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THE EFFECTS OF WINTER FIRE AND HARVEST ON THE VEGETATIONAL STRUCTURE AND PRIMARY PRODUCTIVITY OF TWO TIDAL MARSH COMMUNITIES IN MISSISSIPPI

(Final Report - 3 Year Study)

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CONTENTS

Abstract

Past and present cultural alterations of coastal marshlands have included harvesting for marsh hay and burning to promote habitats for waterfowl and wildlife. The effects of these two management tools on the annual net primary productivity and vegetational structures of *Juncus roemerianus* and *Spartina cynosuroides* marshes in Mississippi were investigated. Artificial harvesting by clipping the plants to the ground and controlled burning of the marsh in experimental plots were conducted in the winters of 1977, 1978, and 1979. Winter burning and harvesting of the *Juncus* marsh increased the primary productivity of the vascular vegetation by 21 to 48% during the following growing season. In the *Spartina* marsh, primary productivity of burned and harvested plots did not only increase by 12 to 24% over the control but maintained a higher productivity value after two and three successive annual winter fires. Neither burning nor harvesting affected the density of *Juncus* regrowth; however, the height of the plants generally decreased in the harvested plots compared to control. Early flowering and greater number of culms with inflorescences also occurred in plots which received winter burning and harvesting. Minor plant species associated with the *Juncus* dominated marsh generally increased their biomass in treated plots harvested two to three consecutive years presumably due to the removal of the canopy which allowed growth of non-dominant species. Monthly standing crop of belowground materials of all the plots was higher than aboveground per square meter but belowground productivity estimates could not be determined. Caloric, and elemental constituents of both above- and belowground tissues did not show any seasonal pattern nor did they show clear-cut trends among treatment plots or between treatment and control plots.

Introduction

Human cultural alterations of marshlands have primarily included burning and harvesting. Winter fires are a common tool applied in promoting preferred habitat for waterfowls and pelt mammals in low marshes and in clearing high marshy areas for selected agricultural uses. Removal of marsh vegetation periodically for "marsh hay" either for forage or for composting to garden mulch was once a frequent activity along coastal wetlands. The potential for harvesting the marshlands regularly exist if the prospect for using marsh vegetations for extraction of chemical derivatives, cellulose, pulp, and other by-products proved to be of profitable economic value. Federal, state, and local agencies are beginning to address the question of how best to manage coastal marshlands without decreasing their productivity or damaging their ecological value to man and wildlife. Several methods of managing marshes and other types of wetlands have been suggested by various workers (e.g., Chabreck 1976, Weller 1978). In this study, we considered burning and harvesting as management tools, and we investigated the effects of these alterations to the structure and productivity of the dominant vascular vegetation. We measured the primary productivity of the macrophytes which is one of the principle means of estimating the potential ecological and economic value of coastal wetlands.

Marsh Fires.

Fire is an important factor in many ecosystems throughout the world (Cooper 1961; Kozlowski and Ahlgren 1974). The ecological role of fire in tidal marsh ecosystems along the Atlantic and Gulf coasts of the United States was poorly known before the 1940's (Garren 1943). Despite two decades of productivity research on tidal marshes (Keefe 1972; Turner 1976), the effects of fire on this coastal ecosystem are virtually unknown (Komarek 1974).

The effects of fire on marsh communities may vary according to prevailing moisture conditions in the soil and intensity of the fire. Lynch (1941) classified three types of marsh fires: (a) cover burns occurring in marshes with some standing water, (b) root burns occurring during lowered water table conditions, and (c) peat burns occurring during the periods of drought. The former is used routinely for management of wildlife habitat, while the latter two types of fire may be destructive to the vegetation and the substrate.

The use of fire as a management tool in the coastal wetlands of the Gulf coast has been described by Lynch (1941), O'Neal (1949), Givens (1962), and Perkins (1968). These reports dealt primarily with the maintenance, through periodic burning, of sedge species (*Scirpus* spp.) to provide food and habitat for fur bearing mammals. Myers (1956) and Whipple and White (1977) both reported an increase in *Scirpus* species following a fire. *Scirpus* and other members of the Cyperacea family are the favorite food of marsh mammals. Coastal wetlands are also burned in Louisiana to enhance the growth of succulent plant species for migratory birds (Chabreck 1976). The proper nesting habitats for certain ducks, e.g., the mottled duck, *Anas fulvigula maculosa*, are also maintained by periodic fires (Hackney and Hackney 1976). Marsh fires result in an altered habitat which may provide more food for certain wildlife species. Burning also makes the marsh more accessible to trappers and hunters.

The primary cause of fire in coastal marshes is through intentional burning by trappers and accidental burning during other human activities (O'Neal 1949). There have also been cases of spontaneous combustion during severe droughts (Viosca 1928, 1931) and lightning induced fires (Lynch 1941).

Besides the obvious loss of large amounts of organic material and some changes in plant species composition, little is known of the long-term effects of fire on tidal marsh communities. Most previous studies were oriented towards improving wildlife habitat and were interested in converting plant communities containing species which are not favorable to wildlife species (e.g., Juncus roemerianus, Distichlis spicata, and Spartina patens) to communities which provide better quality food (Myers 1956; Hoffpauir 1961; McNease and Glasgow 1970; Whipple and White 1977). Scirpus species are preferred by wildlife and contain higher protein concentrations than other species (de la Cruz 1973; de la Cruz and Poe 1975).

Fire affects the plant community composition in many wetland ecosystems (Zontec 1966; Robertson 1963; Klukas 1972; Schlictemier 1967). The importance of burning to suppress the overgrowth of an exotic species (e.g., Phragmites communis) in the wetlands of Manitoba, Canada was noted by Ward (1968). Volk et al. (1975) observed that species diversity was greater but not biomass in burned marsh areas when compared to unburned sites. Vogl (1973) noted that plant species composition changed little after a controlled winter fire in northern Florida, probably due to the area's past history of fire. Indeed, fires may be so prevalent in some areas that, it is impossible to determine the original species composition (Whipple and White 1977) of the community.

Observations on the increased yield of vegetation following controlled fire may be attributed to removal of accumulated debris and mulch, better solar radiation, and possible soil enrichment from ash deposition. Penfound and Hathaway (1938), however, felt that ash deposition might, in fact, retard recovery of vegetation.

Fire influences the physico-chemical properties of soils by oxidizing aboveground vegetative cover and, depending upon soil moisture content, may ignite soil organic matter (Penfound and Hathaway 1938; Lynch 1941). Thermal effects may be profound during low water or drought. The ability of ash-borne nutrients to be retained in marsh sediments after a fire is dependent to a large extent upon meteorological conditions, including wind and tidal regimes. Smith and Bowes (1974) indicated that nutrient losses in fly-ash during low temperature burns in old-field communities may be significant and estimated that as much as 30% of particulate-borne nutrients were deposited in adjacent sites.

On the Mississippi Gulf Coast, some marshes are burned by arsonists. There are, however, marshlands leased by local trappers and hunters which are burned during winter every 2-3 years. During the first week in February 1976, for example, a section of a marsh island on the western side of St. Louis Bay, Mississippi was burned. The fire was set on the southern side at several locations and burned in a northerly direction until contained by a tidal creek. Based on the movement of the fire, the wind was probably from the southeast. Our record shows that this same marsh was last burned in the winter of 1973. This unmanaged fire offered the opportunity to study the primary productivity of a burned marsh. A grant from the Mississippi Marine Resources Council (now Bureau of Marine Resources) made this preliminary study possible. We found that the fire enhanced the productivity of the marsh dominated by *Spartina cynosuroides* during the following growing season. The effect on a nearby community dominated by *Juncus roemerianus* was different. Productivity was lower than *Spartina* but still slightly higher than unburned control plots.

Marsh Harvests.

The harvests of marsh vegetation can occur in two ways; one, the periodic actual removal of the aboveground vegetation by clipping or cutting manually or mechanically; and two, the constant grazing by forage animals. Various marsh plants are grazed by sheep and goats in the Danube Delta, Romania, (de la Cruz 1976) and by cattle along the eastern and Gulf Coasts (Reimold 1976). This repeated harvest of biomass and the trampling effect of the animals has been shown to diminish the yield of grazed plants (Williams 1955). Contrarily, Reimold et al. (1975) found an increase in mean dry weight biomass following simulated grazing in a Georgia Spartina alterniflora marsh. Clipping experiments in a Mississippi Juncus roemerianus dominated brackish marsh indicated that neither repeated clippings nor single clippings altered the growth rate of the plants (Gabriel and de la Cruz 1974). In the simulated grazing study of Reimold et al. (1975) and the clipping experiments of Gabriel and de la Cruz (1974), compaction of the substrate is either absent or minimized.

Today, no harvest of marsh plants of significant economic impact is employed in the U.S. Though once a common practice, particularly in the east coast marshes, harvesting of Spartina patens as forage for animals and for garden mulch (de la Cruz 1976) is now an infrequent occurrence. In the vast reedlands of the Danube Delta in Romania, the common reed Phragmites communis is annually harvested for pulp and paper production (de la Cruz 1978). A systematic cropping scheme, mechanized harvesting, and irrigation systems to farm the high marsh areas for P. communis and also the giant cane, Arundo donax, have been developed for this wetland industry. If present works on chemical derivatives (Miles and de la Cruz 1976), on the pulping potential and on the cellulose by-products and alcohol fermentation (de la Cruz and Lightsey 1981) of marsh plants prove to be of economic value, the prospect of cropping certain marshland areas in parts of the world with extensive wetlands under managed farm-plantation schemes exist. The impact of regularly harvesting appropriate vegetations on the marsh ecosystem may have ecological consequences thus, investigations of primary productivity on harvested marsh areas is a timely pursuit.

Our preliminary observations on burning and harvesting coupled with the findings of other investigators (e.g., Gabriel and de la Cruz 1974; Reimold et al. 1975) led us to pose a number of questions: (1) How is primary productivity increased after a fire or following clipping? (2) Why is the increase not the same in the _Spartina_ and _Juncus_ marsh communities? (3) Will productivity continue to increase, if fire or harvest occurs annually? (4) If so, what will be the long-term effect on the marsh ecosystem? (5) If not, how frequent can the marsh be burned or harvested? (6) How much organic material vis-a-vis nutrients is removed from the marsh after a fire or removal of vegetation? These questions prompted us to undertake a more lengthy investigation of simulated winter fires and harvests on the marsh by controlled burning and managed harvesting of experimental plots and systematic monitoring of post-treatment vegetation growth.

The purpose of the present study, therefore, was to determine the effects of annual winter fire and harvest on the species composition, phenology, and primary productivity of a _J. roemerianus_ and a _S. cynosuroides_ marsh and to determine the frequency or time interval by which these management procedures can be applied in the Gulf Coast marshes.

Materials and Methods

This study was conducted on a bar-built island on the western side of St. Louis Bay in Hancock County, Mississippi (Figure 1). The plant communities on this island were previously described by de la Cruz (1973) and Gabriel and de la Cruz (1974). Winter fires have occurred regularly on certain sections of this island at intervals of 2-3 years, but the two study sites used in the experimental burning have not been burned since 1973. An adjoining area (Figure 2) was burned in the winter of 1976 and this was sampled for the

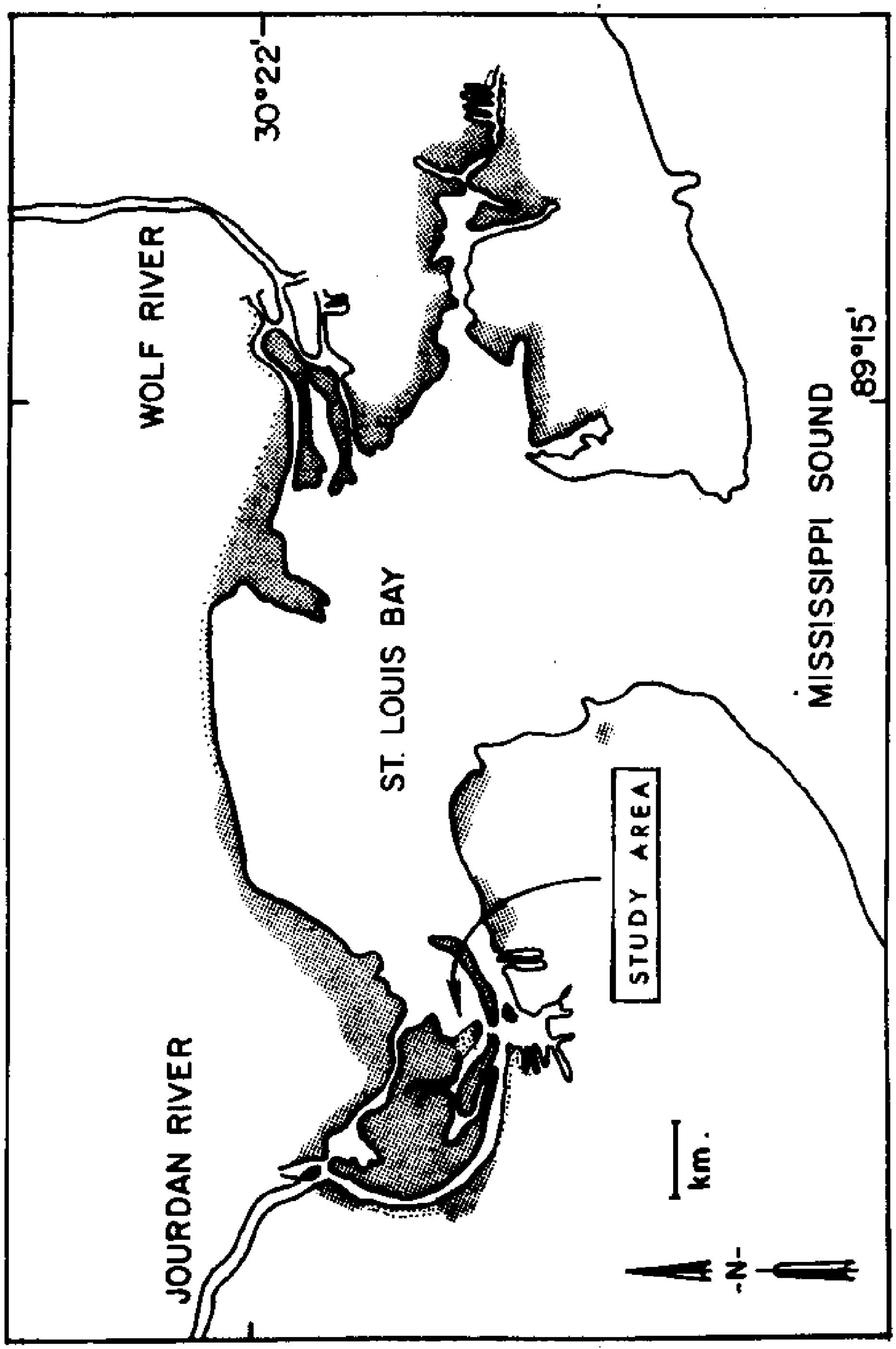

Figure 1. Study area in St. Louis Bay, Hancock County, Mississippi.

Figure 2. Aerial photograph of marsh island showing the _Spartina cynosuroides_ (SC) and _Juncus roemerianus_ (JR) marsh areas. The area (NB) enclosed by dotted lines was burned in 1976 and was used in the preliminary study. CB is Catfish Bayou and SLB is the western side of St. Louis Bay.

preliminary study. No harvest or removal of vegetation has taken place on this marsh except in spring when nutria and occasionally feral pigs graze the young sprouts of *S. cynosuroides*. The *Juncus roemerianus* marsh was located on the southwestern side of the island approximately 100 m south of a small tidal creek; the *Spartina cynosuroides* community was located on the eastern side of the island, about 20 m from a larger tidal creek (Figure 2). The two marshes appear monotypic, but each harbors at least three associated minor species.

Series of ten square meter plots were established in the two marsh communities (Figure 3) by isolating the plots with a 2 m wide firebreak lane from the surrounding marshes. Winter fire was simulated on the Burn plots during days deemed suitable for controlled burning. Burning was done at low tide, early in the morning when the marsh had not completely dried and when a very light northerly wind was blowing. Propylene torches were used to start the fire. The experimental plots were burned in mid-February, 1977. In 1978, the 1977 plot referred to as Burn 1 was burned again in the *S. cynosuroides* marsh and another experimental plot (Burn 2) was established; in 1979, the 1977 (Burn 1) and 1978 (Burn 2) plots were reburned and a third experimental plot (Burn 3) was established. Thus, in the *S. cynosuroides* community the 1977 or Burn 1 plot received three successive annual controlled winter fires, the 1978 or Burn 2 plot received two successive annual winter fires, and the 1979 or Burn 3 plot received one winter fire. The *Juncus* marsh could not be reburned and only the newly established plots were burned in 1978 and 1979. The recovery of the *Juncus* plots burned in the previous year was observed through 1979. The control plot originally established in 1977 was expanded to adjacent locations in subsequent years and used throughout the duration of the study.

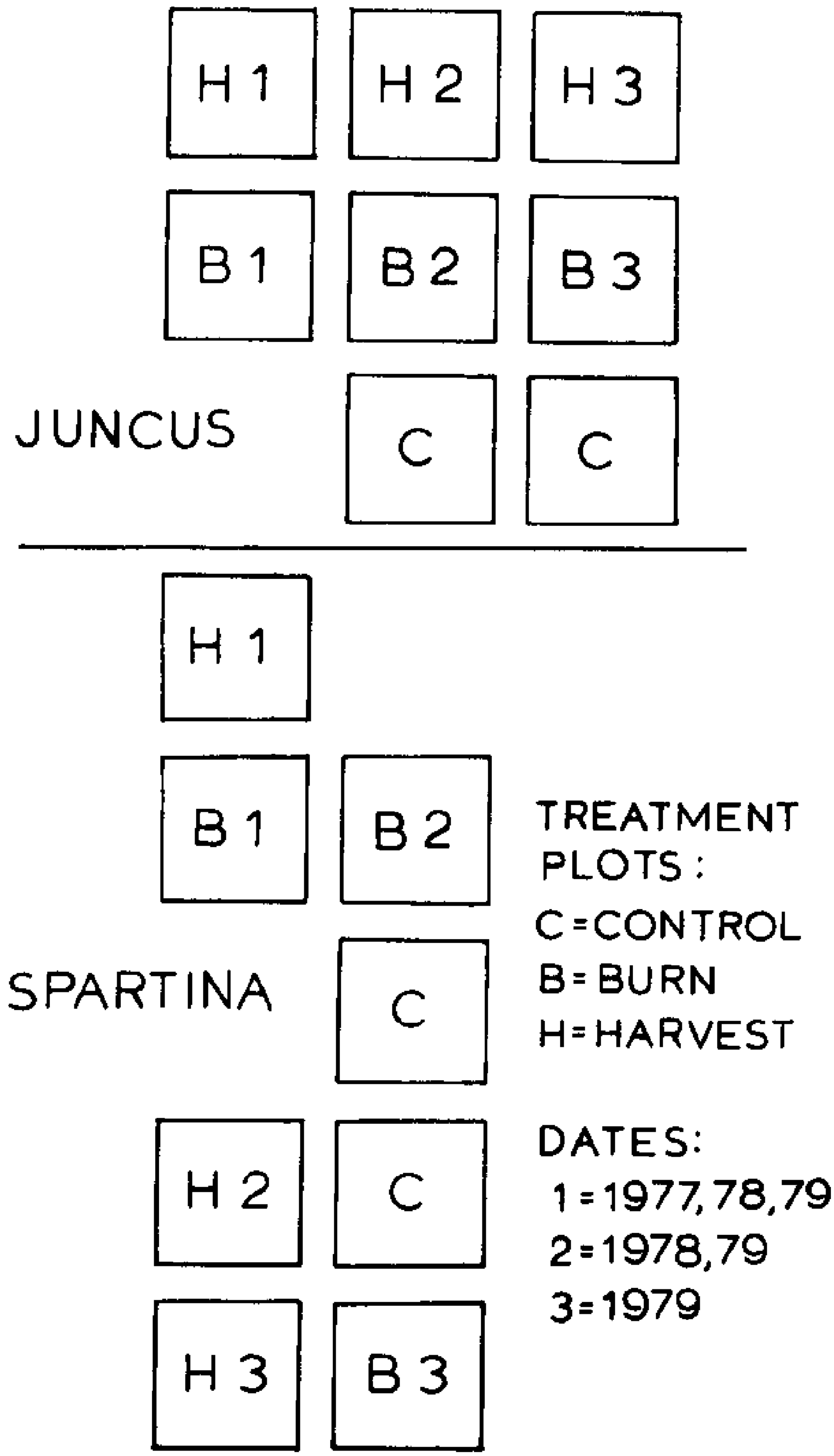

Figure 3. Diagram of the relative positions of the control and experimental plots in the Juncus and Spartina marshes during the three-year study.

The harvest plots were clipped close to the ground manually by means of garden shears during the 1977 and 1978 experiments and by a metal blade motorized grass cutter in 1979. Three sets of experimental harvest plots in both the *Juncus* and *Spartina* marshes received the following treatment: the 1977 plots (Harvest 1) received three successive annual clippings, the 1978 plots (Harvest 2) received two successive annual clippings, and the 1979 plots (Harvest 3) received one clipping.

Six 0.5 x 0.5 m quadrats were collected monthly from April through September 1977, 1978 and 1979 from each experimental and control plot. All living and dead materials were removed from each harvested plot including ground litter. Using the same procedures, a sample was collected in February before the burn and harvest treatments for background dead biomass data and in November after most of the seasonal growth had occurred. An additional collection was made on December 20, 1978, to replace the November sample lost in a drying oven fire. Using the wooden stakes as reference points, a random stratified sampling procedure was used. Such a procedure randomly selected certain areas within each study plot without causing severe trampling damage to the marsh. The six replicates were randomly collected from within this subarea.

Each sample was transported to the laboratory where it was separated into living and standing dead plants (those plants that were dead, but still attached to the roots or rhizomes), and litter on the ground. Living plants were separated according to species, dried to constant weight at 103°C and weighed. Aliquot samples of the dominant living vegetation from each area was retained for caloric and ash-free weight determinations. Annual net aboveground primary productivity (NAPP) was estimated from changes in standing live biomass using maximum minus minimum (max-min) values obtained by the predictive periodic model (PPM) described by Hackney and Hackney (1978). Whenever significant differences are noted between treatments, those differences are between predictive models describing the changes in live biomass. A model that predicted the accumulation of dead standing biomass was developed for each treatment and added to the periodic model to correct the net annual primary productivity for the loss of biomass due to early death of the plants. All statistical differences are at the $\alpha = 0.05$ level.

