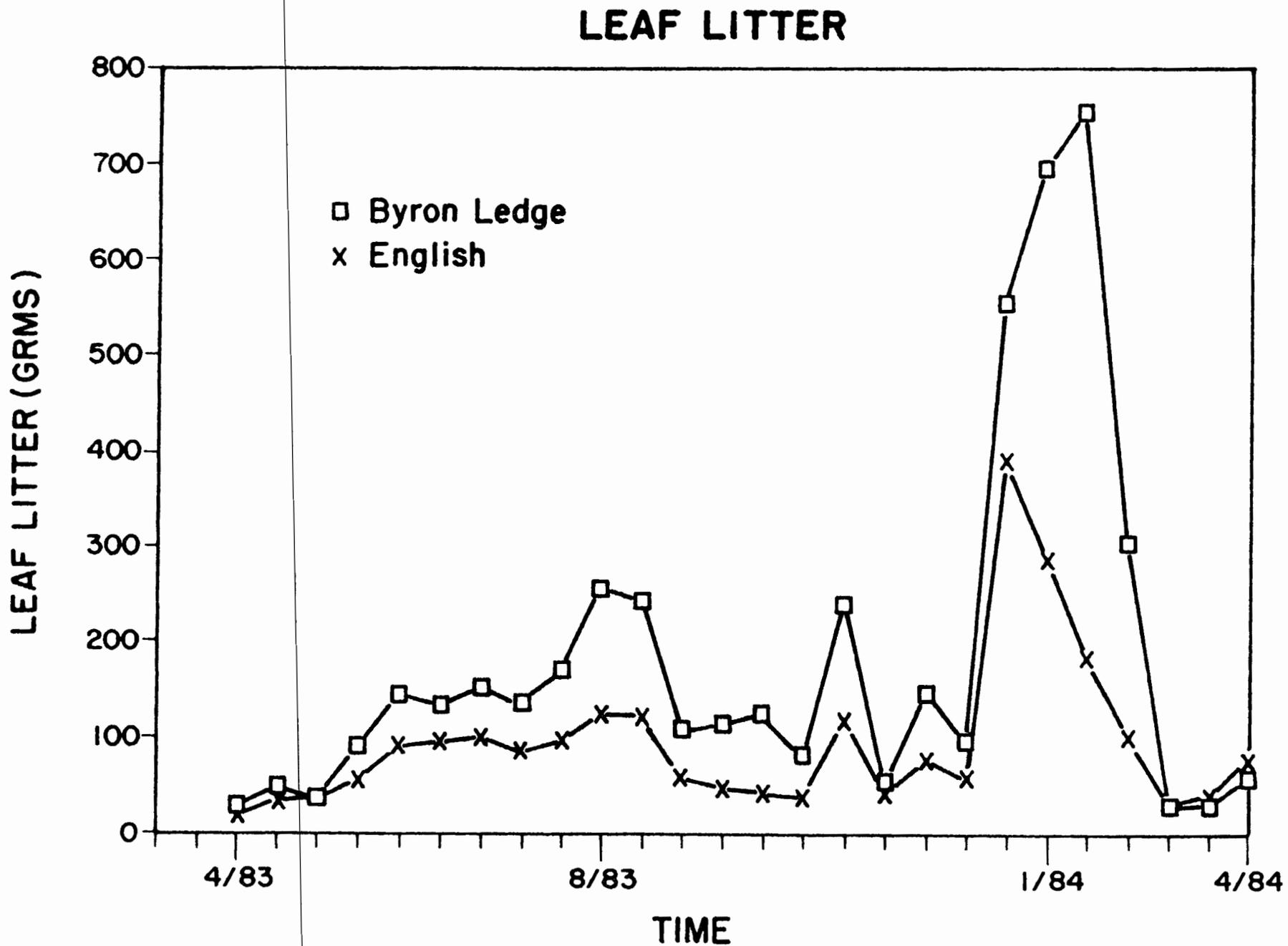


Figure 10. Grams of leaf fall from ten litter traps for each of the Byron Ledge and English phenology monitoring sites.