During the first year of the study (1977), six belowground samples were collected from each experimental and control plot at the same time as the aboveground with a coring device (10 cm diameter) previously described by de la Cruz and Hackney (1977). Each core was cut into 2 sections, 0-10 (surface), and 10-20 cm (subsurface) in length and were referred to as sections A and B, respectively. Most of the living subterranean material were previously observed to be located in the upper 20 cm of the marsh substrate (de la Cruz and Hackney 1977). Each core section was transported to the laboratory and washed thoroughly, but carefully, in running tap water over a 1 mm sieve. Living and dead rhizome and root materials could not be accurately separated. Each core was dried to a constant weight at 103°C. A subsample from the A and B core-sections was also retained from each collection period for caloric and ash-free weight analyses. Annual net belowground primary productivity (NBPP) was attempted from the mean monthly standing crop values using a general periodic regression curve as described by Bliss (1970) and applied previously by de la Cruz and Hackney (1977).

Additional aboveground and belowground samples were collected in 1977 from each plot and dried at 50°C for analyses of carbon, hydrogen, nitrogen and phosphorus content. All samples for elemental, caloric and ash-free weight analyses were ground in a Wiley-Mill with a No. 60 sieve. All samples were analyzed as follows: ash-free dry weight by ignition at 550°C for 6 hr; energy content by combustion in a PARR Adiabatic Bomb Calorimeter Model 1214; carbon and hydrogen by means of a Coleman C-H Analyzer Model 33; and nitrogen by means of a Coleman N Analyzer Model 29-021. Total phosphorous was determined by perchloric acid digestion according to the method outlined by Howitz (1975).

During the 1979-80 field study, phenological data were also collected such as average stem height, average stem weight, period of blooms, and number of inflorescences. Three square meter plots were marked off and all the inflorescence within the area was counted in the Juncus Control, Burn 3 and Harvest 3 plots on April 26, 1980; and in the Spartina Control, Burn 1, 2, and 3, and Harvest 1, 2, and 3 plots on July 18, 1980.

A regression coefficient analysis was used to compare the control, burn, and harvest plots among each other between treatments and between years.

Results

Burning and Harvesting the Marsh.

Burning the marsh was a fairly safe and easy task because the experimental plots were properly laid out with adequate fire breaks of 2 m clearance along their boundaries. The fire ignited quickly and swept the 10 x 10 m^2 plots within several minutes. The heat generated was intense as the dry plant material burned with a characteristic crackling sound. Attempts to record the temperature of the marsh surface failed due to malfunctions in the recording thermistor during the first try and accidental disintegration of the wiring during the second attempt. Within minutes after the fire, the marsh surface cooled quickly so that the ash and mud were just warm to the touch. Plants normally burned completely to the ground, except for some large clumps of stalks that left several centimeters of unburned stubbles.

The *Spartina* marsh burned faster and with greater intensity than the *Juncus* marsh. *Spartina* experimental burn plots also burned more uniformly and burned readily even after receiving one or more burns in previous years. It is evident that *Spartina* marsh can be burned and will burn annually because the plants produce enough litter and accumulate sufficient debris on the marsh surface to spread the fire effectively. The *Juncus* marsh did not burn readily and uniformly, especially the experimental plots with less floor-litter material. *Juncus* plots that were burned the previous years, were not burned again for the following reasons: a) *Juncus* marsh did not undergo a complete die-back in winter so that a great deal of green material remained; b) dead culms were generally still green at the base where growth takes place and, therefore, less vulnerable to controlled burning; c) the experimental plots had not accumulated enough litter mat to carry the fire over the entire plot. Thus, *Juncus* marsh would not easily or accidentally burn annually. Trappers are able to burn *Juncus*-dominated marshes only every three or more years, or only when the marsh is extremely dry.

Cutting the plants did not cause undue trampling of the substrate as due care was taken not to go through the same spot or path twice. Raking the surface of the mud very lightly, using regular yard rakes to remove the chopped pieces of plant material that had fallen to the ground, partially loosened the compacted surfaces created along footpaths. The *Juncus* plots were easier to cut than the *Spartina* plots, but more difficult to clean. Numerous bits and pieces of leaves were left on the surface. Plant regrowth was uniform in all the plots; the foliage looked very lush and was bright green.

Net Aboveground Primary Productivity.

The annual net aboveground primary productivity (NAPP) of experimental and control _J. roemerianus_ stands and experimental and control _S. cynosuroides_ stands are summarized in Tables 1 and 2. In these tables, the treatments designated as "natural burn" are marsh areas which were burned due to an unknown cause during the winter (February) of 1976 (See Figure 2). This fire could have been intentionally set by trappers or accidentally ignited by fishermen. These burned areas, and neighboring unburned marsh which served as control areas, were sampled during the 1976 growing season beginning the month of April. The treatments designated as "experimental burn or harvest" were series of 10 x 10 m plots which were experimentally burned or cut during the winters of 1977 (February 14), 1978 (February 19), and 1979 (March 2). Adjoining 10 x 10 m plots not burned or harvested served as control.

The response of the _Juncus_ marsh to winter fires and harvests was different from that of the _Spartina_ marsh, thus they will be discussed separately.

Juncus Marsh. The NAPP of the marsh which burned in 1976 (natural burn) was 31% higher than the control marsh (Table 1). In the experimental burn plots, NAPP of the 1977, 1978, and 1979 experiments were 33% (Burn 1), 36% (Burn 2), and 49% (Burn 3) higher than their corresponding control plots, respectively. The productivity models of the controls were significantly different ($\alpha = 0.05$) than the burn plots. Significant differences were due to the constant parameters α_0 which is a measure of the average standing crop (Table 3). Thus, the average standing stock of the burned plots was statistically lower than the controls during every year. As can be seen in Table 1, the net aboveground primary productivity level of the burn plots of both natural and experimental burn areas returned to the level of the control plots (535-580 g m^{-2} yr^{-1}) during the next year's growing season except Burn 1 in 1978. The 46% increase in NAPP of the Burn 1 plot during the second year growth in 1978 could be due to the mild winter season of 1978. The mild

Table 1. Aboveground net primary productivity ($g\ m^{-2}\ yr^{-1}$) of the Juncus roemerianus marsh communities which received simulated winter fires and harvests for one, two and three times annually. Values based on the periodic max-min model.

Marsh Communities and Treatment	1976	1977	1978	1979
Natural Control	557*	535	-	-
Natural Burn	812	495	-	-
Experimental Control	-	580	540	573
Experimental Burn 1	-	875**	1265	611
Experimental Burn 2	-	-	847**	645
Experimental Burn 3	-	-	-	1092**
Experimental Harvest 1	-	877***	1113***	611***
Experimental Harvest 2	-	-	681***	669***
Experimental Harvest 3	-	-	-	828***

*No productivity determination was done for Juncus control plot in 1976, thus data is based on the average value of all subsequent control measurements.

**These plots were burned during the winter immediately prior to growing season.

***These plots were harvested during the winter immediately prior to growing season.

Table 2. Aboveground net primary productivity (g m^{-2} yr^{-1}) of the *Spartina cynosuroides* marsh communities which received simulated winter fires for one, two and three times annually. Values are based on the periodic max-min model.

Marsh Communities and Treatment	1976	1977	1978	1979
Natural Control	1683	1673	-	-
Natural Burn	1822	1557	-	-
Experimental Control	-	1740	1430	1961
Experimental Burn 1	-	2152*	3765*	2239*
Experimental Burn 2	-	-	3925*	2339*
Experimental Burn 3	-	-	-	2419*
Experimental Harvest 1	-	1755*	2089**	2318**
Experimental Harvest 2	-	-	3450**	2009**
Experimental Harvest 3	-	-	-	2370**

*These plots were burned during the winter immediately prior to growing season.

**These plots were harvested during the winter immediately prior to growing season.

Table 3. Summary of the Periodic Regression Models used to determine primary productivity of the respective plant community.

General Periodic Regression Model

$$Y_i = \alpha_0 + \alpha_1 \cos(cox_i) + \alpha_2 \sin(cx_i) + e_i$$

where Y_i = dependent variable

α_0 = constant parameter (mean standing biomass g/m^2)

α_1, α_2 = coefficients of the harmonic function of X_i

$C = 2/n$

X_i = independent variable (time)

e_i = error

Treatment	α_0	α_1	α_2	α_3	α_4	r^2
			<u>Juncus roemerianus</u>			
Natural Control (1976)	937.6	76.2	-193.2			.593*
Natural Burn (1976)	770.9	-88.7	-162.9			.493
Control 1977	687.0	-143.2	-182.6			.394
Control 1978	858.3	-209.0	-54.7	-106.6	33.8	.373
Control 1979	843.6	-143.2	-192.0			.169
Burn 1 1977	561.3	-215.9	77.4			.532*
Burn 1 1978	647.1	-254.8	-4.83	-206.2	248.9	.559*
Burn 1 1979	833.2	-314.4	-396.6			.555*
Burn 2 1978	610.3	-268.3	104.6	36.1	47.1	.610*
Burn 2 1979	704.8	-252.8	-113.2			.465
Burn 3 1979	622.0	-233.6	110.8			.571*
Harvest 1 1977	546.3	-217.8	-19.7			.606*
Harvest 1 1978	635.5	-265.6	137.2	-11.9	147.0	.720*
Harvest 1 1979	461.2	-233.2	-101.2			.357
Harvest 2 1978	567.9	-221.0	49.0	71.7	-2.6	.520*
Harvest 2 1979	466.0	-282.0	-62.8			.659*
Harvest 3 1979	461.6	-339.2	-139.6			.807*

Table 3. (cont'd.)

Treatment	α_0	α_1	α_2	α_3	α_4	r^2
			Spartina cynosuroides			
Natural Control (1976)	645.2	-389.3	-535.6			.810*
Burn Control (1976)	571.0	-120.0	-598.0			.795*
Control 1977	606.4	-344.5	-675.8			.700*
Control 1978	847.1	-764.6	-441.5			.750*
Control 1979	758.8	-622.0	388.4			.604*
Burn 1 1977	812.6	-454.3	854.1			.826*
Burn 1 1978	978.4	-795.9	-715.6			.650*
Burn 1 1979	805.2	-612.0	-692.0			.627*
Burn 2 1978	1075.6	-817.1	-810.4			.660*
Burn 2 1979	877.2	-815.6	-578.4			.572*
Burn 3 1979	815.6	-708.4	-508.0			.545*
Harvest 1 1977	804.1	-427.7	-691.4			.740*
Harvest 1 1978	843.7	-508.6	-374.0			.400
Harvest 1 1979	775.6	-550.0	-678.0			.748*
Harvest 2 1978	1040.4	-694.5	-801.8			.630*
Harvest 2 1979	736.0	-623.2	-560.4			.700*
Harvest 3 1979	635.6	-658.8	-666.8			.696*

* Significant at 0.05.

winter produced a second period of growth which was reflected in the addition of a second periodic component in five of the 1978 periodic models for the Juncus communities (Table 3). NAPP of the 1977 (Harvest 1), 1978 (Harvest 2), and 1979 (Harvest 3) cut plots were 34%, 21%, and 31% greater than that of their respective experimental control in the Juncus marsh (Table 1). Again, these were statistically significant. Burn 1 and Harvest 1 plots had very similar NAPP over the 3-year periods. Burn 2 and 3 plots were 20-24% higher than the Harvest 2 and 3 plots, respectively. In 1979, after two and three consecutive annual treatments, the NAPP of Harvest 1 and 2 plots were similar to the Burn 1 and 2 plots, and closer to the productivity values of both natural and experimental control.

Analysis of the monthly standing dry biomass of the control plots during the growing season revealed some significant differences ($\alpha = 0.05$) among the predicted values for 1977, 1978, and 1979 samples (Figures 4 and 5). For comparative purposes, the average curve for the three control plots were fitted in the model. It will be seen that all the monthly biomass values of the Burn and Harvest plots fall below the mean of the control values (Figures 6-9) except for the 1979 Burn 1 plot.

As indicated earlier, Burn 2 was supposed to be burned again in February 1978, and Burn 3 in February 1978 and March 1979, but they would not burn due primarily to the insufficient litter mat on the marsh floor even after at least 2 years since the last winter fire.

Spartina Marsh. The NAPP of Spartina marsh which burned in 1976 (natural burn) was 8% higher than the natural control marsh but returned to the level of the control marsh the following growing season. In the experimental burn plots, NAPP value of plot Burn 1 (which received three annual winter fires) were all higher than the NAPP of the corresponding control plots. Burn 2

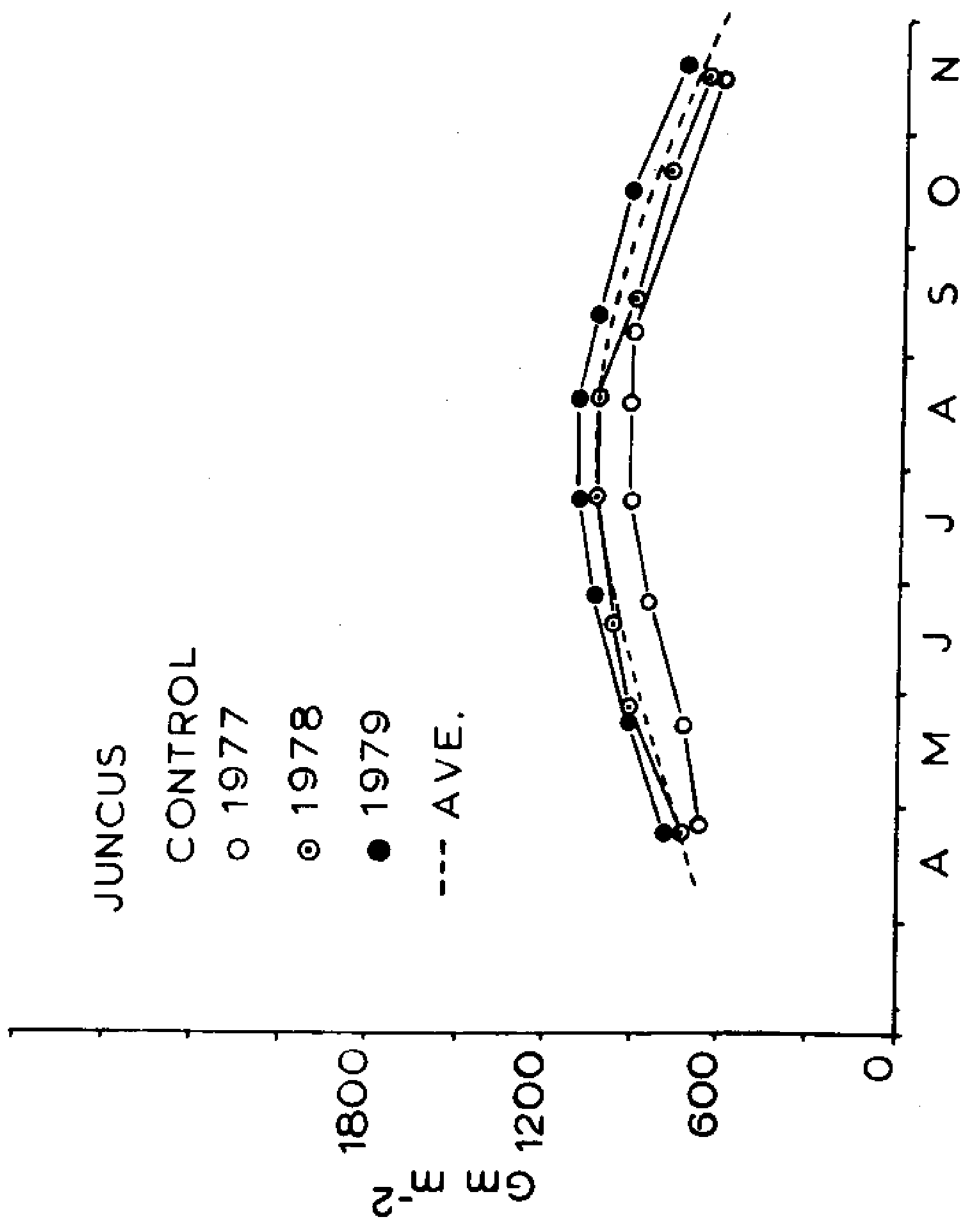

Figure 4. Predicted values of monthly total live biomass of J. roemerianus Control plots in 1977, 1978, and 1979.

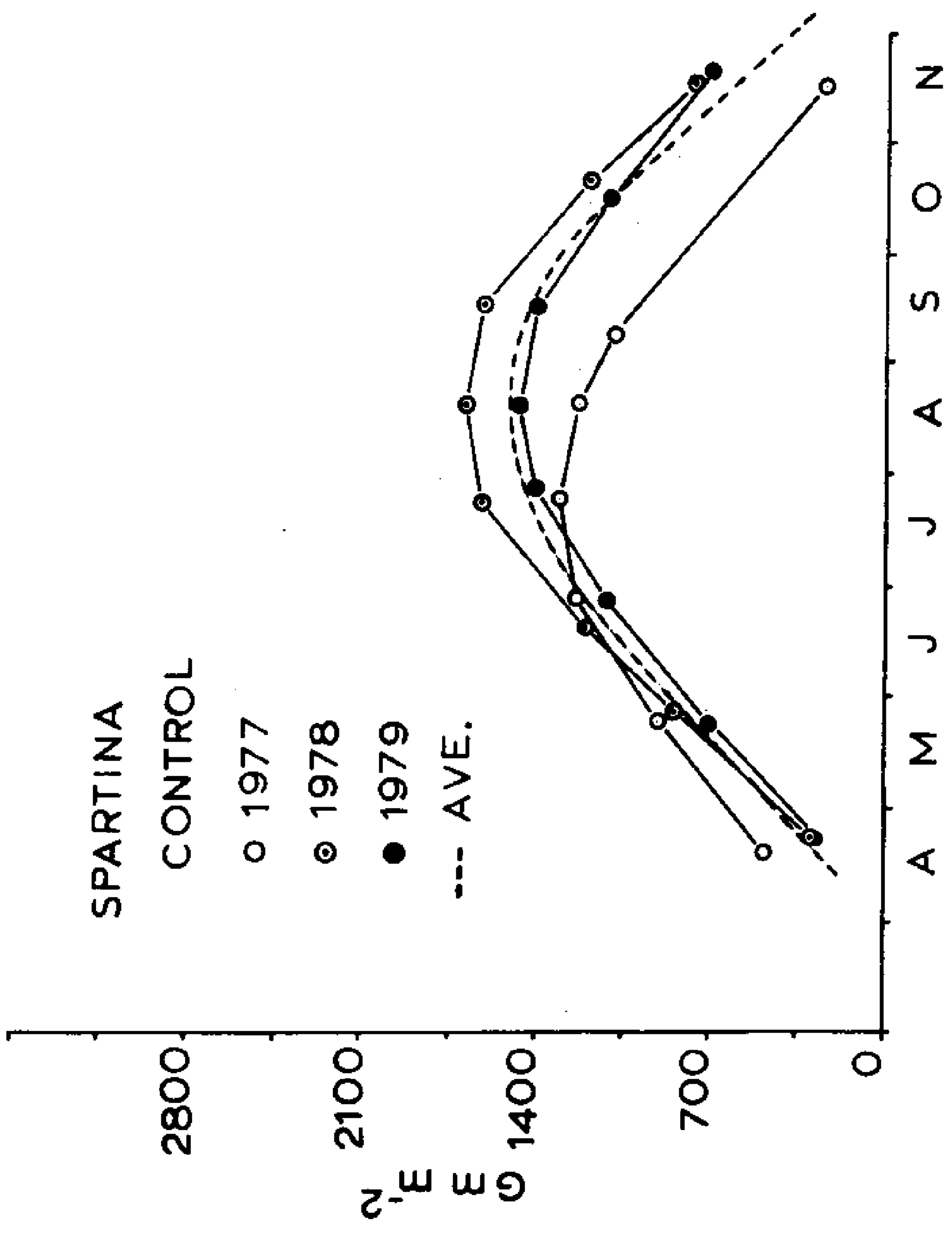

Figure 5. Predicted values of monthly total live biomass of S. cynosuroides Control plots in 1977, 1978, and 1979.

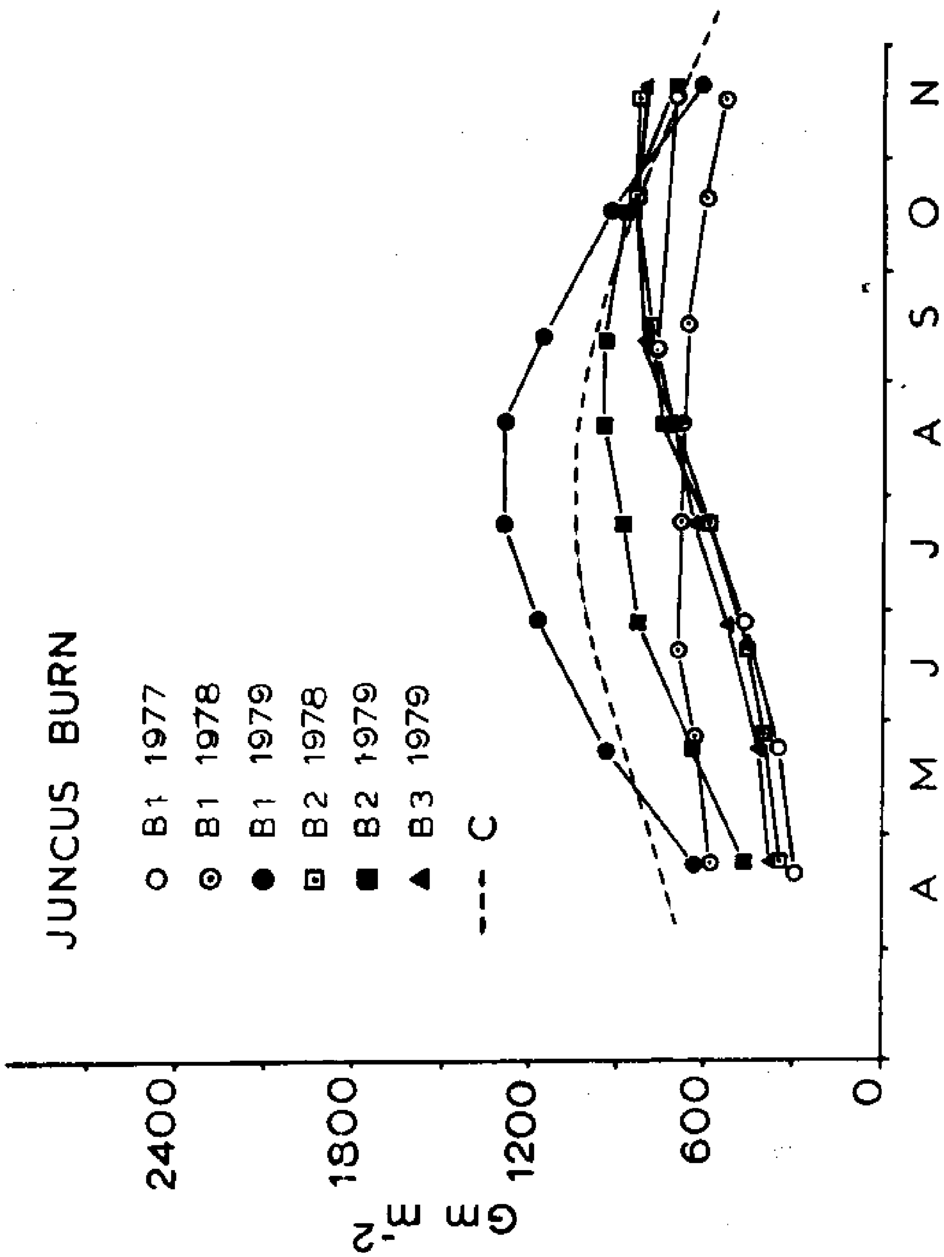

Figure 6. Predicted values of monthly total live biomass of J. roemerianus Burn plots compared to the annual average of Control plots. B_1 was burned in the winters of 1977, 1978, and 1979; B_2 in the winters of 1978 and 1979; and B_3 in the winter of 1979.

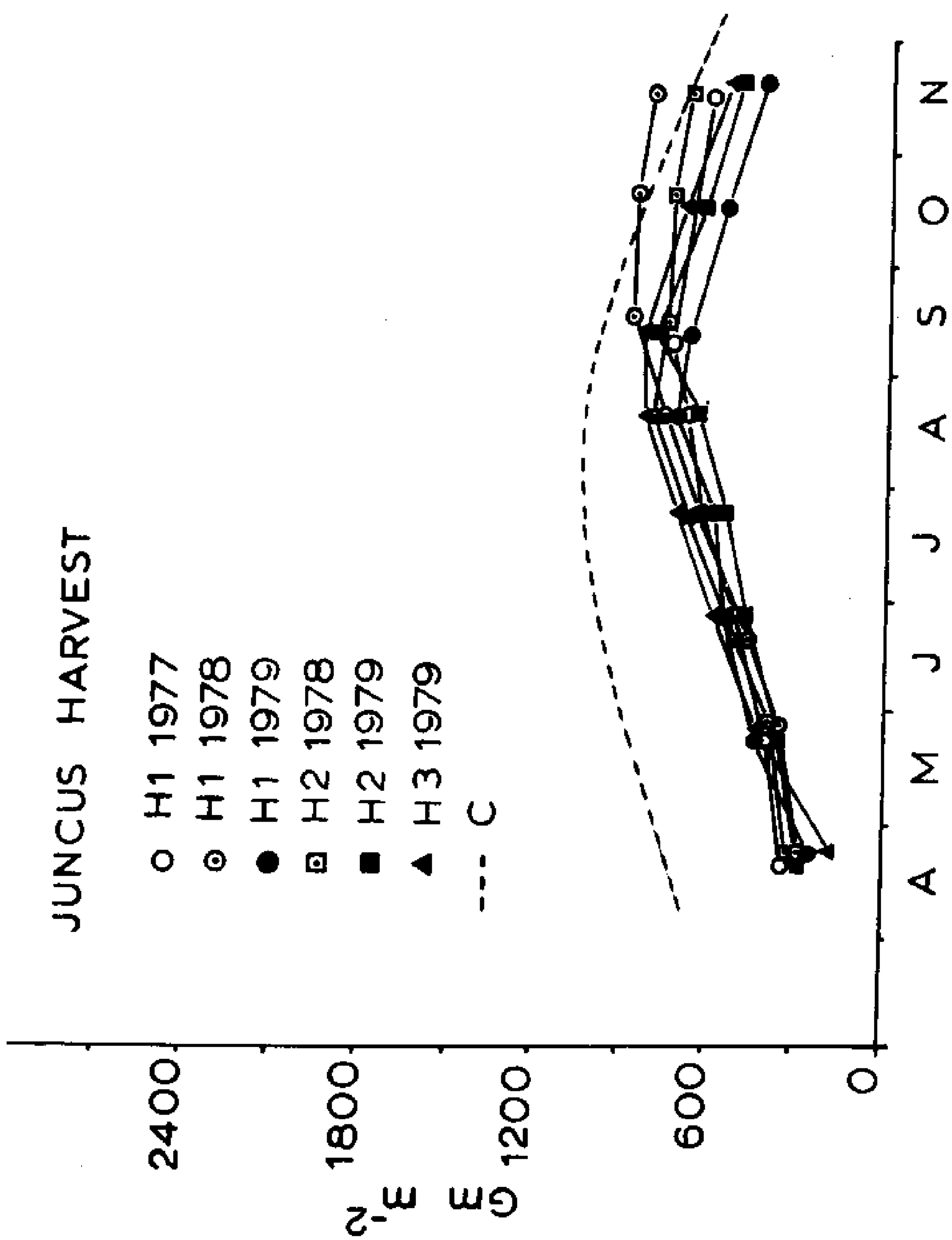

Figure 7. Predicted values of monthly total live biomass of J. roemerianus Harvest plots compared to annual average of Control plots. H_1 was harvested in the winters of 1977, 1978 and 1979; H_2 in the winters of 1978 and 1979; and H_3 in the winter of 1979.

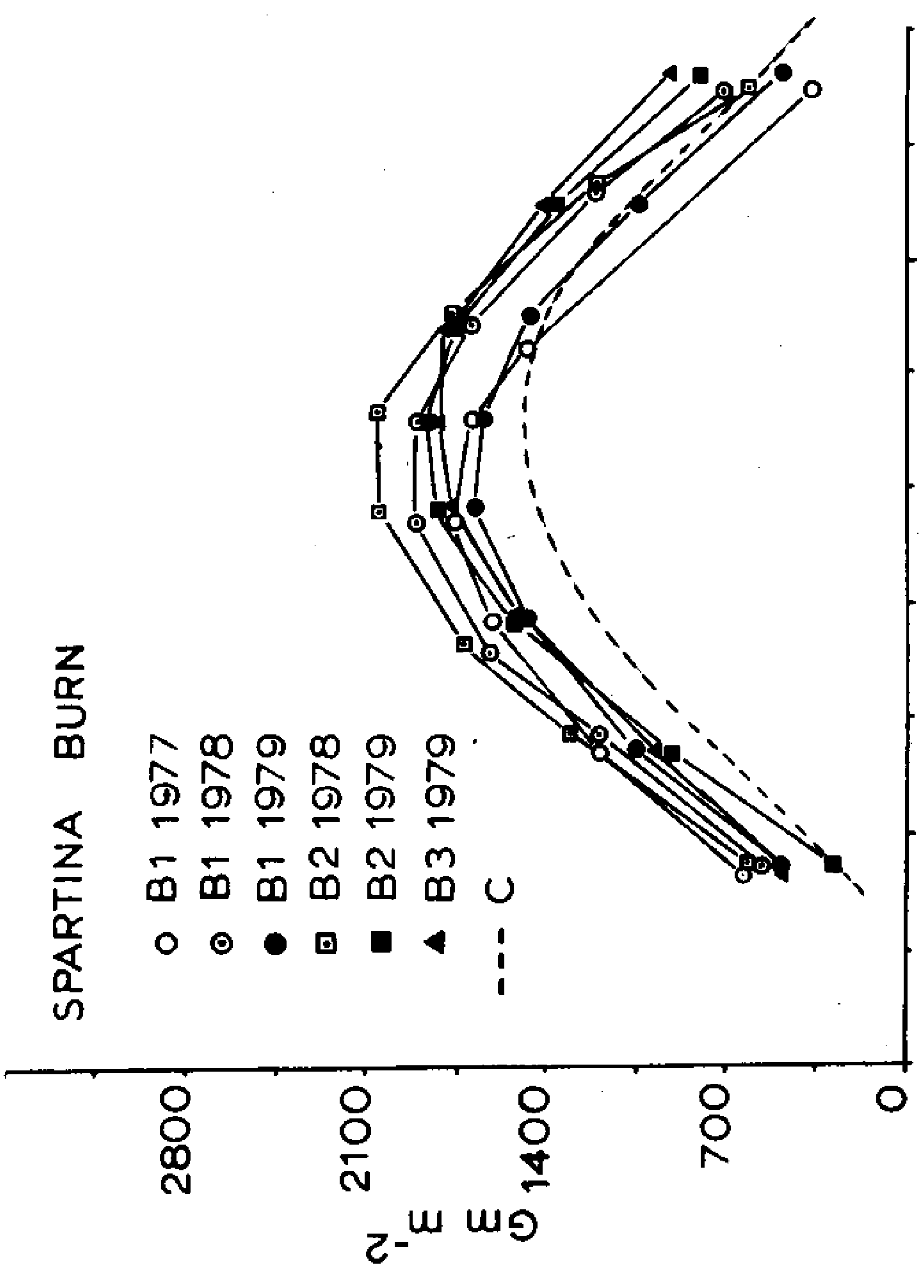

Figure 8. Predicted values of total monthly live biomass of S. cynosuroides Burn plots compared to annual average of Control plots. B_1 was burned in the winters of 1977, 1978, and 1979; B_2 in the winters of 1978 and 1979; and B_3 in the winter of 1979.

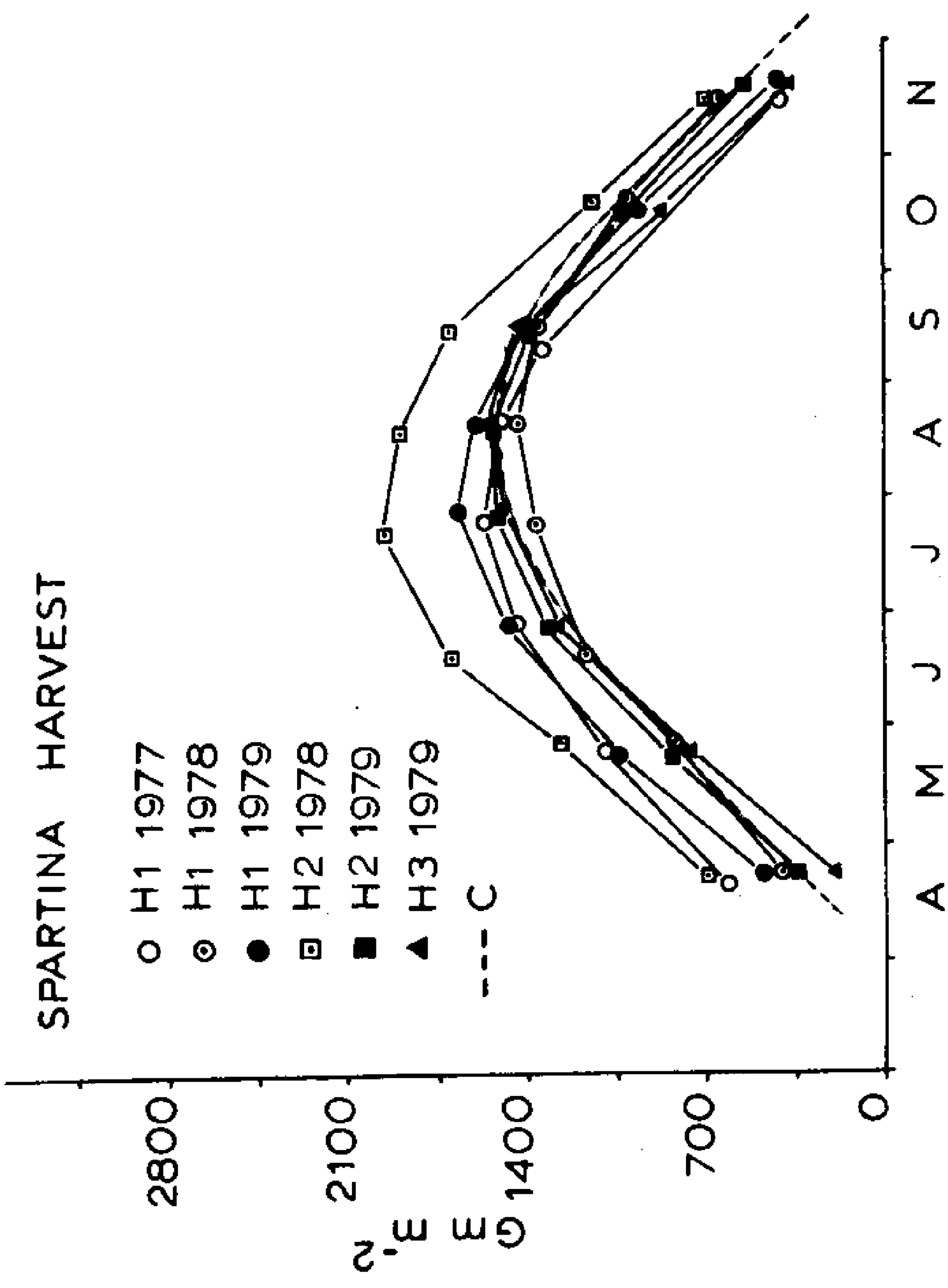

Figure 9. Predicted values of total monthly live biomass of _S_. _cynosuroides_ Harvest plots compared to annual average of Control plots. H_1 was harvested in the winters of 1977, 1978, and 1979; H_2 in the winters of 1978 and 1979; H_3 in the winter of 1979.

which received two annual winter fires in 1978 and 1979 had 16 and 27% more biomass production over the controls, respectively; and Burn 3 plot which was burned once in 1979 winter showed NAPP value which was 19% more than the control (Table 2). The harvested plots showed some increases in NAPP (15-17%) over the control also but not as much as in the burned plots. As already indicated, the 1978 growing season was preceded by a very mild winter which allowed the plants to grow for a longer period and resulted in increased biomass production in the control (2860 g m^{-2} yr^{-1}), burn (3765-3925 g $m^{-2} yr^{-1}$), and harvest (2089-3450 g m^{-2} yr^{-1}) plots.

All the control and treatment plots showed similar patterns of growth with a biomass peak occurring between July and August. The monthly growth curves for the 1977 control was significantly different ($\alpha = 0.1$) from the 1978 and 1979 curves (Figure 5). In general, the monthly biomass curves for all the Burn (Figure 8) and Harvest (Figure 9) plots were higher than the three-year average value of the control.

The experimental burn plots burned readily when the conditions for the controlled fire were present. Spartina marshes are more vulnerable to annual winter fires. Our results indicated that aboveground primary productivity of Spartina is not negatively affected by annual burning and, in fact, is enhanced by winter burning and harvesting.

The Primary Productivity Model. The periodic regression models used to determine the primary productivity of the various marsh communities are summarized in Table 3. The periodic maximum minus minimum technique (PPM model) is a conservative estimate which allows the use of all data collected over the year, instead of just the lowest and highest values (Hackney and Hackney 1978). Such a model can be compared statistically and differences between communities or treatments can then be detected. R squared values were all significant (α = 0.05) for all the treatments of *Spartina* marsh except Harvest 1 (1978) plot, and for most of the treatments of *Juncus* marsh except the control plots and the 1979 Burn 2 and 1979 Harvest 1 plots.

Plant Vigor and Flowering.

Winter fire did not affect the density of the culms in the *Juncus* marsh. There was, however, a decrease in the height of the culms. When compared to the control plot, which had a maximum culm height of 150-200 cm throughout the growing season, Burn 3 plot which received one fire during the 1979 winter showed maximum culm height below 150 cm (Figure 10). Burn 1 plot which was burned two years previously and Burn 2 plot which was burned a year before showed maximum culm heights that progressively approximate that of the control. Maximum culm height was achieved during late summer (July-September) in all the plots. Culm heights in all the three harvested plots were all significantly less than the control. Harvest 1 plot which was cut for three consecutive winters had the shortest culm heights. Mean dry weight per culm among the experimental burn and harvest plots showed the same relationship to the control plot (Figure 11). Maximum biomass per culm also occurred between July and September in all the plots. It is evident that fire and harvest negatively affect the height and weight of *Juncus* (Table 4), but the vigor of the plants seems to return to normal, i.e., to the level of the plants in the control plot, within three years after the initial treatment.

Figure 12 compares the mean dry weight of each *Spartina* shoot in the control plot and those in the Burn 3 and Harvest 3 plots which received one fire in 1979. There was essentially no difference between the control and burn plots except for samples measured during the month of November when the mean dry weight per shoot of the control was 10-20 g more than the burn and harvest plots, respectively. The harvested plot showed a lower monthly dry biomass

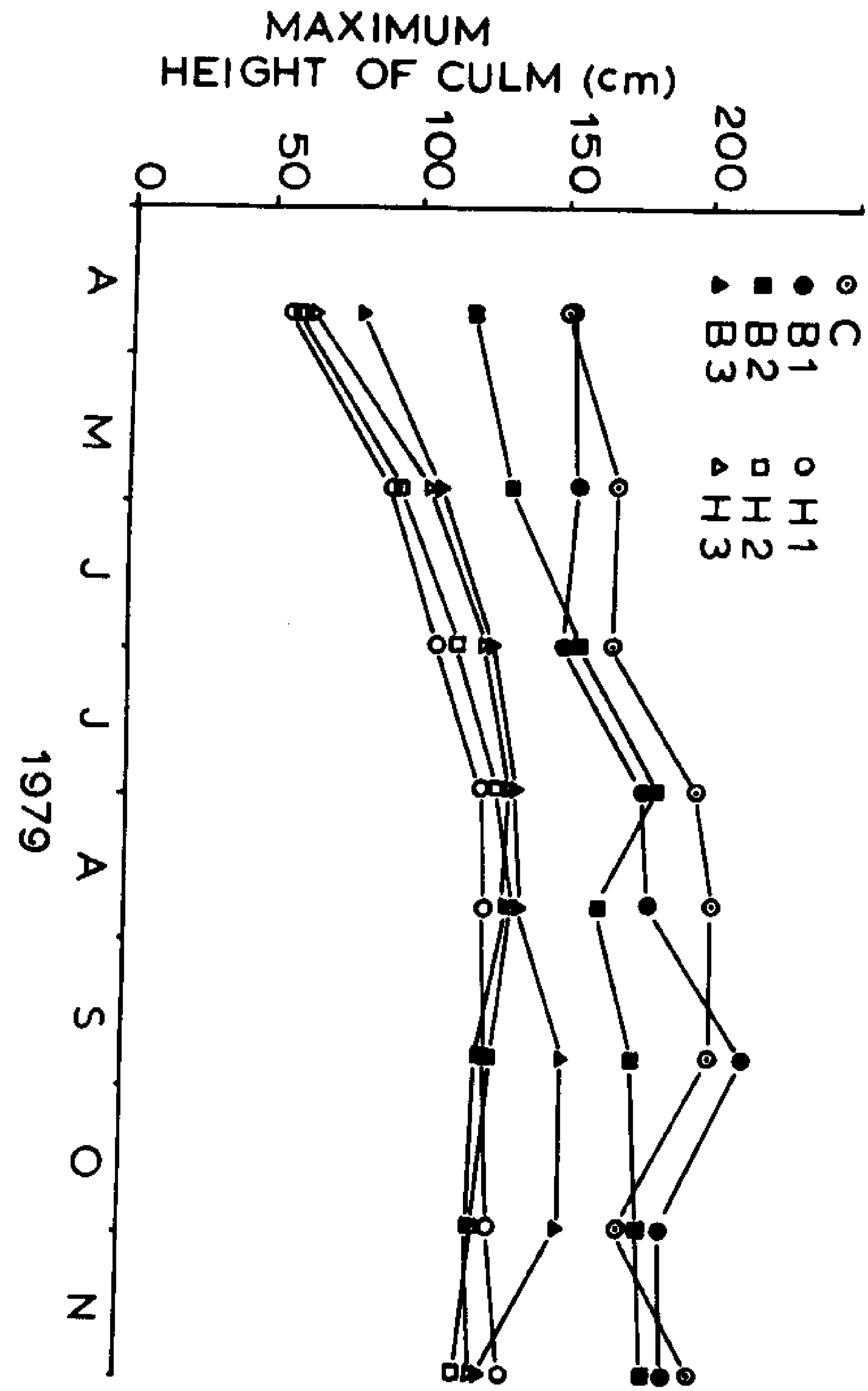

Figure 10. Monthly average of maximum height of Juncus culms during the 1979 growing season in the three Burn (B) and Harvest (H) plots which received one (3), two (2), and three (1) simulated annual winter fires and clippings compared to an untreated Control (c) plot.