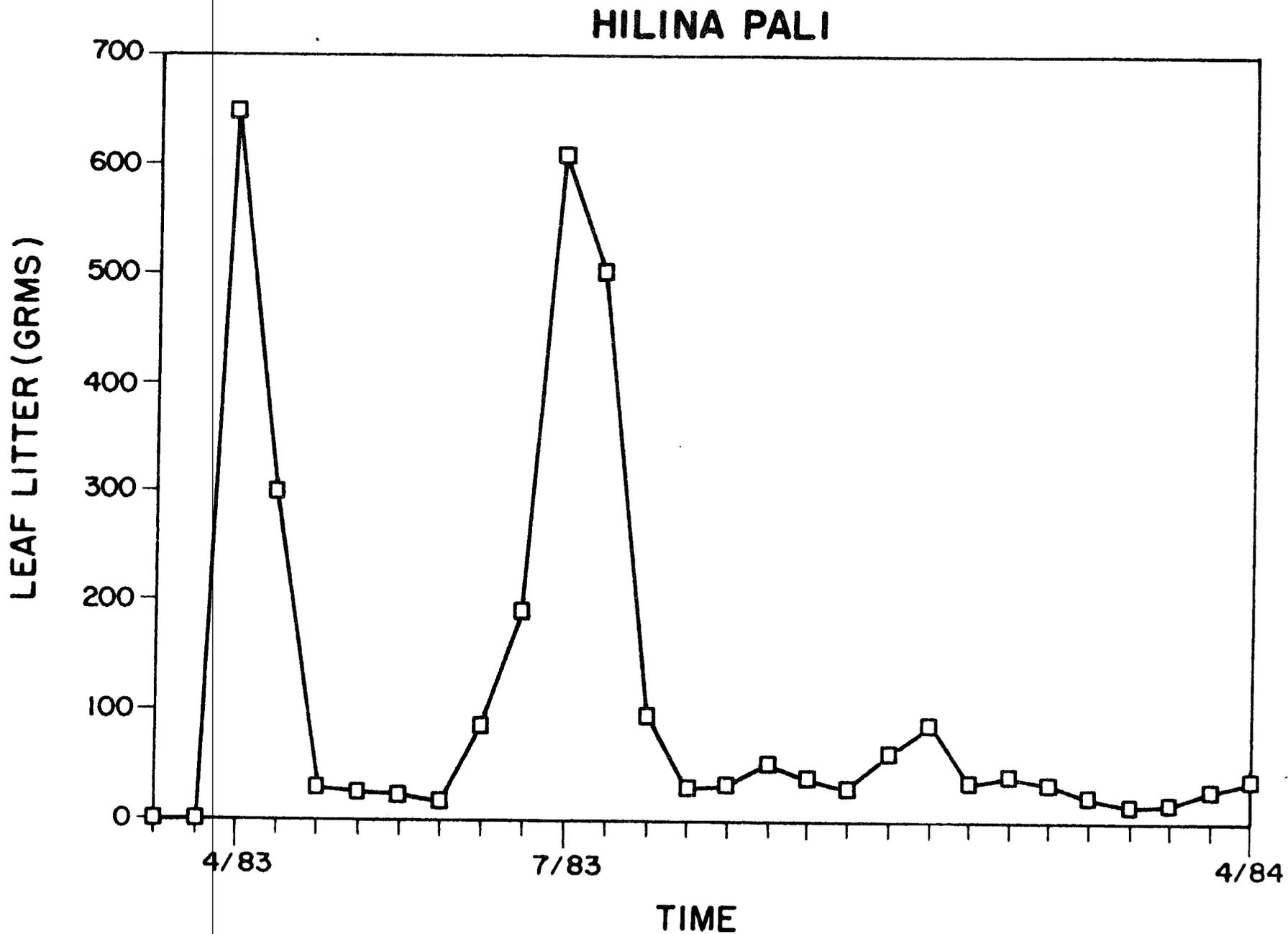


Figure 11. Grams of leaf fall from ten litter traps for the Hilina Pali phenology monitoring site.