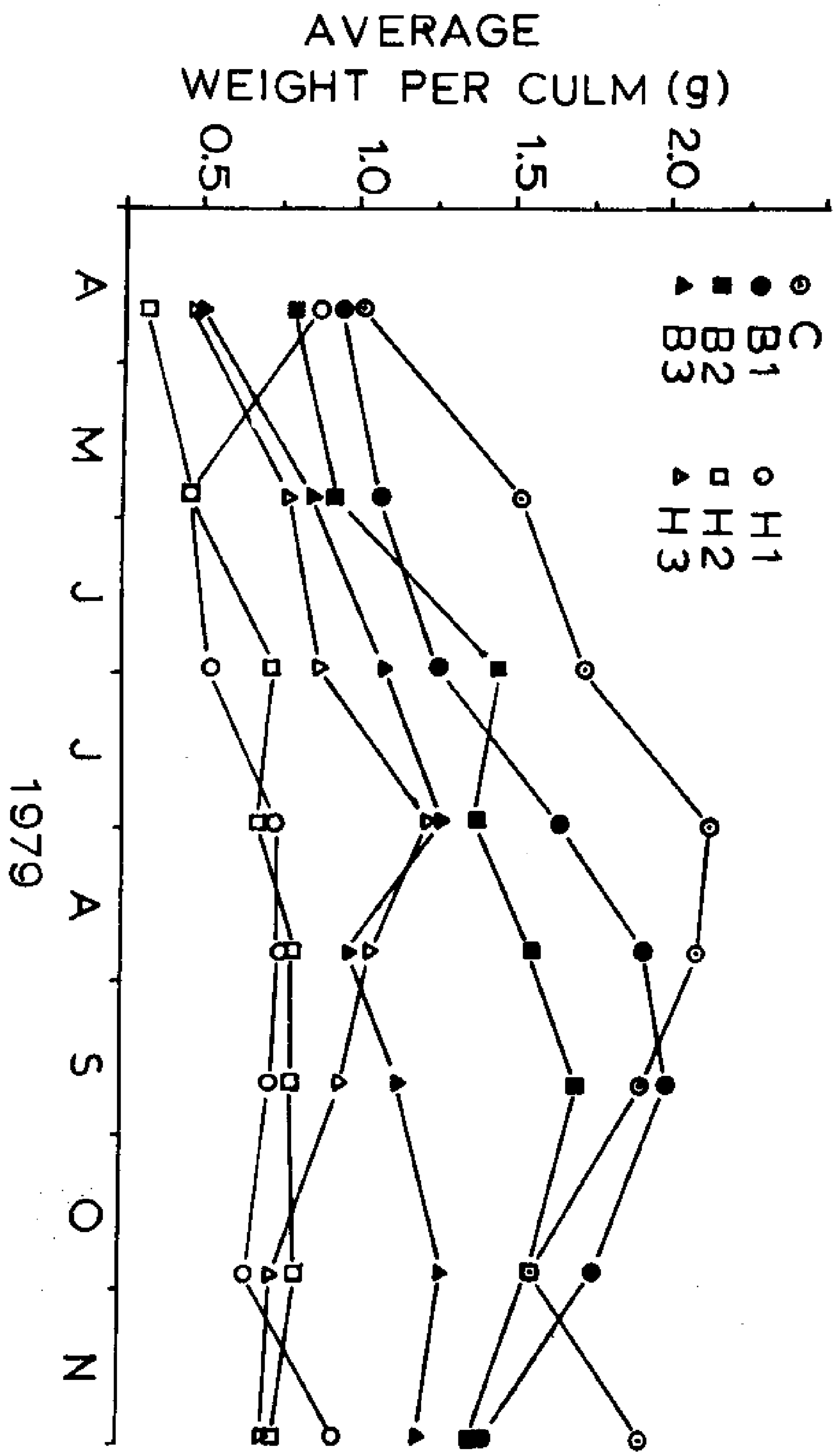

Figure 11. Monthly average of mean dry weight per <u>Juncus</u> culm during the 1979 growing season in the Control, Burn, and Harvest plots.

Table 4. Mean maximum height and mean dry weight per culm per square meter in the *Juncus* and *Spartina* control and burn plots in 1979. Number followed by the same letters are not significantly different according to Duncan's New Multiple Range Test.

Marsh/Treatment	Mean Height (cm)	Mean Dry Weight (gm)
J. roemerianus		
Control	187[a]	1.74[a]
Burn 1	177[a]	1.51[ab]
Burn 2	161[a]	1.34[b]
Burn 3	127[b]	1.03[c]
Harvest 1	111[b]	0.66[d]
Harvest 2	113[b]	0.70[d]
Harvest 3	116[b]	0.82[cd]
S. cynosuroides		
Control	*	18.7[ab]
Burn 1		13.9[ab]
Burn 2		14.7[ab]
Burn 3		20.7[b]
Harvest 1		10.6[a]
Harvest 2		11.1[a]
Harvest 3		11.1[a]

*No measurement was taken due to the difficulty of obtaining accurate height data for each individual culm.

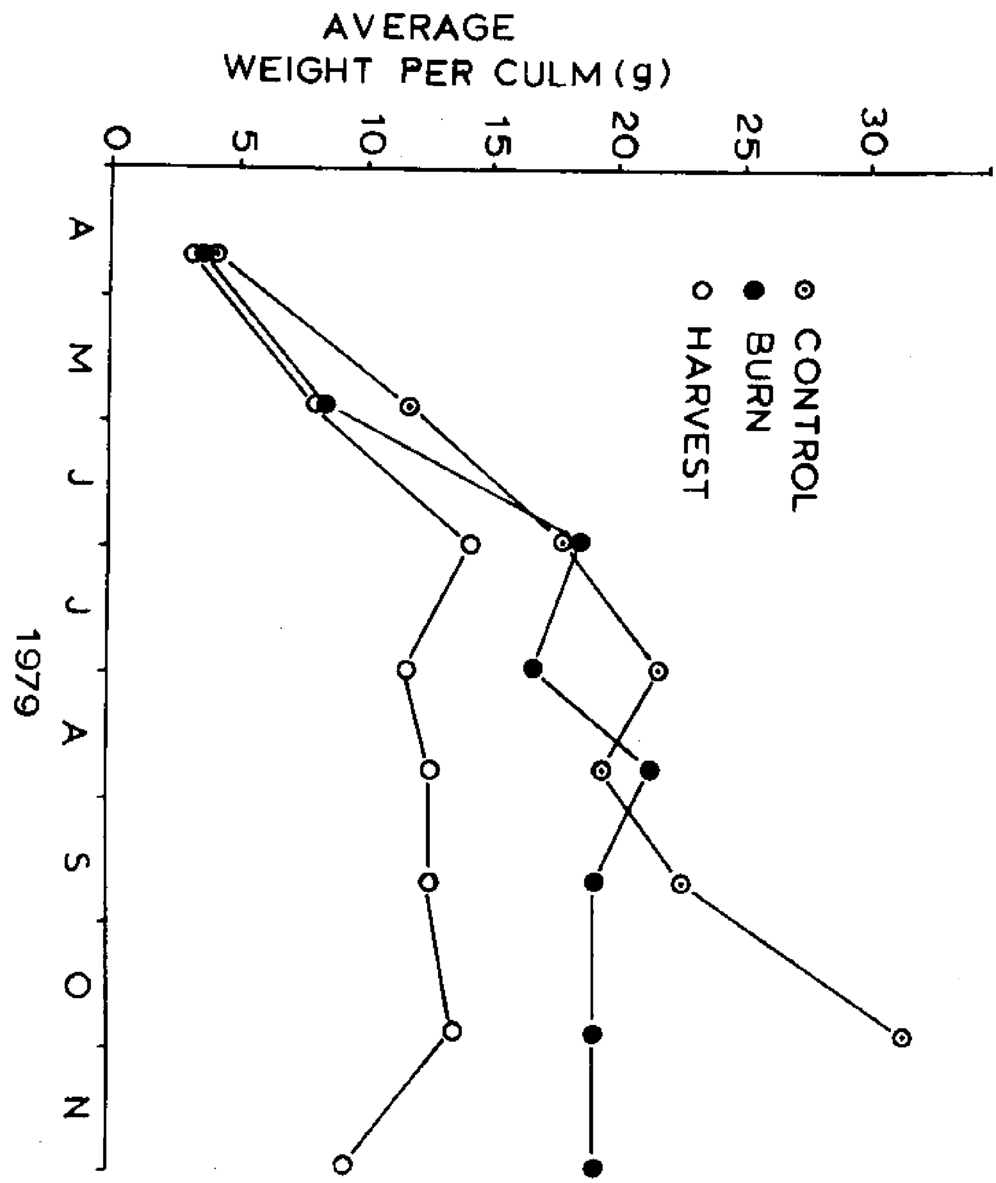

Figure 12. Monthly average of mean dry weight per <u>Spartina</u> shoot during the 1979 growing season in the Control, Burn and Harvest plots.

value than the control.

In 1978, we noted an increase in the number of inflorescence of both J. roemerianus and S. cynosuroides in their respective communities. We noted this increase in the original burn plots. Consequently, we followed the flowering patterns carefully in 1979 and found that the Juncus Burn 2 and Harvest 2 plots produced more inflorescence than the control plots (Figure 13). There were 28 inflorescences per m^2 in the Burn 2 and Harvest 2 areas during the blooming season as compared with 3.6 per m^2 in the control (Table 5). These differences were statistically significant. Juncus produced more flowers the second season following a fire and returned to control levels the following year while the Spartina responded the same year as the fire.

In 1980 we returned to the study sites and found that the Burn 3 and Harvest 3 plots in the Juncus plots produced more flowers (Table 5). This was essentially the same pattern we observed the year before in the Juncus community, i.e., that maximum flowering occurred one year after fire and harvest treatment. In the Spartina community, none of the plants produced more inflorescences than the control in 1980.

The removal of the vegetation seems to be the factor promoting the production of flowers in the Juncus community since the burn plots increased their flower production. There is a limitation on flower production since repeated burning does not have the same effect. This is not surprising for the Juncus since the living plant is damaged by the fire.

Community Structure: Minor Species.

Following one treatment, either fire or harvest, there was very little difference in the percent composition of minor species when compared to the control. Because the burn treatment was not repeated, no change was evident in the burned plots during the study (Figure 14). Repeated removal of the

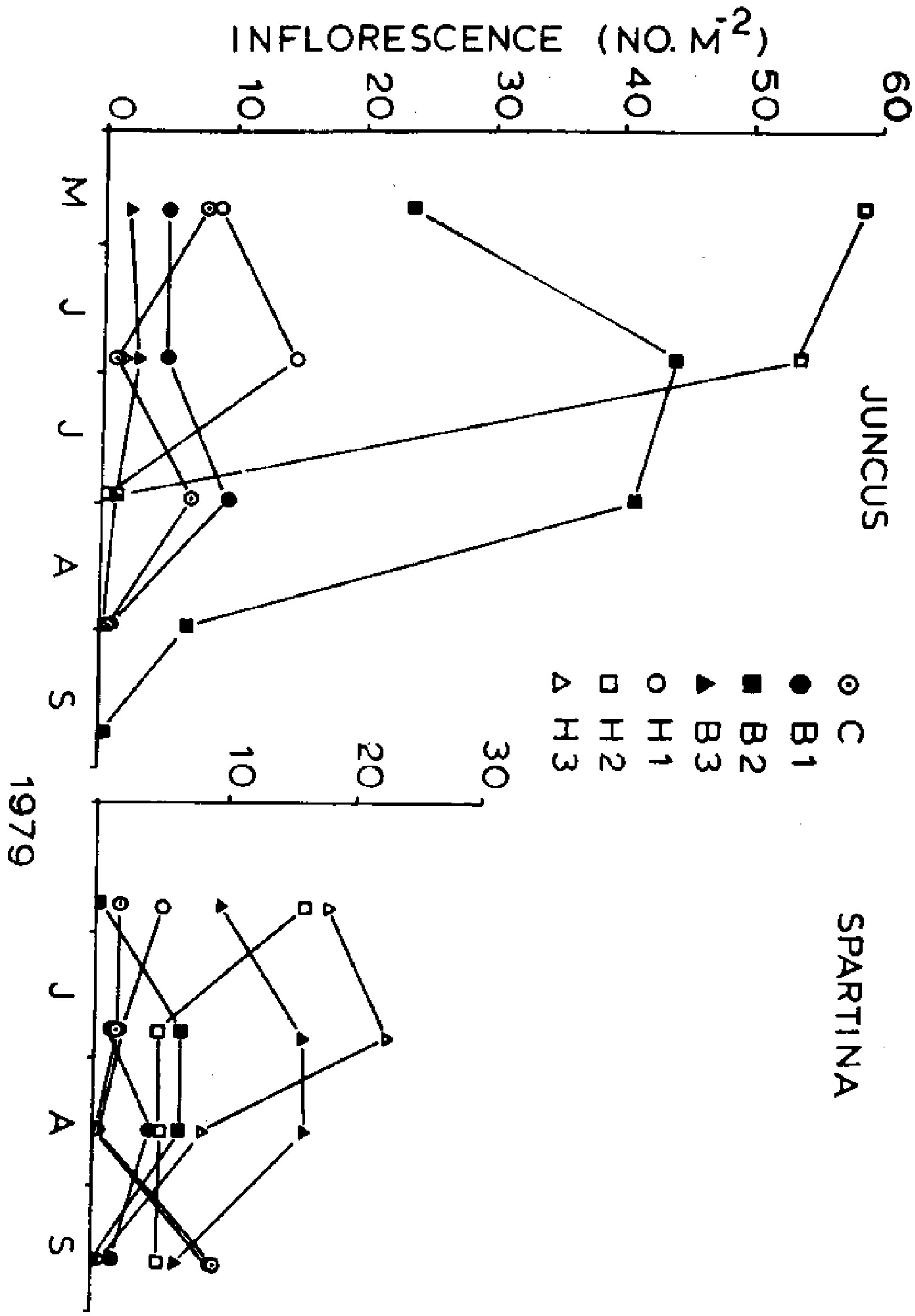

Figure 13. Number of inflorescence per square meter in the Control, Harvest, and Burn plots of Juncus and Spartina communities during the 1979 flowering season.

Table 5. Number of inflorescence per square meter in the *Juncus* and *Spartina* Control, Burn and Harvest plots in 1979 and 1980. Number followed by the same letter are not significantly different according to Duncan's New Multiple Range Test.

	Number Inflorescence per Square Meter	
Marsh/Treatment	1979	1980
J. roemerianus		
Control	3.6[a]	1.7[a]
Burn 1	4.8[a]	-
Burn 2	28.2[b]	-
Burn 3	1.2[a]	33.7[b]
Harvest 1	5.8[a]	12.5
Harvest 2	28.0[b]	13.8
Harvest 3	0.2[a]	40.8
S. cynosuroides		
Control	1.5	0
Burn 1	1.0[a]	0
Burn 2	1.5[a]	0
Burn 3	5.0[a]	0
Harvest 1	1.3[a]	0
Harvest 2	2.8[a]	0.6[a]
Harvest 3	5.0[a]	2.0[a]

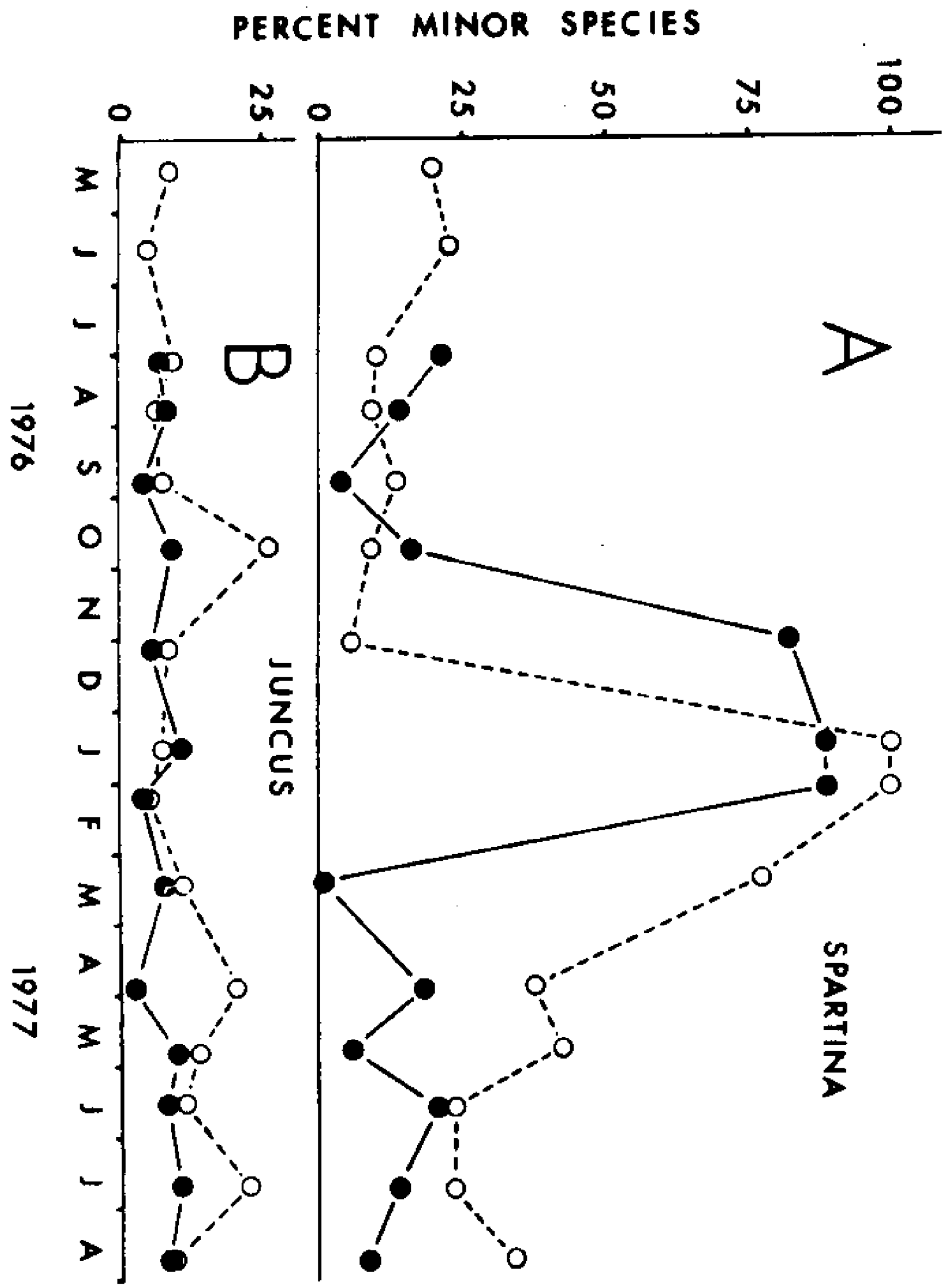

Figure 14. Changes in the dry biomass of the minor species expressed as a percent of the total dry biomass from 1976-1977. Solid dots represent controls and open dots the burned areas.

vegetation by cutting, however, changed the community structure in the Harvest or Cut 1 plot during the second year of the study. That trend was even more apparent during the third year when both Harvest 1 and 2 differed from the control (Figure 15). Minor species comprised more than 50% of the biomass in these plots with the increased contribution of minor species due to an increased standing stock of *Fimbristilis castanea* (one of the minor species) and *S. cynosuroides*. Continued removal of vegetation from a *Juncus* marsh community increased productivity but changed the structure of the plant community. This was observed in the Harvest or Cut plots and presumably would have occurred in the Burn plots if the plots had been burned each year.

The *Spartina* Burn and Harvest or Cut plots also contained other plant species, most notably *Panicum virgatum*. The percentage of minor species decreased in the control community after August 1978 but remained high in the treated plots. The difference was even more notable in 1979 when Burn and Harvest plots routinely contained more than 50% minor species. During the same time period, the percent minor species in the control decreased to near zero.

Belowground Biomass.

The standing crop of belowground materials in both Control, Harvest 1, and Burn 1 plots in both the *Juncus* and *Spartina* marshes remained constant throughout the 1977 growing season, thus, no productivity estimate could be made. Comparison of the monthly belowground biomass data (Tables 6 and 7) indicated the following: a) There appears to be the same amount of dry material in 0-10 cm and 10-20 cm depths in the *Juncus* marsh and a greater biomass in the 10-20 cm depth than in the 0-10 cm depth in the *Spartina* marsh; b) Both marshes showed higher belowground standing crop at the 0-10 cm depth in the Burn and Harvest plots during the peak of the growing season (May-July) than

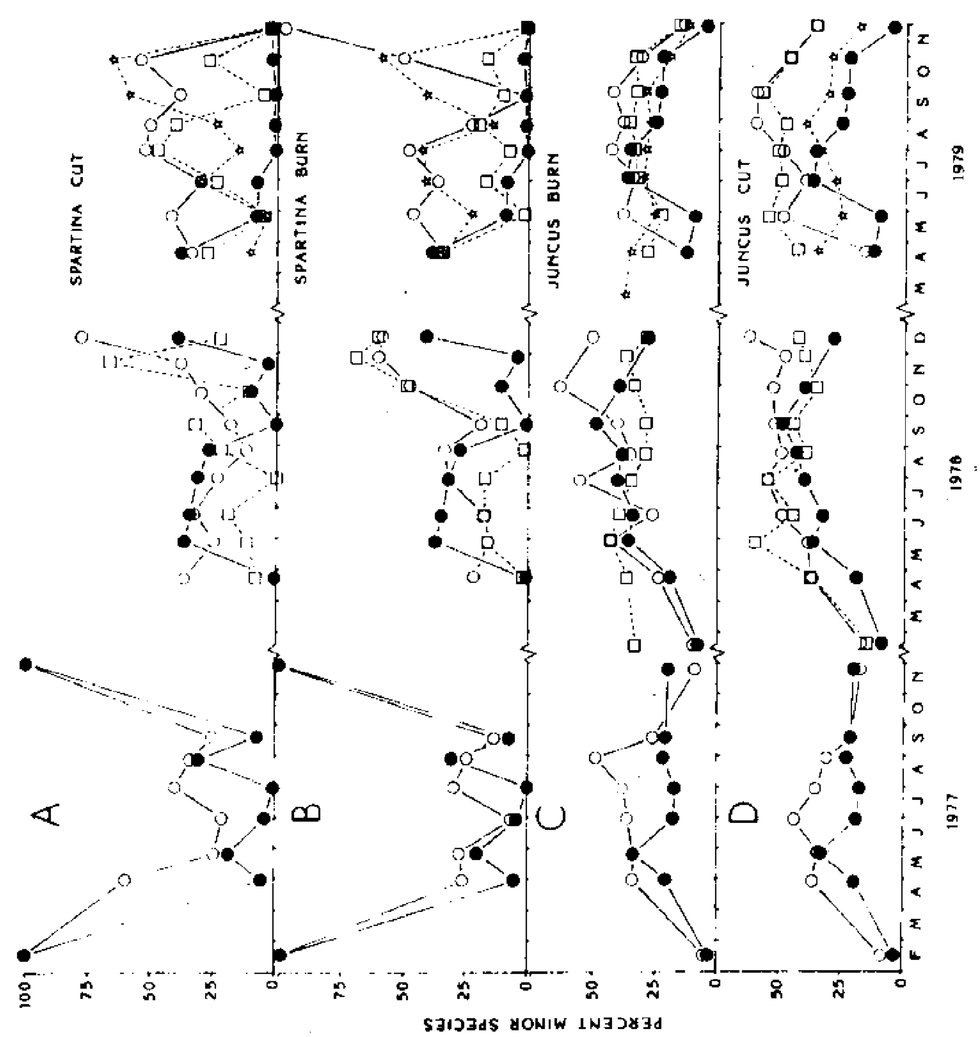

Figure 15. Changes in the dry biomass of the minor species in the Burn and Harvest (cut) plots expressed as a percent of the total dry biomass from 1977 to 1979. Solid dots represent controls; open dots, treatments begun in 1977; open squares, treatments begun in 1978; and stars, treatments begun in 1979.

Table 6. Monthly standing crop of belowground biomass (kg/m^2) in the Mississippi *J. roemerianus* Control, Burn 1 and Harvest 1 plots at the 0-10 cm and the 11-20 cm depth levels during 1977 growing season.

Date	Control	Burn	Harvest
	0-10 cm Depth Level		
2-15-77	3.24	2.99	3.44
4-27-77	3.00	3.57	3.62
5-25-77	2.46	3.30	2.67
6-29-77	3.88	4.00	3.91
7-29-77	2.24	3.81	3.72
8-26-77	2.84	2.74	3.79
9-17-77	3.88	2.88	3.03
11-26-77	2.86	3.09	3.63
	11-20 cm Depth Level		
2-15-77	2.42	2.64	2.37
4-27-77	2.90	3.00	2.57
5-25-77	2.46	2.67	2.66
6-29-77	2.53	2.80	2.43
7-29-77	2.30	2.52	2.48
8-26-77	2.23	3.06	2.78
9-17-77	2.23	2.52	1.96
11-26-77	2.57	2.72	2.79

Table 7. Monthly standing crop of belowground biomass (kg/m^2) in the *S. cynosuroides* Control, Burn 1, and Harvest 1 plots marsh in the 0-10 cm and 11-20 cm depth levels during 1977 growing season.

Date	Control	Burn	Harvest
		0-10 cm Depth Level	
2-15-77	2.84	2.92	2.61
4-19-77	2.64	2.27	2.93
5-24-77	2.37	2.56	3.88
6-28-77	2.80	3.60	4.06
7-28-77	3.97	4.01	3.95
8-26-77	2.25	2.46	4.41
9-17-77	2.85	2.25	2.53
11-26-77	2.23	3.60	2.94
		11-20 cm Depth Level	
2-15-77	4.07	5.21	4.71
4-19-77	4.66	3.91	3.45
5-24-77	3.92	5.41	4.71
6-28-77	4.55	4.62	4.71
7-28-77	4.88	4.71	3.78
8-26-77	4.75	4.33	5.26
9-17-77	4.19	4.24	4.48
11-26-77	3.51	4.00	5.04

the control plots.

Chemical Composition.

In general, the caloric value (Kcal/g AFDW) and nutrient (C, H, N, P) concentrations in the monthly samples of above- and belowground materials did not show any pattern of change during the year (1977). Neither were there any significant differences between the Control, Harvest, and Burn plots. However, the following observations can be made from the results of the analyses (Tables 8 to 13): a) Aboveground nitrogen and phosphorus concentrations were higher in the Juncus Burn and Harvest plots in the April sample; b) Belowground (0-10 cm depth) phosphorus in the May, June, and July samples was higher in the Juncus Burn and Harvest plots; c) Aboveground nitrogen and phosphorus in the April sample were higher in the Spartina control plot; d) Belowground (0-10 cm depth) nitrogen in the April and June samples was higher in the Spartina control plot. These observations may be indicative of the dissimilar response Juncus and Spartina marshes have towards burning and harvesting.

Discussion

The accumulation of three consecutive years of data has allowed us to make more realistic comparisons of the growth and biomass of J. roemerianus and S. cynosuroides marshes following winter fires or harvests. We noted significant variations in the growth of the Juncus community under unaltered situations attributed to annual variation. For example, the 1977 growth was different from that of 1979 (Figure 16). Likewise, the 1977 Spartina control community differed from 1978 and 1979 (Figure 17). The aboveground primary productivity of the Spartina marsh also showed annual variation (Table 2), while only a small annual difference was noted in the aboveground primary productivity of Juncus community (Table 1). We could not statistically

Table 8. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi _J. roemerianus_ Control plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.815
4-26-77	44.875	6.585	0.726	0.077	4.593
5-25-77	46.683	6.044	0.704	0.078	4.571
6-29-77	44.954	6.072	0.410	0.072	4.746
7-29-77	45.438	6.296	0.685	0.080	4.554
8-26-77	45.826	6.485	0.811	0.078	4.882
9-17-77	44.011	5.899	0.802	0.079	4.884
11-26-77	44.483	6.061	0.961	0.078	4.884
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.811
4-27-77	42.045	5.852	0.551	0.085	4.780
5-25-77	43.161	5.679	0.549	0.074	4.705
6-29-77	40.830	5.414	0.512	0.058	4.844
7-29-77	40.572	5.520	0.503	0.077	4.863
8-26-77	41.731	5.466	0.500	0.078	5.070
9-17-77	39.537	4.890	0.518	0.075	5.119
11-26-77	41.999	5.278	0.396	0.074	4.982
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	3.845
4-27-77	44.590	5.749	0.417	0.071	4.729
5-25-77	39.866	5.638	0.498	0.069	4.850
6-29-77	42.468	5.343	0.354	0.074	5.134
7-29-77	38.210	5.184	0.533	0.072	5.038
8-26-77	41.961	5.069	0.644	0.071	5.277
9-17-77	43.539	5.034	0.661	0.072	5.249
11-26-77	41.242	5.044	0.664	0.072	5.328

Table 9. Carbon (C), hydrogen (H), nigtrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi *J. roemerianus* Burn I plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.823
4-19-77	44.800	5.817	1.144	0.091	4.641
5-25-77	46.056	6.245	0.808	0.084	4.513
6-29-77	46.320	6.227	0.481	0.080	4.610
7-29-77	43.684	6.430	0.521	0.076	4.704
8-26-77	46.609	6.424	0.719	0.081	4.730
9-17-77	44.543	6.373	0.773	0.075	4.857
11-26-77	45.167	6.381	0.791	0.076	4.790
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.690
4-27-77	------	-----	-----	-----	4.769
5-25-77	39.589	5.779	0.549	0.081	4.773
6-29-77	39.937	5.308	0.488	0.080	4.682
7-29-77	38.952	5.374	0.507	0.080	4.650
8-26-77	39.160	5.128	0.484	0.069	4.946
9-17-77	41.878	5.429	0.469	0.072	4.972
11-26-77	40.891	5.316	0.501	0.070	4.791
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	5.063
4-29-77	43.564	5.714	0.629	0.070	4.893
5-25-77	39.994	5.716	0.809	0.071	4.876
6-29-77	40.644	5.409	0.476	0.071	5.183
7-29-77	40.595	5.504	0.556	0.072	5.085
8-26-77	42.513	5.482	0.511	0.071	5.246
9-17-77	43.828	5.472	0.535	0.070	5.157
11-26-77	44.079	5.088	0.421	0.071	5.238

Table 10. Carbon (C), nitrogen (N), hydrogen (H), phosphorus (P), and energy value Kcal/gAFDW) of aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi *J. roemerianus* Harvest 1 plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.796
4-27-77	44.232	6.152	1.083	0.088	4.658
5-25-77	44.964	6.010	0.682	0.085	4.586
6-29-77	46.475	5.857	0.466	0.081	4.669
7-29-77	43.833	6.324	0.730	0.078	4.706
8-26-77	45.826	6.485	0.811	0.078	4.800
9-17-77	45.008	6.120	0.856	0.080	4.830
11-26-77	44.248	6.044	0.558	0.078	4.921
		Belowground Root and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.963
4-27-77	41.801	5.370	0.322	0.087	4.652
5-25-77	41.911	6.195	0.487	0.082	4.344
6-29-77	38.656	5.291	0.556	0.077	4.633
7-29-77	40.227	5.502	0.458	0.081	4.766
8-26-77	41.963	5.614	0.568	0.086	4.786
9-17-77	43.291	5.220	0.420	0.080	4.915
11-26-77	42.674	5.244	0.362	0.077	4.874
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	5.039
4-27-77	45.383	5.535	0.570	0.071	4.962
5-25-77	40.767	5.344	0.548	0.069	4.848
6-29-77	43.865	5.433	0.628	0.068	5.134
7-29-77	43.387	5.767	0.463	0.071	5.002
8-26-77	41.249	5.537	0.593	0.073	5.379
9-17-77	40.081	5.319	0.566	0.074	5.117
11-26-77	42.487	5.595	0.372	0.074	5.075

Table 11. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of aboveground and belowground materials from the 0-10 and 11-20 cm levels in the *S. cynosuroides* Control plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	------	-----	-----	-----	-----
4-19-77	39.791	6.317	0.795	0.089	4.568
5-25-77	43.013	5.861	0.971	0.090	4.534
6-28-77	40.343	5.778	0.597	0.074	4.427
7-28-77	41.991	5.879	0.572	0.077	4.566
8-26-77	42.894	6.030	0.468	0.746	4.584
9-17-77	42.644	6.086	0.485	0.069	4.616
11-26-77	43.420	5.996	0.742	0.070	4.415
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.241	5.556	0.531	0.066	4.677
4-19-77	40.270	5.266	0.734	0.075	4.677
5-25-77	39.842	5.771	0.484	0.070	4.851
6-28-77	34.071	4.579	0.405	0.069	5.043
7-28-77	37.480	5.343	0.491	0.073	4.468
8-26-77	33.661	4.436	0.431	0.073	4.716
9-17-77	37.084	4.992	0.503	0.073	4.796
11-26-77	37.987	4.976	0.658	0.072	4.678
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	39.307	5.162	0.376	0.069	4.698
4-19-77	39.693	5.261	0.445	0.068	4.990
5-25-77	34.628	5.131	0.511	0.069	4.582
6-28-77	32.883	4.284	0.411	0.070	5.031
7-28-77	39.885	5.374	0.634	0.067	4.746
8-26-77	36.139	4.914	0.406	0.068	4.928
9-17-77	37.109	4.936	0.591	0.072	4.985
11-26-77	38.617	4.950	0.567	0.070	4.891

Table 12. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the S. cynosuroides Burn 1 plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	------	-----	-----	-----	-----
4-19-77	41.468	6.000	0.718	0.086	4.645
5-25-77	40.180	6.352	0.468	0.076	4.491
6-28-77	41.765	5.932	0.433	0.082	4.503
7-28-77	41.781	5.990	0.479	0.074	4.577
8-26-77	44.212	6.159	0.485	0.071	4.615
9-17-77	42.836	6.042	0.628	0.073	4.616
11-26-77	42.580	6.121	0.752	0.072	4.505
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.241	5.556	0.531	0.066	4.620
4-19-77	37.015	4.791	0.509	0.075	4.800
5-25-77	38.295	5.300	0.432	0.069	4.963
6-28-77	27.608	3.948	0.267	0.069	4.636
7-28-77	39.639	5.483	0.436	0.071	4.514
8-26-77	33.870	4.442	0.504	0.073	4.618
9-17-77	39.036	5.363	0.483	0.072	4.570
11-26-77	39.029	5.287	0.457	0.072	4.691
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	39.307	5.162	0.376	0.069	4.687
4-19-77	41.231	5.194	0.453	0.069	4.728
5-25-77	41.189	5.334	0.331	0.069	4.670
6-28-77	38.617	5.206	0.448	0.069	4.665
7-28-77	41.841	5.742	0.644	0.067	4.820
8-26-77	40.976	5.440	0.473	0.070	4.723
9-17-77	40.234	5.423	0.408	0.071	4.770
11-26-77	40.068	5.165	0.486	0.071	4.871

Table 13. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the *S. cynosuroides* Harvest 1 plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	------	-----	-----	-----	-----
4-19-77	41.212	5.899	0.735	0.088	4.665
5-25-77	44.301	6.122	0.454	0.082	4.517
6-28-77	43.167	6.012	0.468	0.072	4.572
7-28-77	42.528	6.200	0.397	0.078	4.641
8-26-77	44.305	6.253	0.503	0.071	4.535
9-17-77	42.519	5.827	0.595	0.069	4.637
11-26-77	41.562	5.766	0.826	0.070	4.539
	Belowground Roots and Rhizomes at 0-10 cm Depth Level				
2-15-77	43.241	5.556	0.531	0.066	4.570
4-19-77	39.944	5.371	0.462	0.078	4.468
5-25-77	40.534	5.539	0.548	0.074	4.475
6-28-77	39.514	5.352	0.496	0.070	4.563
7-28-77	38.498	5.372	0.620	0.074	4.777
8-26-77	37.761	5.183	0.532	0.076	5.022
9-17-77	40.435	5.247	0.676	0.071	4.427
11-26-77	40.125	5.186	0.634	0.071	5.272
	Belowground Roots and Rhizomes at 11-20 cm Depth Level				
2-15-77	39.307	5.162	0.376	0.069	4.784
4-19-77	41.915	5.623	0.636	0.071	4.945
5-25-77	41.788	5.375	0.318	0.065	4.951
6-28-77	43.693	5.681	0.276	0.070	5.027
7-28-77	37.543	5.249	0.415	0.071	5.110
8-26-77	31.336	5.145	0.443	0.071	4.902
9-17-77	38.181	5.436	0.649	0.070	4.899
11-26-77	40.059	5.062	0.443	0.072	4.732

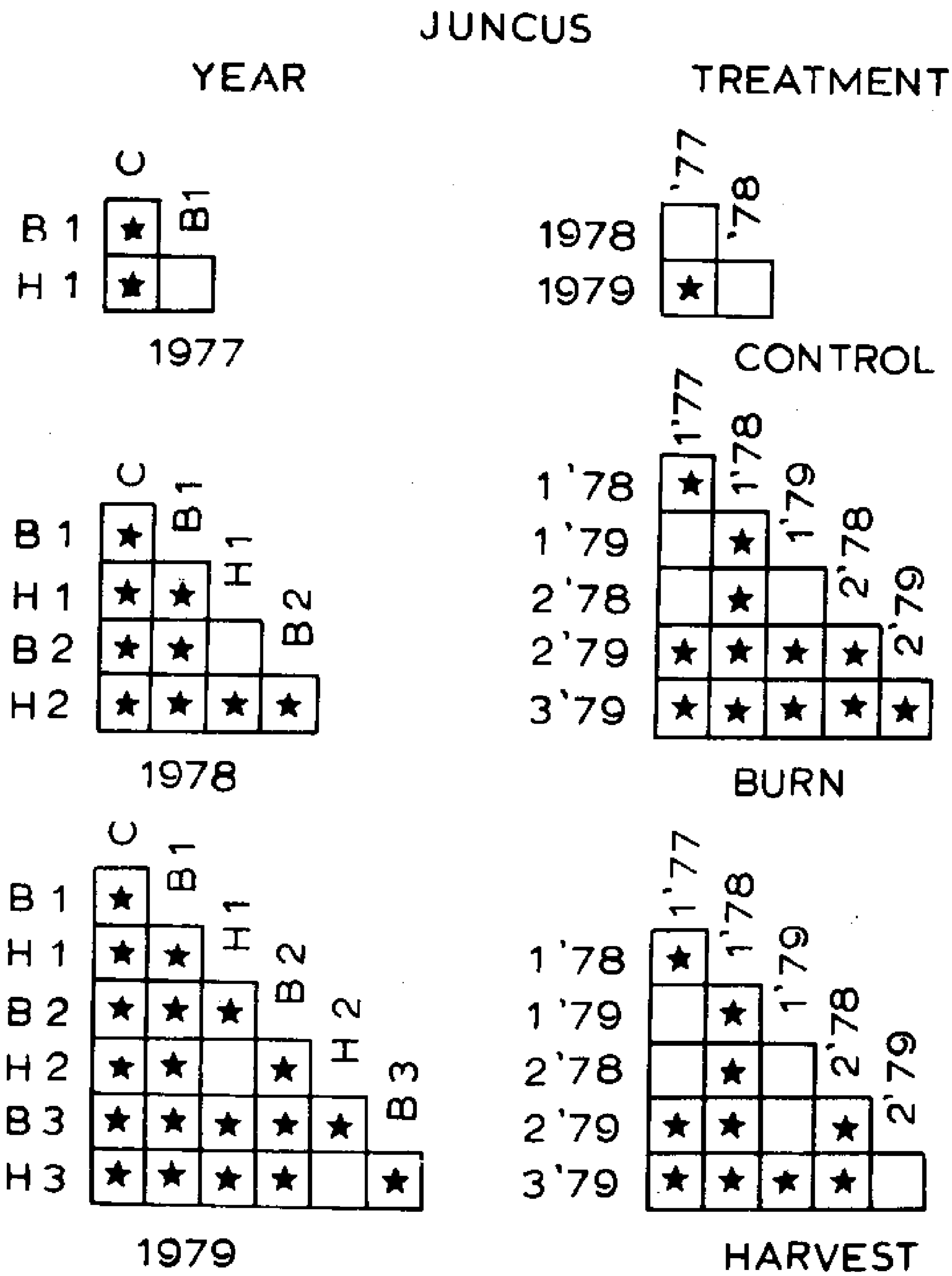

Figure 16. Statistical comparison among years and treatments in the *Juncus* marsh. * = significant difference at $\alpha = 0.05$; C = control; B = burn; H = harvest; 1,2, and 3 = 1977, 1978 and 1979, respectively.

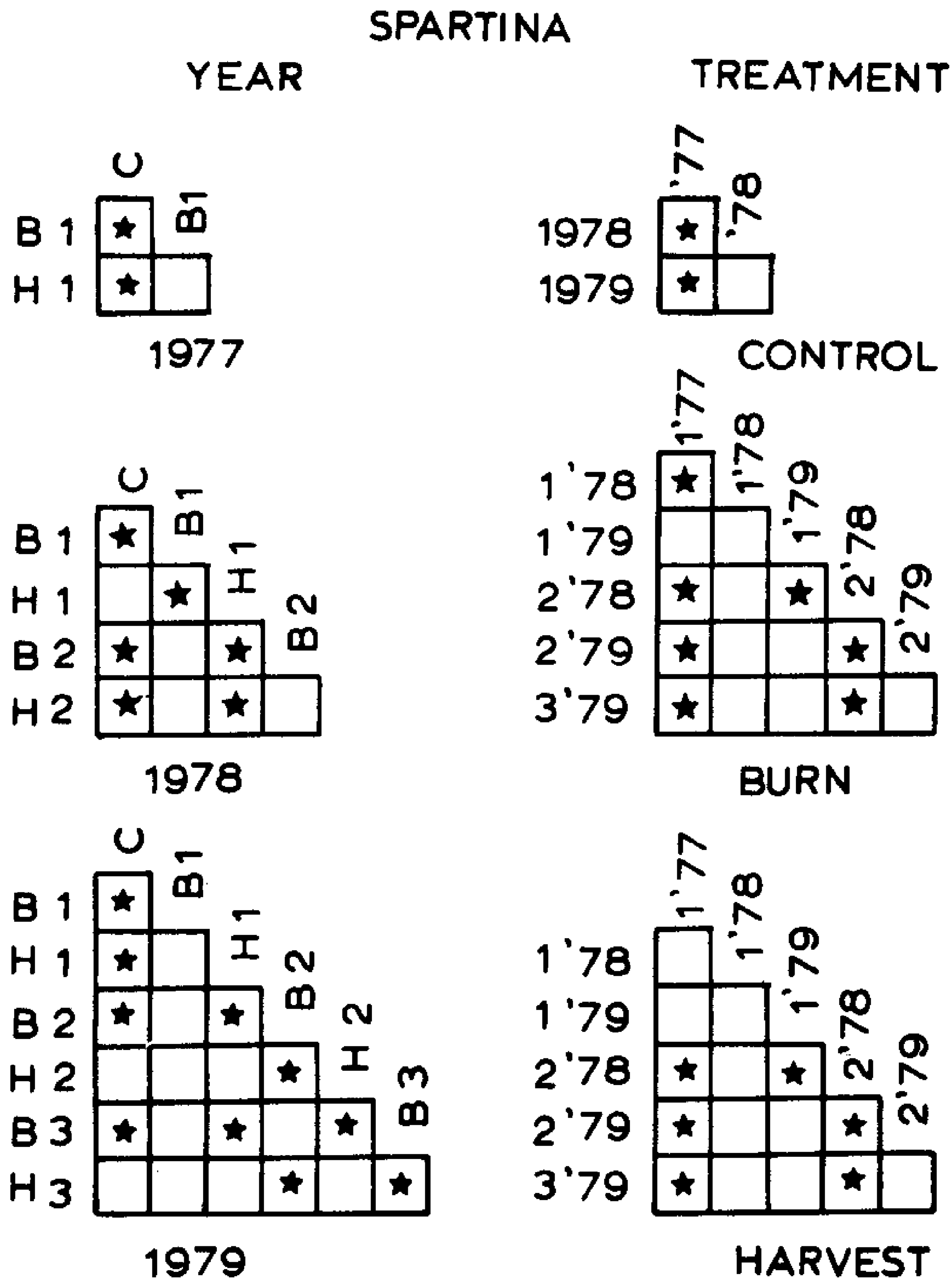

Figure 17. Statistical comparison among years and treatments in the *Spartina* marsh. * = significant difference at α = 0.05; C = control; B = burn; H = harvest; 1,2, and 3 = 1977, 1978, and 1979, respectively.

compare the productivity values thus, statistical significance could occur as a result of different forms of the growth curves which might ultimately lead to the same maximum biomass. That such differences occurred should not be surprising. Variations of climatic conditions along the Gulf coast are normal. An earlier spring warming period or a late initial frost could easily change the form of the growth pattern, as it did in the 1978 growing season in the Juncus community (Table 3). Storm surges which normally occurred during summer could also significantly change the growth conditions. In the summer of 1979, several storms affected the St. Louis Bay marshes (Hackney and Bishop, 1981).

There is little doubt that the productivity of the Juncus community was enhanced following a fire (Table 1), and this stimulation of productivity may be a response of the plant to the fire by mobilizing energy stored belowground in rhizomes. Thus, some of that productivity may not be a part of the net primary productivity, but NPP from past years. The effects of the fire may not be reflected in production. They become evident through an examination of the growth form of the plant. Figure 11 clearly shows the effects of repeated removal of Juncus tillers, a consistent reduction of the mass of Juncus tillers which was statistically significant (Table 4). By the end of the third year, the area burned during the first year of the study was approaching the control levels. Juncus communities require more than three years to return to pre-burn levels. Note the continued decline in size (Figure 10) and mass (Figure 11) of the Juncus tillers with annual harvests. The removal of vegetation produced an abundance of inflorescence one year after either a fire or a harvest. This did not occur again with repeated harvests, apparently because there was not enough reserve energy remaining in the rhizomes. The increase in flowering may be mechanism to take advantage of a newly opened space in the marsh.