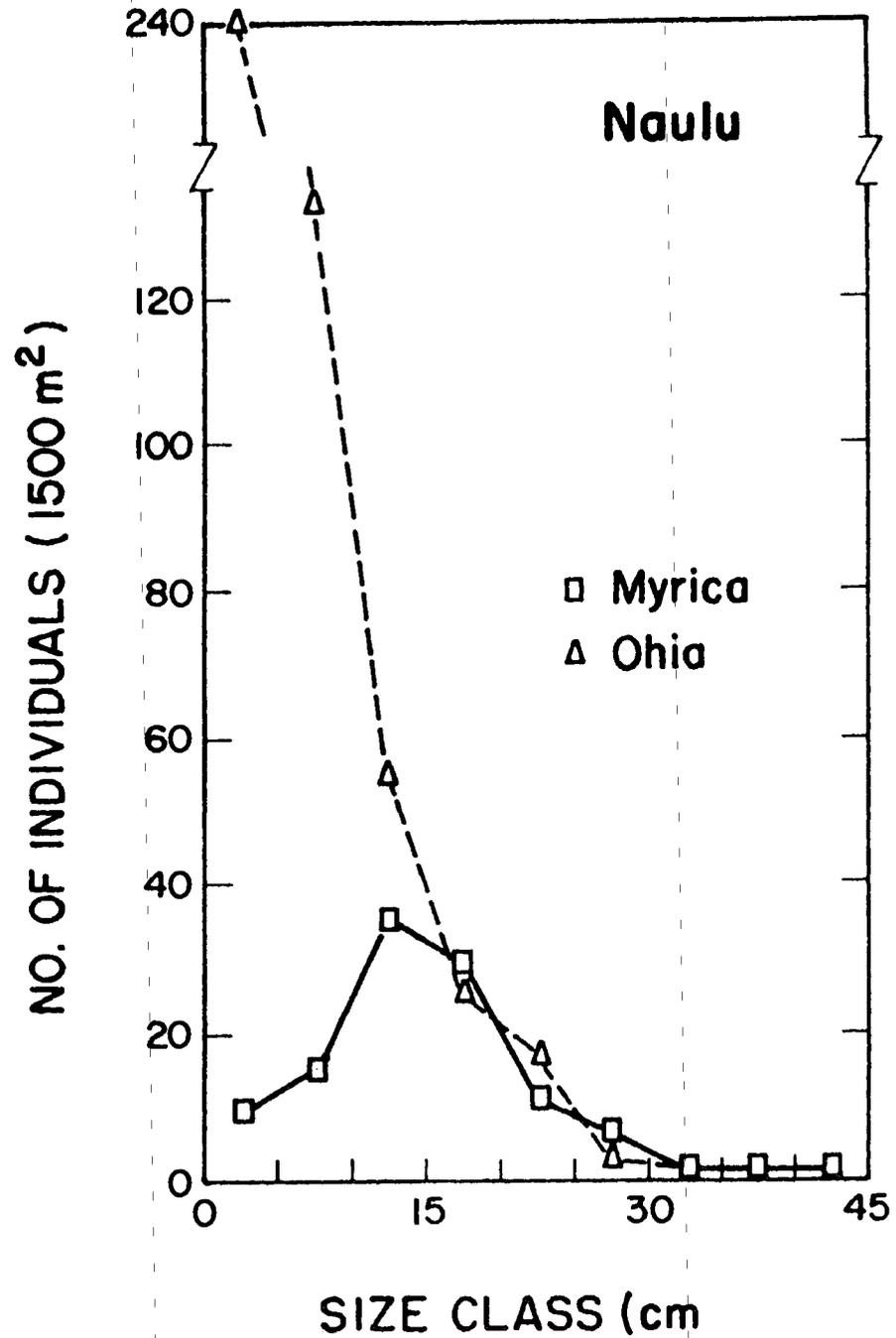
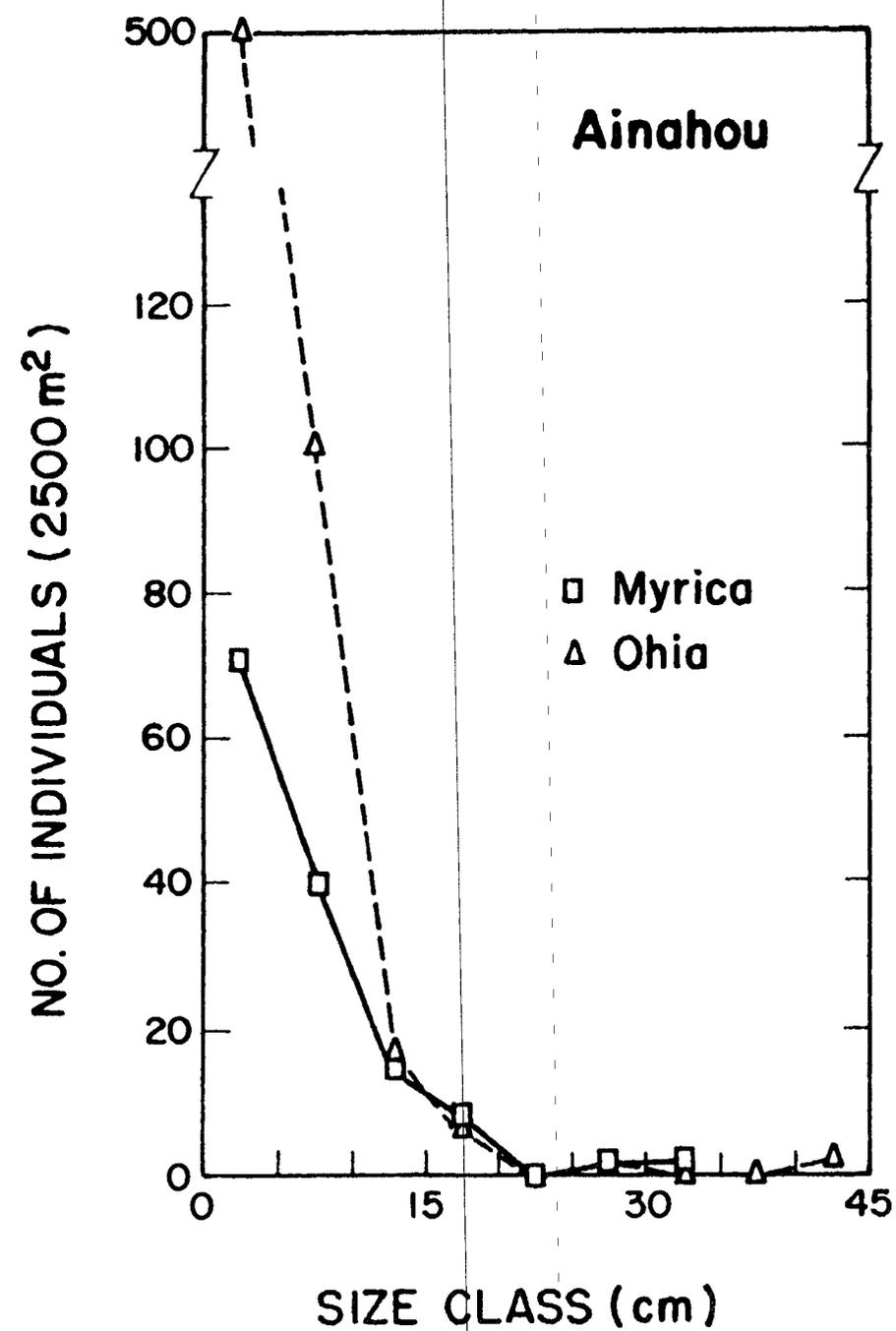


Figure 12. Stand structure from belt transects in the Ainahou and Naulu Forest regions of Hawaii Volcanoes National Park.