It was expected that other marsh species would take advantage of the retarded condition of Juncus. F. castanea and S. cynosuroides became more important in the plots harvested repeatedly while one burn did not affect the percentages of minor species (Figure 15).

The aboveground primary productivity of the Spartina marsh was always higher following fire or harvest (Table 2). The growth form was very consistent (Figure 7); thus, significant statistical differences among treatments were due to different amounts of biomass in each area. Variations from year to year were evident (Figure 17) in the control. These differences were between 1977 and the other two years. Besides the lower productivity in 1977, the growth declined earlier that year (Figure 7). There was not as much variation between productivity in burn plots, except for the two 1978 burned areas (Table 2). Burn treatments were always statistically different than controls (Figure 17). This was not always true when controls were compared to harvested areas. There was more variation in the response of the harvested areas to treatment (Figure 17). Presumably, nutrients left by the ash enhanced the growth of the plants in the burned areas.

The first year after fire or harvest, S. cynosuroides produced more flowers (Figure 13). Such differences were not statistically different because there were few plants per m^2 and there was enough variation to confound the results. After the first year, flower production of burn and harvest treatments resembled the control. A check of the treated area in 1980 confirmed our hypothesis that increased flowering occurred only during the first year of treatment as all areas resembled the control area after that year.

There was no increase in the number of Spartina stems per square meter in the treated areas. Instead, the treated (burned and harvested) plots produced larger stems (Figure 12). There was no difference in the mass of the burned versus the cut stems, but both were statistically different from the control.

Minor species were not affected by the treatments except in 1979. A different pattern emerged in 1979, not caused by an increase of minor species in treated areas, but by a decrease in minor species in the control area (Figure 15). As mentioned earlier, several storm surges occurred in St. Louis Bay in 1979 bringing more saline water onto the marsh for longer periods of time. The Panicum spp. disappeared from the control area, but remained in the treated areas.

Conclusions

Marshes dominated by Juncus roemerianus and Spartina cynosuroides responded differently to fire and harvest treatments. J. roemerianus, with its living aboveground tissues responded to the treatment by increasing productivity while the general vigor of the plants decreased. It required more than three years for the plants to return to a preburn condition. Spartina cynosuroides was not damaged by the treatments because during the winter its aboveground tissue is already dead and removal of this dead material actually enhanced the growth of the plants.

Continued removal of the aboveground tissues increased the contribution of the minor species in the Juncus marsh, but it had little effect on the Spartina marsh.

A management scheme involving harvest or burning of S. cynosuroides communities on an annual basis would not harm the plant community itself. J. roemerianus communities, however, should not be burned or harvested more frequently than every three to four years and in fact, may be naturally protected from frequent fires by the lack of accumulated dry biomass and debris.

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APPENDIX 1

Tables 1-14: Monthly average biomass ($\bar{x}$) and standard deviation(s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Control, Burn, and Harvest plots of *J. roemerianus* and *S. cynosuroides* marsh communities in 1977, 1978, and 1979.

Table 1. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Control _J. roemerianus_ community in Mississippi.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-14-77	581.3	139.3	860.7	242.4	284.7	60.6	1.0	604.3	150.9
4-27-77	379.2	138.8	598.0	146.4	230.1	56.8	1.8	468.3	163.6
5-25-77	448.0	89.8	557.3	138.2	502.7	126.3	2.0	665.0	184.0
6-29-77	805.2	112.4	801.3	122.7	381.5	123.7	3.0	982.0	111.8
7-29-77	872.0	187.2	798.0	130.5	204.1	66.9	2.7	1060.0	235.7
8-26-77	740.0	146.8	1051.3	149.3	290.1	117.3	2.7	948.3	157.4
9-17-77	538.8	66.0	984.0	90.9	242.1	70.1	1.8	684.6	119.3
10-15-77[1]	-	-	-	-	-	-	-	-	-
11-26-77	481.3	166.9	799.6	346.2	261.4	39.9	2.0	601.4	137.1
2-18-78	546.7	22.2	641.3	29.3	390.0	19.4	1.2	599.0	95.1
4-23-78	526.7	27.3	859.3	45.3	220.8	7.4	3.0	654.7	113.6
5-27-78	607.4	59.6	615.3	22.7	252.0	11.4	3.9	959.3	97.3
6-24-78	649.3	16.4	611.3	12.3	365.3	11.3	3.2	989.3	279.0
7-28-78	474.0	5.4	1203.3	44.8	324.0	14.1	3.0	812.0	85.2
8-26-78	610.0	41.5	806.0	23.6	449.3	18.3	2.3	994.7	225.9
9-22-78	586.6	16.7	567.3	30.5	736.6	38.2	2.7	1155.3	258.7
10-28-78	598.7	27.0	952.7	60.8	466.0	27.9	2.3	980.7	181.3
11-26-78[2]	-	-	-	-	-	-	-	-	-
12-16-78	637.3	54.5	910.7	28.9	734.7	35.5	2.3	885.3	295.6
2-03-79[1]	-	-	-	-	-	-	-	-	-
4-20-79	528.7	115.8	579.3	279.2	412.7	100.9	2.3	605.3	134.9
5-25-79	890.7	207.3	621.3	169.2	247.3	58.3	2.0	990.7	210.4
6-30-79	746.0	271.9	494.0	242.9	538.0	146.9	3.7	1192.8	317.2
7-30-79	791.0	87.8	482.7	197.7	534.0	249.5	3.7	1240.4	321.1
8-24-79	568.0	161.1	919.3	160.5	334.7	73.3	3.0	768.7	237.0
9-23-79	665.0	68.3	584.0	76.1	529.3	83.5	3.3	881.5	112.7
10-27-79	827.3	125.3	591.5	65.5	266.0	108.0	2.8	1084.7	160.0
11-30-79	722.2	215.2	411.3	141.8	437.3	166.6	1.5	764.9	244.4

[1]No samples were taken due to inclement weather.

[2]Samples were lost due to fire in the drying oven.

Table 2. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn I[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-14-77[2]	520.0	111.1	1080.3	116.5	364.4	83.5	1.0	551.0	115.9
4-19-77	122.0	17.3	0.0	0.0	512.1	155.9	1.5	186.3	53.3
5-25-77	258.0	35.5	0.0	0.0	299.4	77.4	1.8	393.6	112.1
6-29-77	344.7	86.4	39.3	28.6	408.4	115.4	2.7	543.3	146.0
7-29-77	381.3	78.0	83.3	16.3	306.8	94.0	2.3	616.0	132.9
8-26-77	358.0	54.3	37.3	14.0	162.1	33.5	2.3	703.3	226.9
9-17-77	510.6	106.8	38.6	19.9	419.4	59.9	2.0	694.0	153.2
10-15-77	-	-	-	-	-	-	-	-	-
11-26-77	614.0	68.8	288.0	72.4	212.1	61.0	2.3	699.1	88.5
2-01-78[2]	322.4	46.0	319.6	24.7	251.6	12.0	1.7	361.7	185.1
4-23-78	315.6	25.6	544.0	31.6	215.6	9.2	1.5	412.0	122.3
5-27-78	449.6	21.3	244.0	13.2	88.0	6.3	3.2	799.7	156.9
6-24-78	662.7	41.8	337.3	32.4	112.7	11.4	2.8	900.0	194.7
7-28-78	288.0	20.6	318.7	37.7	143.3	14.9	3.0	655.3	55.0
8-26-78	371.3	32.0	268.0	36.5	128.7	10.4	2.3	577.3	71.0
9-22-78	451.3	56.1	695.3	41.3	377.3	21.7	2.3	773.8	191.4
10-28-78	287.3	24.2	420.7	31.5	152.7	15.5	2.5	816.7	125.5
11-26-78[3]	-	-	-	-	-	-	-	-	-
12-16-78	540.7	23.6	684.0	13.0	161.3	10.0	2.3	1102.7	262.8
2-03-79[4]	-	-	-	-	-	-	-	-	-
4-20-79	566.7	215.8	599.3	172.5	360.7	131.5	2.7	660.7	240.5
5-25-79	558.0	202.4	738.7	69.9	359.3	103.9	2.8	906.0	162.6
6-30-79	804.7	125.0	497.3	180.4	384.0	119.8	2.8	1249.5	178.8
7-30-79	814.0	156.6	616.0	139.6	294.7	75.6	3.2	1462.7	124.0
8-24-79	662.7	118.4	598.7	72.3	228.7	63.2	2.3	1097.3	264.5
9-23-79	682.3	67.1	460.7	168.0	354.0	125.5	2.7	1204.7	256.5
10-27-79	708.0	178.7	552.7	201.4	353.3	31.6	2.2	1048.7	210.8
11-30-79	542.0	210.7	432.0	163.8	342.0	97.0	1.2	639.0	254.1

[1]Burned February 14, 1977 and reburned February 18, 1978 and March 2, 1979.

[2]Preburn sample.

[3]No samples were taken due to inclement weather.

[4]Samples were lost due to fire in the drying oven.

Table 3. Average biomass ($\overline{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Harvest I[1] *J. roemerianus* community in Mississippi.

Date	Live $\overline{x}$	Live s	Dead $\overline{x}$	Dead s	Litter $\overline{x}$	Litter s	Assoc. Minor Spp. $\overline{x}$ no.	Total Live Biomass of All Species $\overline{x}$	Total Live Biomass of All Species s
2-14-77[2]	424.7	129.6	844.3	216.2	407.4	131.7	1.0	463.3	127.7
4-19-77	167.7	26.3	0.0	0.0	327.4	85.4	1.7	263.7	42.0
5-25-77	250.0	54.4	0.0	0.0	202.8	97.3	2.2	384.0	108.6
6-27-77	373.3	47.2	2.7	3.0	92.1	36.2	2.7	660.0	166.3
7-29-77	422.7	59.4	56.7	15.3	175.4	91.1	2.7	656.0	143.1
8-26-77	499.3	82.1	32.0	6.7	109.8	61.2	2.5	728.7	91.0
9-17-77	417.3	138.8	89.3	37.2	191.5	72.4	3.0	752.7	130.0
10-15-77[3]	-	-	-	-	-	-	-	-	-
11-26-77	497.3	76.6	185.3	32.1	173.4	81.4	2.5	616.1	95.6
2-01-78[2]	368.8	29.3	263.7	16.1	50.0	4.7	1.7	448.0	137.1
4-23-78	121.6	6.1	5.3	3.3	124.0	6.1	1.0	196.0	24.7
5-27-78	301.6	4.8	6.7	1.4	61.3	6.3	2.7	492.0	76.7
6-24-78	296.0	11.2	0	0	106.7	11.5	2.5	584.0	96.7
7-28-78	319.3	29.5	136.7	13.4	91.3	5.8	2.5	714.7	104.3
8-26-78	340.0	17.3	118.7	19.3	140.0	20.9	2.8	670.0	121.5
9-22-78	386.6	17.2	230.6	27.1	246.6	12.5	2.5	812.7	148.5
10-28-78	439.3	15.5	624.0	41.8	296.7	21.1	2.3	934.0	217.9
11-26-78	432.7	33.7	293.3	26.1	150.7	12.8	2.3	844.0	127.1
12-16-78	383.3	17.9	252.0	21.0	86.0	6.2	3.3	1025.3	217.2
2-03-79[3]	-	-	-	-	-	-	-	-	-
4-20-79	342.7	386.3	2.3	2.0	10.7	9.0	2.8	412.3	402.6
5-25-79	178.7	32.4	6.7	3.0	0.0	0.0	2.7	354.7	45.5
6-30-79	246.7	24.1	8.7	5.9	4.0	2.5	2.5	421.3	78.3
7-30-79	366.0	74.0	9.0	4.1	68.7	26.5	3.0	725.7	109.5
8-24-79	308.0	38.6	192.0	58.1	28.7	7.8	2.8	783.0	58.4
9-23-79	295.3	75.2	88.7	22.8	20.0	10.7	3.2	749.1	144.2
10-27-79	310.7	55.0	68.0	13.8	14.7	16.9	2.8	589.3	197.3
11-30-79	270.9	95.3	106.7	53.7	62.7	13.1	1.5	427.1	107.1

[1]Harvested February 14, 1977 and reharvested February 18, 1978 and February 20, 1979.

[2]Preharvest sample.

[3]No samples were taken due to inclement weather.

Table 4. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn II[1] *J. roemerianus* community in Mississippi.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-01-78[2]	582.8	13.1	794.4	61.6	371.6	8.4	1.0	879.7	599.1
4-23-78	132.8	4.0	40.8	7.2	360.0	10.2	1.9	211.3	37.6
5-27-78	234.8	15.6	18.8	3.3	208.0	15.9	3.2	405.3	78.6
6-24-78	304.7	12.5	-	-	263.3	18.2	3.3	514.0	109.7
7-28-78	464.0	14.9	66.7	2.6	174.7	11.5	3.3	718.0	88.3
8-26-78	478.7	34.4	203.3	35.2	383.3	36.4	2.1	680.0	126.3
9-22-78	734.0	41.8	147.3	16.4	556.6	31.7	3.2	1037.3	275.8
10-28-78	497.3	27.8	236.0	23.2	206.7	11.5	3.0	754.0	136.0
11-26-78	457.0	38.1	497.0	14.6	344.0	23.7	3.5	735.3	193.9
12-16-78	617.3	59.6	357.7	39.0	386.7	16.1	2.3	866.0	169.5
2-03-79[3]	-	-	-	-	-	-	-	-	-
4-20-79	413.0	110.2	436.0	140.4	532.7	61.8	3.3	587.3	103.2
5-25-79	514.0	160.6	241.3	110.2	133.3	62.8	2.8	674.7	131.0
6-30-79	485.6	90.7	499.3	200.4	428.0	92.9	3.7	715.8	77.2
7-30-79	558.7	165.8	472.7	174.1	333.3	94.0	4.0	879.3	161.0
8-24-79	626.7	83.0	454.7	80.9	172.7	20.6	3.5	997.3	181.2
9-23-79	679.3	89.4	368.0	20.7	372.7	47.7	3.2	1040.7	171.0
10-27-79	610.3	147.6	436.7	150.2	198.0	55.9	3.7	1008.3	227.9
11-30-79	483.3	144.2	582.7	44.3	253.3	55.2	2.2	576.0	113.8

[1]Burned February 18, 1978 and reburned March 2, 1979.

[2]Preburn sample.

[3]No samples were taken due to inclement weather.

Table 5. Average biomass ($\overline{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Harvest II[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\overline{x}$	s	$\overline{x}$	s	$\overline{x}$	s	$\overline{x}$ no.	$\overline{x}$	s
2-01-78[2]	516.0	36.4	817.3	32.2	386.0	15.8	1.5	611.7	197.6
4-23-78	128.0	5.3	0.0[3]	0.0	250.0	25.8	1.7	204.7	44.1
5-27-78	172.0	3.5	0.0	0.0	86.0	14.4	3.7	455.3	74.3
6-24-78	260.0	14.3	0.0	0.0	28.7	2.6	2.8	466.7	107.1
7-28-78	272.0	20.5	92.0	8.7	76.7	6.4	4.0	592.7	117.9
8-26-78	495.0	57.4	176.0	13.7	86.7	4.6	3.0	816.7	181.0
9-22-78	544.0	31.1	215.3	26.1	429.3	22.8	3.0	997.3	200.4
10-28-78	314.7	16.7	315.7	18.9	62.0	8.6	3.8	492.7	58.0
11-26-78	393.3	10.7	282.0	4.1	63.7	4.3	3.0	674.7	95.0
12-16-78	396.3	14.2	257.3	14.8	97.3	9.6	2.2	685.3	183.0
2-03-79[4]	-	-	-	-	-	-	-	-	-
4-20-79	130.7	19.7	3.3	3.9	9.0	3.5	3.5	230.7	43.4
5-25-79	189.3	28.5	4.7	3.0	0.0	0.0	4.8	420.0	76.9
6-30-79	203.3	74.7	27.7	15.7	6.0	3.3	4.0	409.7	111.0
7-30-79	332.7	95.5	77.3	43.2	54.7	18.7	3.5	691.3	172.0
8-24-79	391.3	63.8	62.7	13.1	15.3	1.6	3.8	764.7	114.0
9-23-79	326.7	142.5	72.0	59.9	32.0	11.9	3.8	778.7	173.6
10-27-79	360.0	35.7	60.7	31.4	16.7	8.5	3.5	679.7	155.2
11-30-79	342.7	91.3	140.7	27.9	64.0	21.0	2.7	539.7	99.4

[1]Harvested February 18, 1978 and reharvested February 20, 1979.

[2]Preharvest samples.

[3]Means no dead plants were collected.

[4]No samples were taken due to inclement weather.

Table 6. Average biomass ($\bar{x}$) standard deviation (s) of live and standing dead plant shoots, total litter, number of species, and total live biomass (g/m^2) of all species in the Burn III[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-03-79[2]	486.0	70.1	652.7	184.8	293.3	81.5	2.0	781.3	103.8
4-20-79	135.3	23.2	244.7	28.6	450.7	62.9	2.2	208.7	47.5
5-25-79	256.0	23.2	12.7	18.3	191.3	27.4	2.7	344.0	45.5
6-30-79	430.0	99.6	7.3	4.7	356.0	91.1	2.8	628.0	87.2
7-30-79	478.7	41.1	13.3	11.2	384.7	53.9	3.0	688.4	162.3
8-24-79	522.0	153.4	43.3	42.5	205.3	38.7	3.3	729.0	136.9
9-23-79	586.7	212.2	209.3	52.5	280.0	86.2	3.3	839.7	246.6
10-27-79	668.0	100.2	244.7	95.2	206.0	64.0	2.8	848.7	116.2
11-30-79	644.0	100.4	137.3	61.1	186.7	42.1	2.2	733.7	128.9

[1]Burned March 2, 1979.

[2]Preburn sample.

Table 7. Average biomass ($\bar{x}$) standard deviation (s) of live and standing dead plant shoots, total litter, number of species, and total live biomass (g/m^2) of all species in the Harvest III[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-03-79[2]	-	-	-	-	-	-	-	-	-
4-20-79	138.0	25.1	0.0[3]	0.0	11.3	10.6	2.7	213.3	24.0
5-25-79	256.7	31.0	4.0	4.4	2.7	2.1	3.5	346.0	35.5
6-30-79	406.7	87.6	6.1	6.9	2.3	1.9	3.2	561.8	58.9
7-30-79	548.0	140.6	9.3	7.9	68.0	13.9	3.7	833.0	82.9
8-24-79	490.0	160.0	102.7	70.0	26.0	9.7	3.8	831.3	172.1
9-23-79	535.3	91.4	37.3	14.9	4.0	0.0	3.3	766.1	88.7
10-27-79	488.0	99.1	65.7	12.3	5.3	7.4	3.7	702.0	124.9
11-30-79	427.3	129.5	115.7	19.3	22.7	8.6	2.3	528.7	130.3

[1]Harvested February 20, 1979.

[2]No preharvest samples were collected.

[3]Means no dead plants were collected.

Table 8. Average biomass ($\bar{x}$) and standard deviations (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Control S. cynosuroides community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-14-77[1]	0.0	0.0	2172.6	426.4	785.4	163.0	0.8	120.7	152.3
4-27-77	376.3	110.3	1218.0	498.5	864.0	111.9	0.5	397.7	95.7
5-25-77	700.3	311.5	1485.3	621.5	988.7	93.8	0.8	865.3	291.6
6-29-77	1220.0	598.5	1656.7	318.9	1076.0	143.4	0.5	1279.7	557.8
7-29-77	1210.0	400.1	1122.7	122.6	792.7	148.9	0.0	1210.0	400.1
8-26-77	1072.0	300.0	1160.0	138.2	767.4	184.3	1.5	1557.3	350.6
9-17-77	1035.3	360.0	1014.7	282.2	1137.4	204.5	0.5	1122.7	345.9
10-15-77[2]	-	-	-	-	-	-	-	-	-
11-26-77	0.0	0.0	1806.7	221.3	804.1	188.1	0.2	0.7	1.6
2-18-78[1]	0.0	0.0	1855.3	64.9	1437.3	50.5	0.0	0.0	0.0
4-23-78	228.7	20.3	279.3	86.1	1235.3	89.8	0.3	232.7	83.3
5-27-78	498.7	44.5	1141.3	48.3	1202.7	64.2	1.0	766.0	179.0
6-24-78	790.0	47.8	928.0	74.7	1092.7	67.4	1.0	1219.3	111.1
7-28-78	1296.7	28.0	990.7	92.4	883.3	25.8	1.0	1927.3	214.7
8-26-78	943.3	77.6	1766.6	147.3	1400.0	61.8	1.0	1298.7	285.5
9-22-78	1660.6	78.1	1426.6	106.3	1764.0	60.8	0.0	1660.7	312.3
10-28-78	1203.3	43.8	1341.6	76.6	1296.7	41.3	0.5	1360.7	264.0
11-26-78	581.3	41.5	2680.7	162.6	1369.3	92.7	0.2	606.0	171.5
12-16-78	206.0	61.3	2376.0	134.2	1342.0	172.0	0.7	354.7	68.6
2-03-79[2]	-	-	-	-	-	-	-	-	-
4-20-79	332.7	87.9	1489.3	467.1	1386.7	188.9	1.2	543.3	436.4
5-25-79	562.0	156.6	1355.3	236.9	523.3	171.3	0.3	614.0	172.2
6-30-79	1218.7	228.4	1208.0	462.7	292.0	99.5	0.3	1325.3	350.8
7-30-79	1247.3	471.8	727.3	311.3	1695.3	448.1	0.2	1248.0	471.2
8-24-79	1319.3	175.8	786.7	345.5	497.3	177.4	0.2	1336.0	205.1
9-23-79	1746.0	471.0	400.7	353.2	532.0	106.5	0.3	1769.3	457.4
10-27-79	991.3	196.0	678.7	194.7	548.0	93.9	0.2	1014.7	188.2
11-30-79	550.7	262.0	1060.7	317.9	391.3	138.9	1.5	810.0	196.8

[1] 0 means no living plants during this winter month.

[2] No samples were taken due to inclement weather.

Table 9. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn I[1] S. cynosuroides community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-14-77[2]	0.0	0.0	2028.0	757.2	597.7	93.9	1.0	65.3	58.3
4-19-77	446.7	515.7	0.0	0.0	409.4	99.8	1.5	609.7	105.8
5-24-77	839.7	305.8	0.0	0.0	449.4	179.2	1.7	1159.7	406.1
6-28-77	1480.0	389.0	57.0	47.1	483.4	89.0	0.7	1586.0	427.8
7-28-77	1229.3	490.6	47.3	13.5	444.8	87.8	2.5	1733.3	374.1
8-26-77	1303.7	435.0	61.0	57.1	487.4	81.7	0.8	1717.7	465.2
9-17-77	1419.3	552.7	34.0	40.6	826.7	237.1	0.5	1641.3	434.5
10-15-77[3]	-	-	-	-	-	-	-	-	-
11-26-77	0.0	0.0	1085.3	223.7	656.0	94.6	0.8	147.4	204.5
2-18-78[2]	0.0	0.0	1055.3	125.0	1678.7	65.7	0.0	0.0	0.0
4-23-78	376.7	27.0	113.3	27.5	296.7	53.6	1.3	484.0	103.7
5-27-78	817.3	58.3	37.3	8.1	188.0	15.0	2.2	982.3	161.5
6-24-78	1553.3	66.4	31.3	1.3	404.7	81.4	1.2	1883.3	386.0
7-28-78	1284.0	134.2	70.0	12.1	480.7	40.4	2.0	1922.7	431.9
8-26-78	976.7	47.9	934.0	108.1	414.6	19.8	1.3	1478.0	305.1
9-22-78	1944.6	124.4	216.0	31.2	592.0	21.2	0.8	2398.7	568.3
10-28-78	549.3	80.6	616.7	69.4	281.3	12.7	1.6	1057.3	466.6
11-26-78	221.3	36.1	1954.0	128.5	552.7	39.5	0.8	558.7	321.0
12-16-78	146.0	12.4	1472.7	44.1	618.0	21.8	1.2	354.0	251.9
2-03-79[3]	-	-	-	-	-	-	-	-	-
4-20-79	394.2	82.8	0.0	0.0	365.3	163.9	1.5	592.0	151.5
5-25-79	428.7	93.7	323.3	310.3	38.7	48.1	3.0	801.3	267.2
6-30-79	1082.7	516.9	165.3	171.5	242.0	57.3	1.0	1700.7	420.3
7-30-79	848.7	432.7	79.3	55.2	512.0	141.0	1.7	1614.7	292.9
8-24-79	1360.7	553.9	916.7	289.3	88.7	73.6	1.7	1745.3	755.7
9-23-79	1378.0	95.9	631.3	116.2	268.0	107.5	1.0	1387.3	91.1
10-27-79	621.3	235.8	101.3	43.4	341.3	62.4	2.2	1265.3	233.5
11-30-79	365.3	185.2	880.7	488.9	315.3	68.3	1.0	365.3	187.2

[1]Burned February 14, 1977 and reburned February 18, 1978 and March 2, 1979.
[2]Preburn sample; 0 means no living plants during this winter month.
[3]No samples were taken due to inclement weather.

Table 10. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Harvest I[1] S. cynosuroides community.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-14-77[2]	0.0	0.0	989.0	391.3	521.4	112.6	1.7	156.3	137.4
4-19-77	212.7	81.4	0.0	0.0	62.8	10.3	3.0	531.3	79.6
5-24-77	867.0	281.4	0.0	0.0	78.8	17.8	2.3	1144.0	348.3
6-28-77	1077.3	158.1	20.0	16.0	363.7	103.1	1.7	1371.7	178.3
7-28-77	935.3	265.3	49.7	39.9	273.4	141.9	2.5	1575.3	359.8
8-26-77	1042.0	328.8	79.0	44.9	507.4	72.6	1.7	1578.0	402.0
9-17-77	1160.0	308.4	47.3	33.6	258.0	48.3	0.8	1549.3	577.0
10-15-77[3]	-	-	-	-	-	-	-	-	-
11-26-77	0.7	1.6	1178.7	274.4	394.0	69.9	0.8	291.4	325.5
2-18-78[2]	0.0	0.0	1144.7	67.4	324.7	14.3	0.0	0.0	0.0
4-23-78	192.0	2.8	0.0	0.0	114.7	15.9	2.2	309.3	127.9
5-27-78	753.3	52.7	0.0	0.0	48.7	5.2	1.8	1007.3	198.1
6-24-78	830.7	57.7	96.7	16.3	622.7	134.0	2.0	1265.3	455.3
7-28-78	1014.0	94.4	82.4	5.4	174.0	18.2	3.0	1344.0	321.7
8-26-78	938.0	57.1	654.6	95.6	189.3	24.1	1.6	1084.7	301.5
9-22-78	1591.3	46.4	224.0	43.3	416.0	22.0	1.7	1961.3	381.8
10-28-78	511.3	60.6	524.0	49.1	168.7	6.4	1.5	748.7	177.4
11-26-78	312.0	27.5	1104.0	103.3	360.0	25.1	1.3	510.0	138.0
12-16-78	157.0	23.4	1140.7	98.1	139.3	5.4	2.0	767.3	641.1
2-03-79[3]	-	-	-	-	-	-	-	-	-
4-20-79	254.7	130.9	0.0	0.0	47.3	21.2	1.8	386.7	123.3
5-25-79	679.3	201.8	10.0	14.9	17.3	17.6	2.3	1188.7	188.6
6-30-79	1086.4	217.3	28.0	51.5	136.8	64.3	1.8	1584.8	92.5
7-30-79	656.7	188.1	52.0	23.7	24.7	38.2	3.0	1378.0	390.6
8-24-79	774.7	314.2	36.7	29.5	97.3	30.6	3.0	1601.3	131.5
9-23-79	860.0	335.4	132.7	129.4	78.7	34.3	2.5	1420.0	330.5
10-27-79	542.7	179.7	233.3	77.1	143.3	11.1	1.3	1187.3	191.7
11-30-79	320.0	140.4	653.3	228.1	152.7	23.9	1.5	320.0	140.4

[1]Harvested February 1, 1977 and reharvested February 18, 1978 and February 20, 1979.

[2]Preharvest sample; 0 means no live Spartina during this winter month.

[3]No samples taken due to inclement weather.

Table 11. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn II[1] *S. cynosuroides* community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-18-78[2]	0.0	0.0	1849.3	217.1	1069.3	53.7	0.0	0.0	0.0
4-23-78	394.0	119.2	14.0	8.6	608.7	32.5	0.3	408.0	202.8
5-27-78	1235.3	86.5	0.0	0.0	355.3	30.2	1.3	1504.0	319.4
6-24-78	1472.7	113.1	44.7	4.3	586.7	37.0	0.5	1793.3	355.9
7-28-78	1922.7	181.4	61.3	11.3	412.0	34.9	1.0	2322.7	620.8
8-26-78	1480.0	95.5	760.0	169.1	864.6	22.7	0.2	1508.0	389.9
9-22-78	2211.3	84.8	232.0	23.2	556.0	88.1	0.5	2486.0	446.0
10-26-78	506.7	74.4	881.3	109.3	726.7	34.9	1.6	1014.0	348.6
11-26-78	248.7	34.1	1518.0	128.5	588.7	41.7	0.8	800.7	395.5
12-16-78	112.7	11.5	1561.3	69.1	730.0	75.5	1.2	285.3	135.7
2-03-79[3]	-	-	-	-	-	-	-	-	-
4-20-79	219.3	53.6	0.0	0.0	464.7	101.9	2.5	334.7	56.1
5-25-79	631.3	313.4	30.0	45.7	208.7	118.5	1.0	643.3	311.7
6-30-79	1485.3	247.3	66.7	42.7	474.7	93.1	1.0	1807.3	549.8
7-30-79	1533.3	470.9	110.0	54.7	323.3	113.7	1.5	1652.0	562.5
8-24-79	1678.0	307.6	122.7	74.0	286.0	135.7	1.2	2087.3	374.3
9-23-79	1175.3	293.4	114.7	55.9	242.0	84.5	1.0	1316.0	510.8
10-27-79	1327.3	291.8	167.3	42.7	560.7	75.4	1.0	1590.0	475.6
11-30-79	780.7	235.0	748.0	290.1	328.7	51.4	0.2	780.7	235.0

[1]Burned February 18, 1978 and reburned March 2, 1979.

[2]Preburn sample; 0 means no live *Spartina* during this winter month.

[3]No samples were taken due to inclement weather.

Table 12. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Clipped II[1] *S. cynosuroides* community.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-18-78[2]	0.0	0.0	1024.0	115.5	482.0	22.5	0.2	1.3	3.3
4-23-78	501.3	20.0	0.0	0.0	368.7	23.9	1.0	548.7	121.1
5-27-78	1108.0	74.3	0.0	0.0	341.3	53.8	0.5	1263.3	391.2
6-24-78	1318.7	102.2	44.0	7.9	401.3	34.6	0.8	1658.0	263.5
7-28-78	2858.0	142.0	0.0	0.0	380.0	13.8	0.0	2858.0	567.7
8-26-78	1044.6	117.8	891.3	78.1	275.3	10.9	0.5	1350.0	385.6
9-22-78	1151.3	30.1	408.1	68.5	383.3	13.9	1.2	1740.7	339.2
10-28-78	909.3	80.0	1232.7	113.8	442.7	23.6	0.3	920.0	304.7
11-26-78	282.7	31.0	1124.7	109.6	192.7	7.0	1.3	898.7	313.6
12-16-78	232.0	28.5	1346.7	58.5	-	-[3]	2.0	301.3	102.0
2-03-79[4]	-	-	-	-	-	-	-	-	-
4-20-79	263.0	72.9	0.0	0.0	184.0	49.7	1.2	368.0	95.3
5-25-79	811.3	281.3	14.7	19.9	20.0	23.7	1.0	842.7	294.5
6-30-79	1029.3	391.9	26.0	24.9	66.7	44.0	1.5	1365.3	331.5
7-30-79	721.3	226.4	68.0	34.2	28.7	35.5	2.8	1406.7	131.8
8-24-79	910.0	274.9	74.0	66.0	54.0	43.1	2.2	1562.0	316.2
9-23-79	1300.0	464.1	138.7	169.9	65.3	55.3	2.2	1374.0	442.4
10-27-79	946.7	342.8	102.0	75.8	282.7	88.7	3.0	1302.0	304.3
11-30-79	380.0	46.4	453.3	252.4	210.7	35.8	1.7	380.0	46.4

[1]Harvested February 18, 1978 and reharvested February 20, 1979.

[2]Preharvest sample.

[3]Sample was lost due to fire in drying oven.

[4]No samples taken due to inclement weather.

Table 13. Average biomass ($\bar{x}$) standard deviation (s) of live and standing dead plant shoots, total litter, number of species, and total live biomass (g/m^2) of all species in the Burn III[1] *S. cynosuroides* community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-03-79[2]	0.0	0.0	1604.0	356.4	888.7	138.6	1.0	526.0	964.6
4-20-79	227.3	41.7	0.0	0.0	16.7	8.5	2.5	349.3	97.2
5-25-79	734.7	158.0	4.0	8.0	81.3	105.5	2.0	943.3	314.2
6-30-79	918.7	317.3	22.0	21.6	157.3	62.8	1.8	1575.3	234.2
7-30-79	1026.7	500.3	90.7	65.8	254.0	79.3	1.3	1778.7	492.0
8-24-79	1556.7	276.8	78.7	55.1	293.3	89.5	2.3	1823.3	367.4
9-23-79	1050.0	407.1	147.3	63.1	170.7	32.2	1.8	1778.0	373.1
10-27-79	746.0	154.8	8.0	17.7	260.0	70.8	1.2	1858.0	200.8
11-30-79	222.0	448.7	730.0	492.5	290.0	103.4	1.0	222.0	448.7

[1]Burned March 2, 1979.
[2]Preharvest samples.

Table 14. Average biomass ($\bar{x}$) standard deviation (s) of live and standing dead plant shoots, total litter, number of species, and total live biomass (g/m^2) of all species in the Harvest III[1] *S. cynosuroides* community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-03-79[2]	-	-	-	-	-	-	-	-	-
4-20-79	302.7	110.1	0.0[3]	0.0	375.3	79.1	1.8	343.3	118.8
5-25-79	801.3	118.5	7.3	12.5	14.7	14.2	1.3	836.7	110.3
6-30-79	894.7	304.1	28.7	13.5	27.3	7.8	1.8	1329.3	123.8
7-30-79	1084.0	261.4	174.7	175.8	115.3	34.0	1.5	1286.0	317.8
8-24-79	1116.0	405.9	158.7	112.5	71.3	24.3	2.2	1472.0	363.1
9-23-79	663.3	323.2	131.3	107.7	79.3	9.3	1.3	1623.3	375.4
10-27-79	390.7	100.7	294.0	170.4	103.3	53.3	1.3	1158.7	420.6
11-30-79	82.7	80.2	642.0	322.9	166.0	18.5	1.0	82.7	80.2

[1]Harvested February 20, 1979.

[2]No preharvest samples were collected.

APPENDIX 2

Plates 1-4: Aerial false color infra-red photographs of study areas and photographs of marsh burning and harvesting.

Plate 1. Aerial false color infra-red photograph showing the locations of the experimental plots on the *Juncus roemerianus* marsh.

C = plots used as control

B_1 = plot burned in 1977, 78, and 79

B_2 = plot burned in 1978 and 79

B_3 = plot burned in 1979

H_1 = plot harvested in 1977, 78, and 79

H_2 = plot harvested in 1978 and 79

H_3 = plot harvested in 1979


MARSH
C
B3
H3
C
B2
H2
B1
H1
CATFISH BAYOU

Plate 2. Aerial false color infra-red photograph showing the locations of the experimental plots in the *Spartina cynosuroides* marsh.

C = plots used as control

B_1 = plot burned in 1977, 78, and 79

B_2 = plot burned in 1978 and 79

B_3 = plot burned in 1979

H_1 = plot harvested in 1977, 78, and 79

H_2 = plot harvested in 1978 and 79

H_3 = plot harvested in 1979

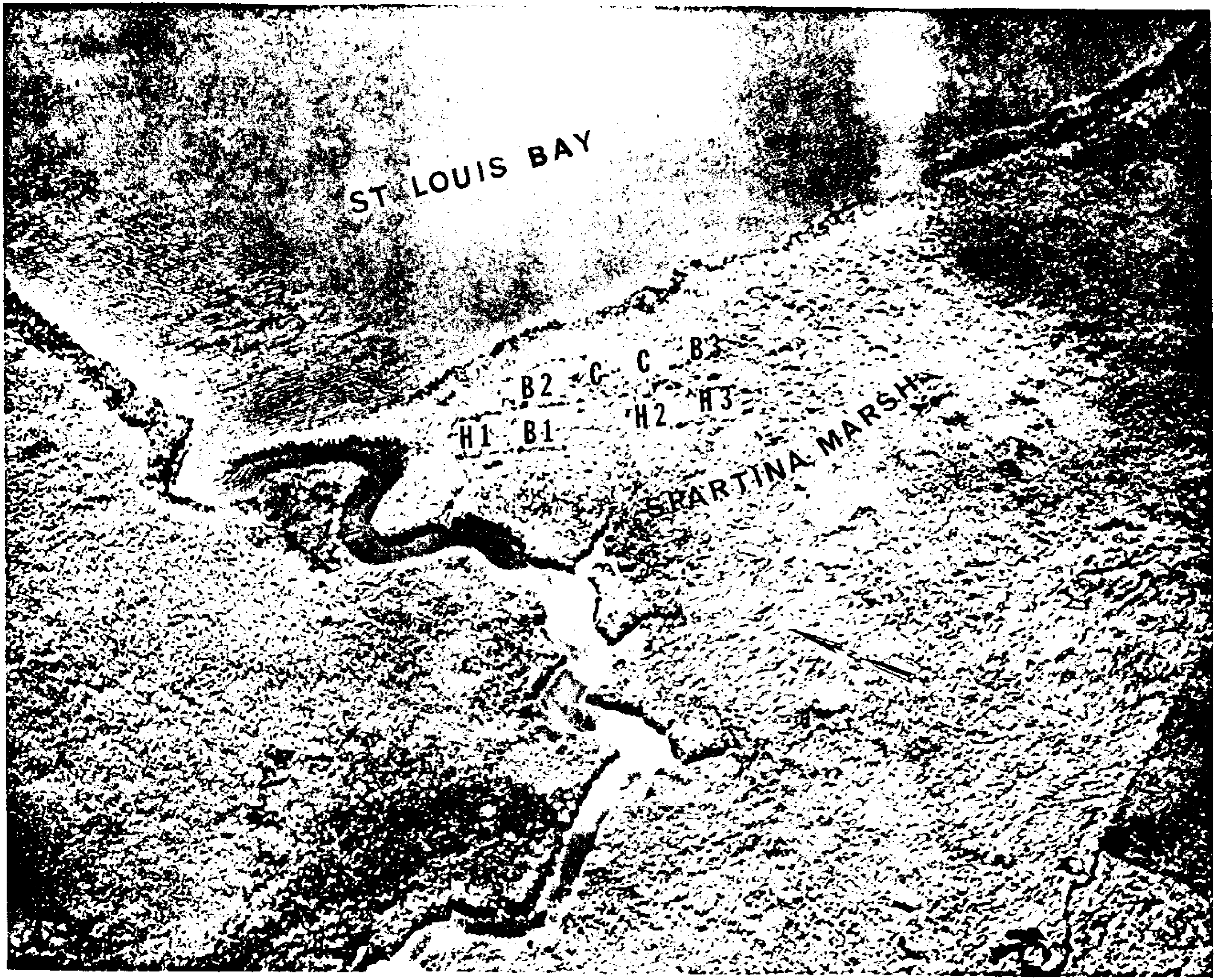
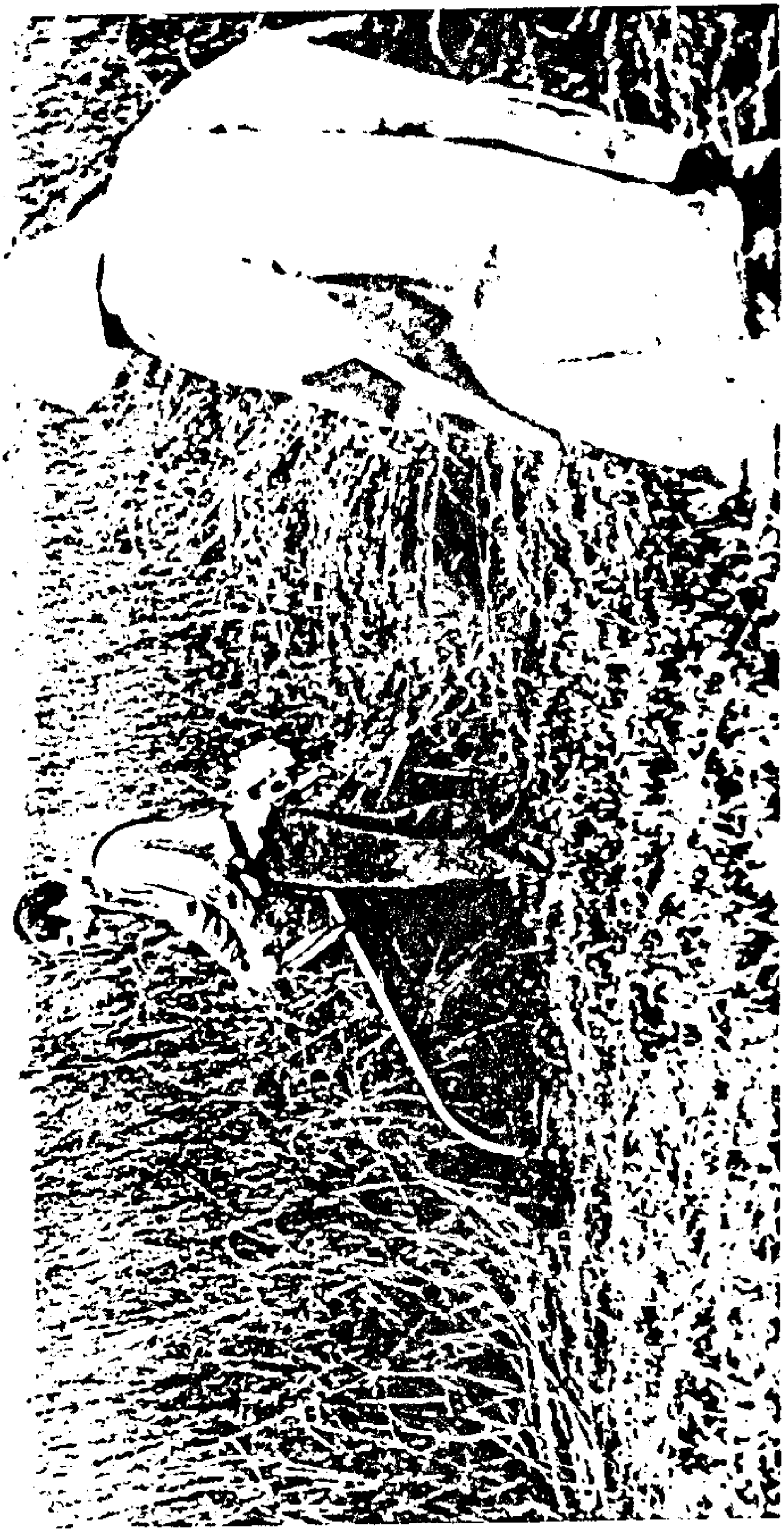

ST LOUIS BAY
B2
C
C
B3
H1
B1
H2
H3
SPARTINA MARSH

Plate 3. *Spartina* marsh burning.

Plate 4. _Juncus_ marsh being cut with a metal-bladed "weed eater."



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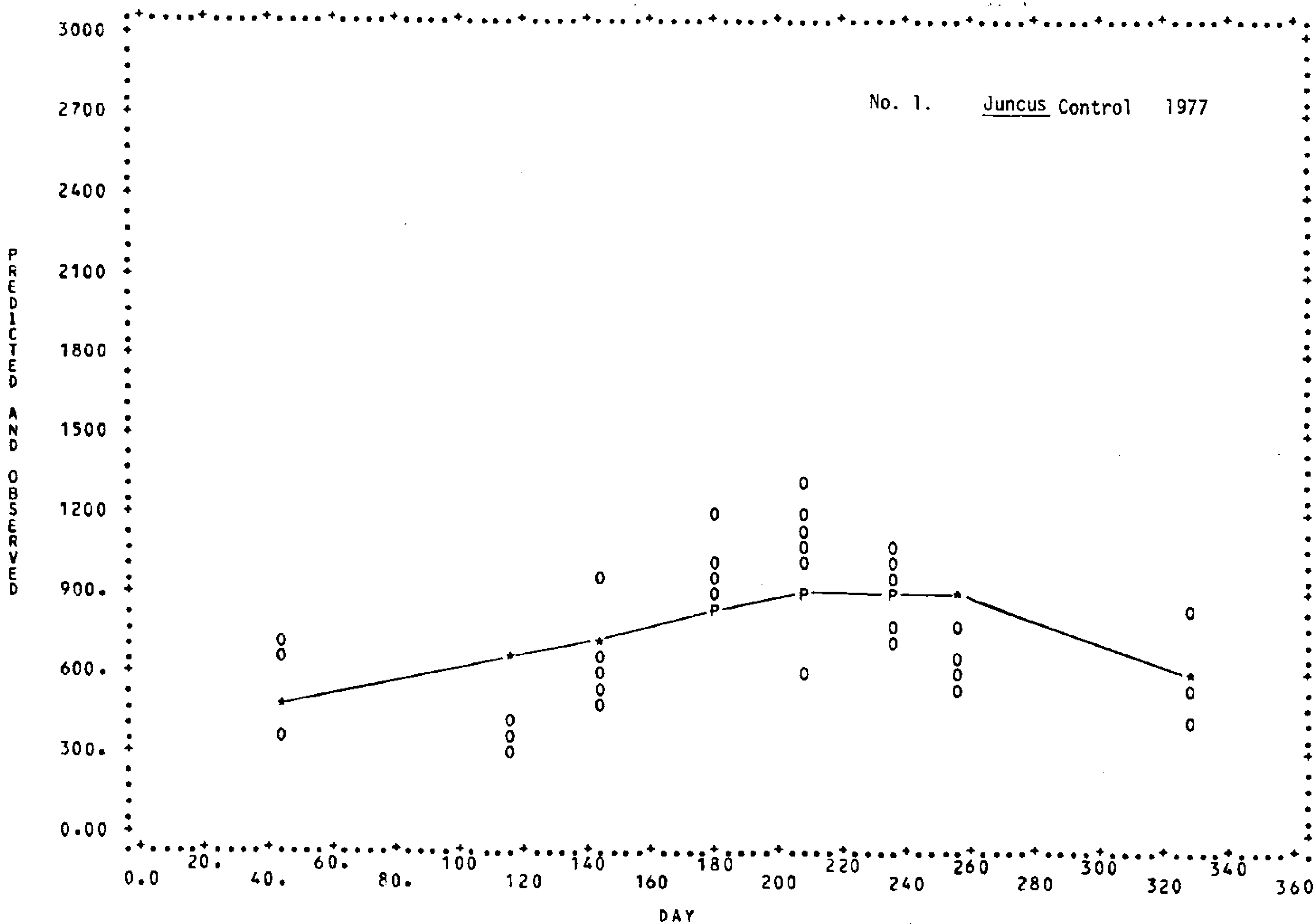
APPENDIX 3

Print-out 1-30: Predicted and observed values of monthly total live biomass in Control, Burn, and Harvest plots in 1977, 1978, and 1979.

31-32: Predicted and observed values of monthly total live biomass of all the control plots in 1977, 1978, and 1979.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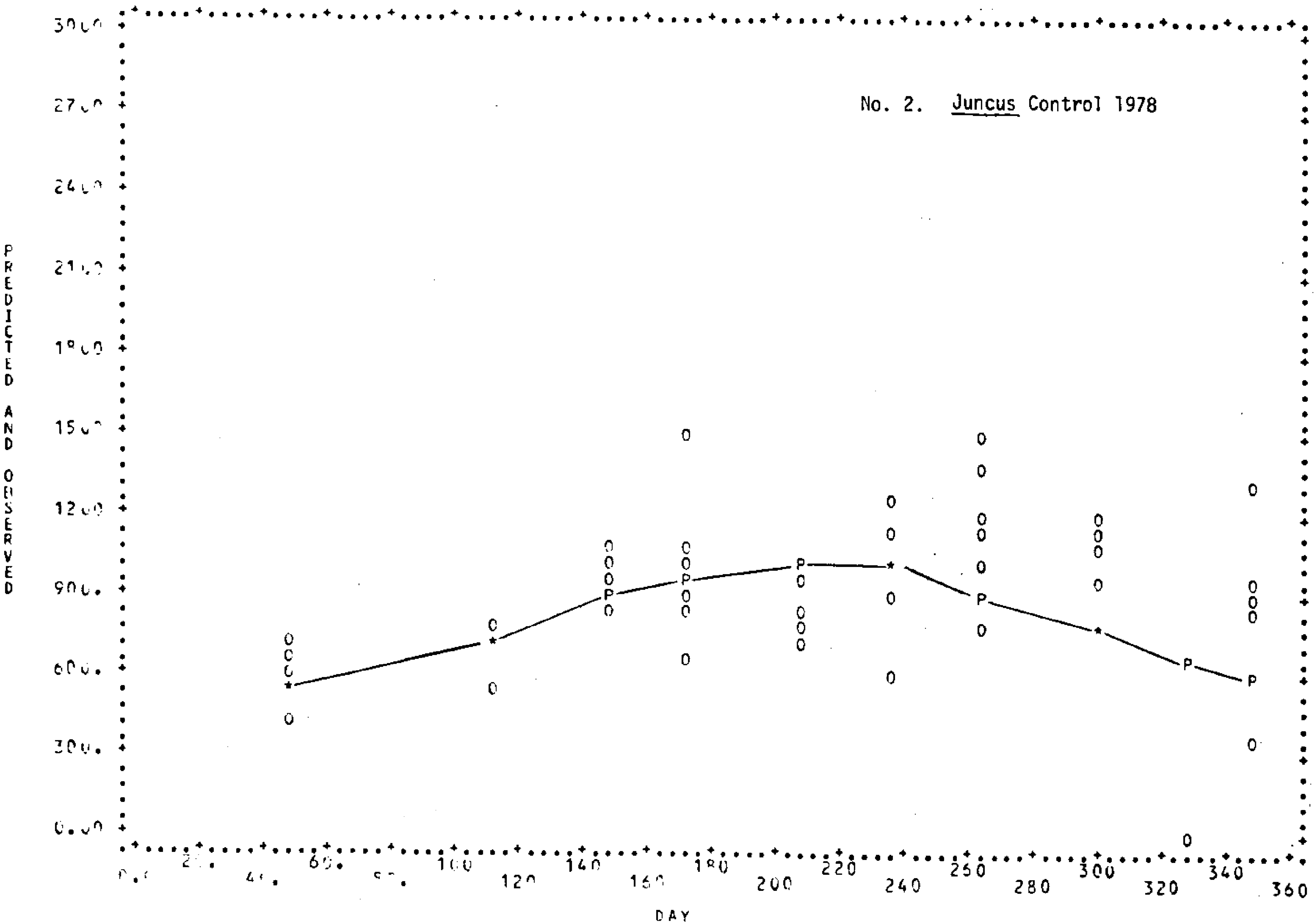
2400
2100
1800
1500
1200
900.
600.
300.
0.00
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY



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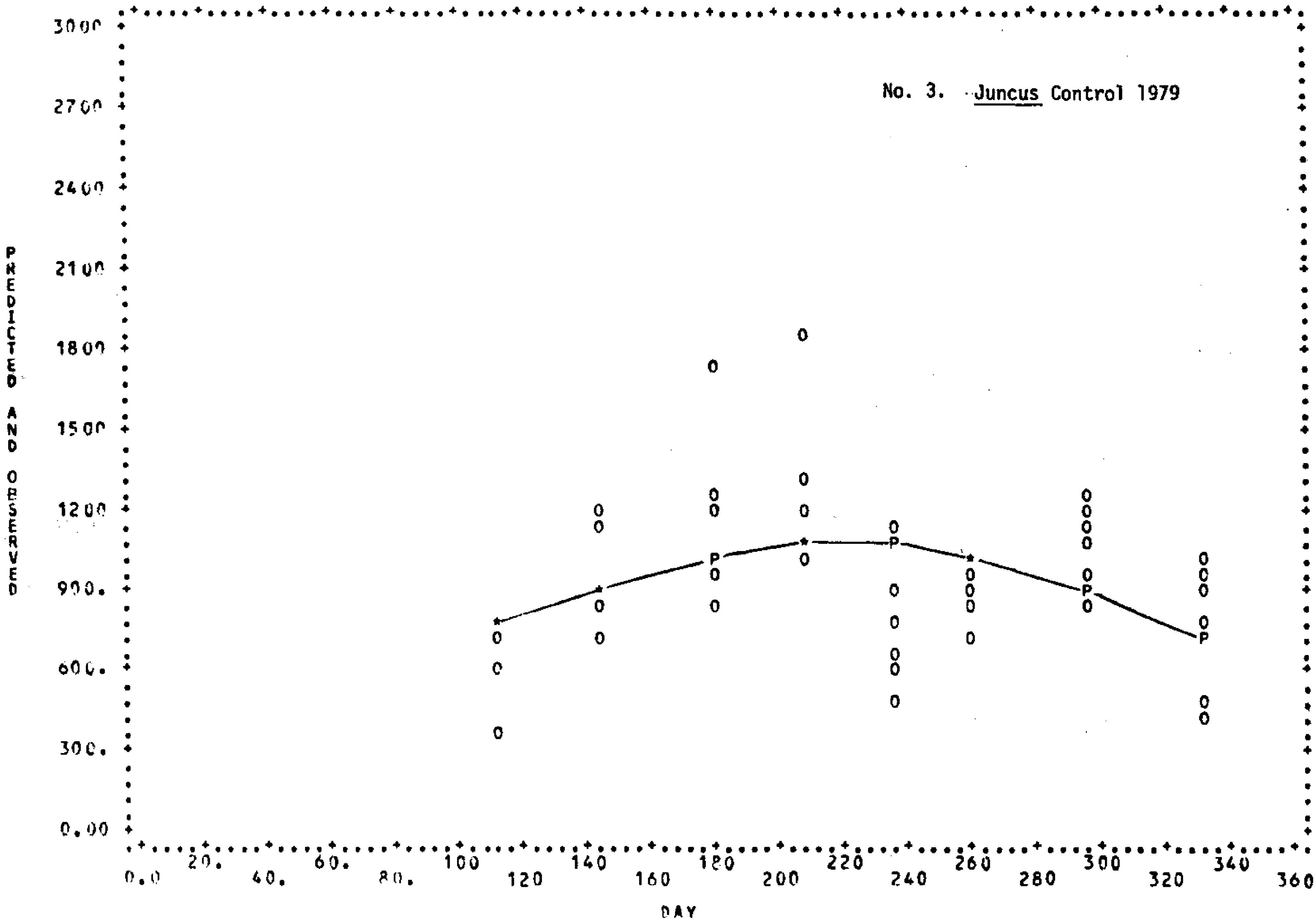
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1800
1500
1200
900.
600.
300.
0.00
0.0
20.
40.
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80.
100
120
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160
180
200
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240
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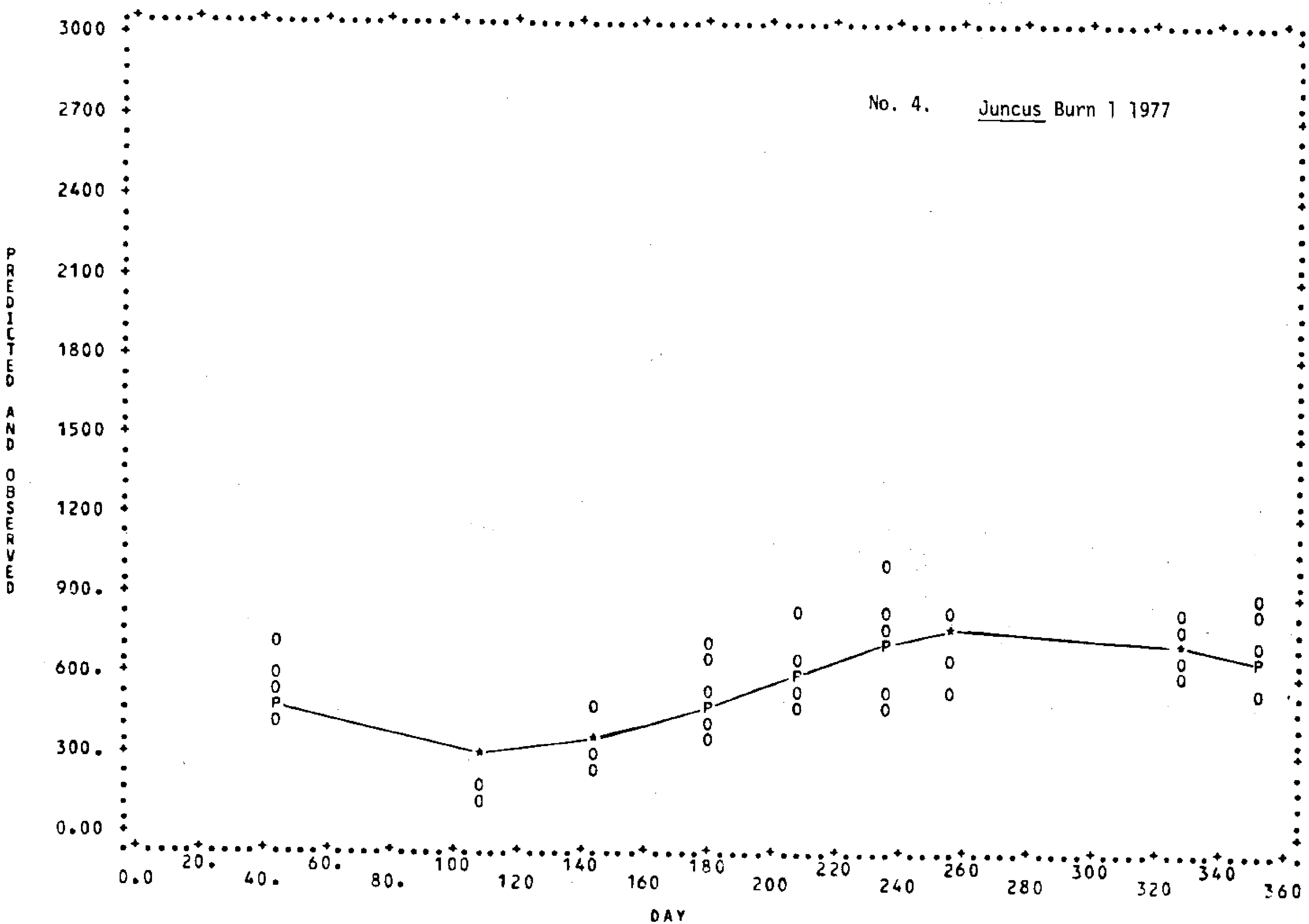
280
300
320
340
360
DAY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2100
1800
1500
1200
900.
600.
300.
0.00
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20.
40.
60.
80.
100
120
140
160
180
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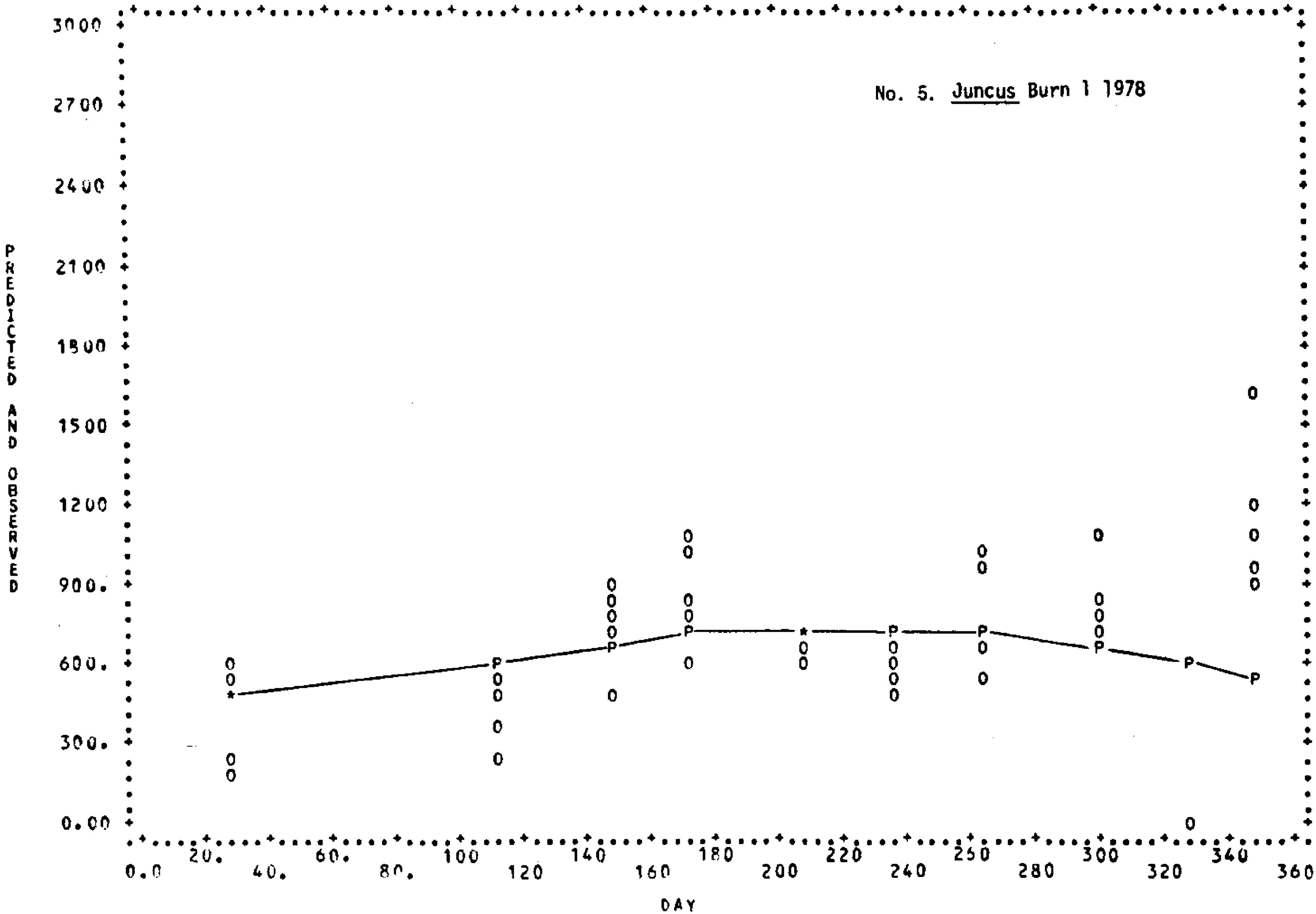
220
240
260
280
300
320
340
360


No. 5. Juncus Burn 1 1978
PREDICTED AND OBSERVED
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1800
1500
1200
900.
600.
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0.00
0.0
20.
40.
60.
80.
100
120
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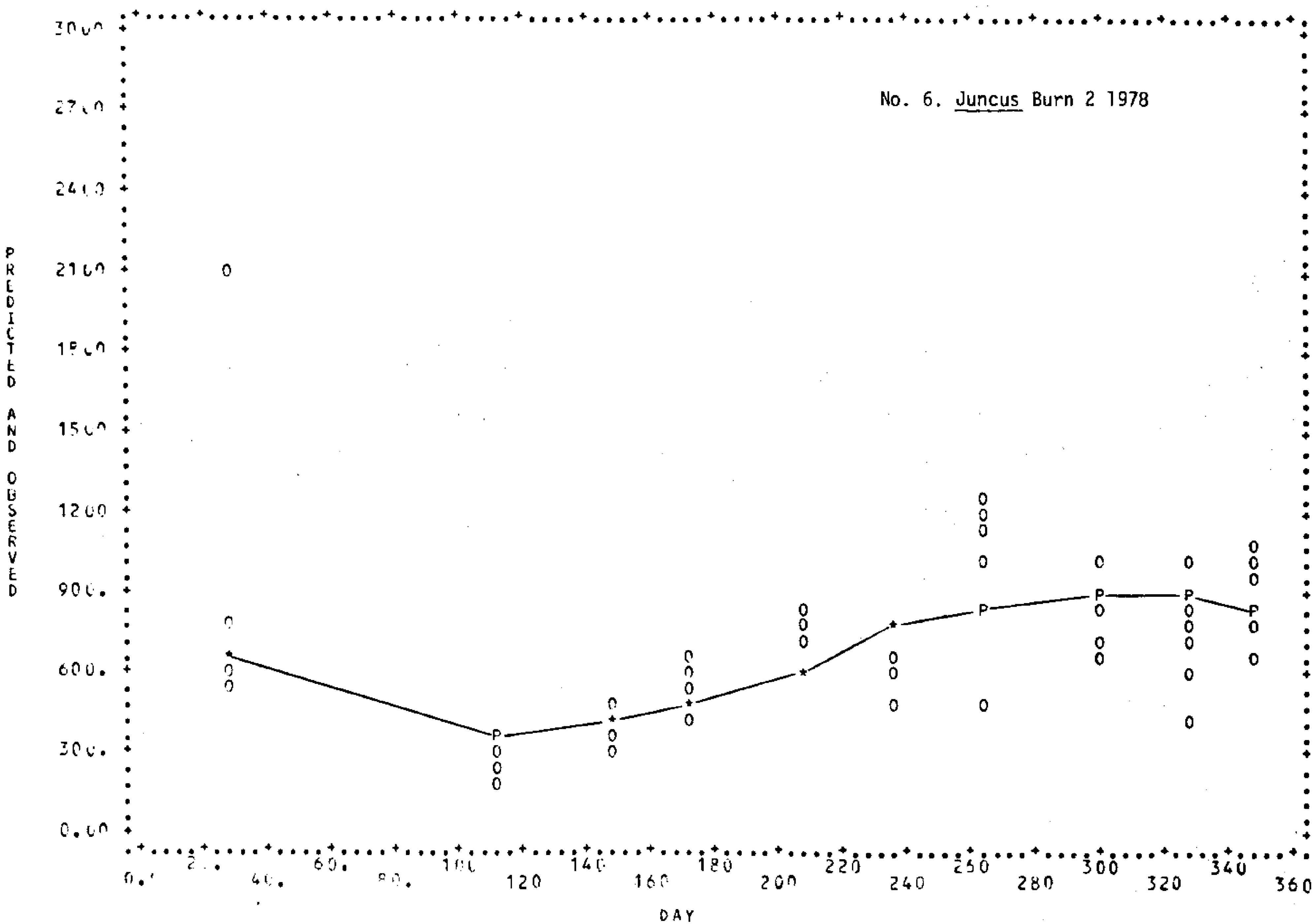
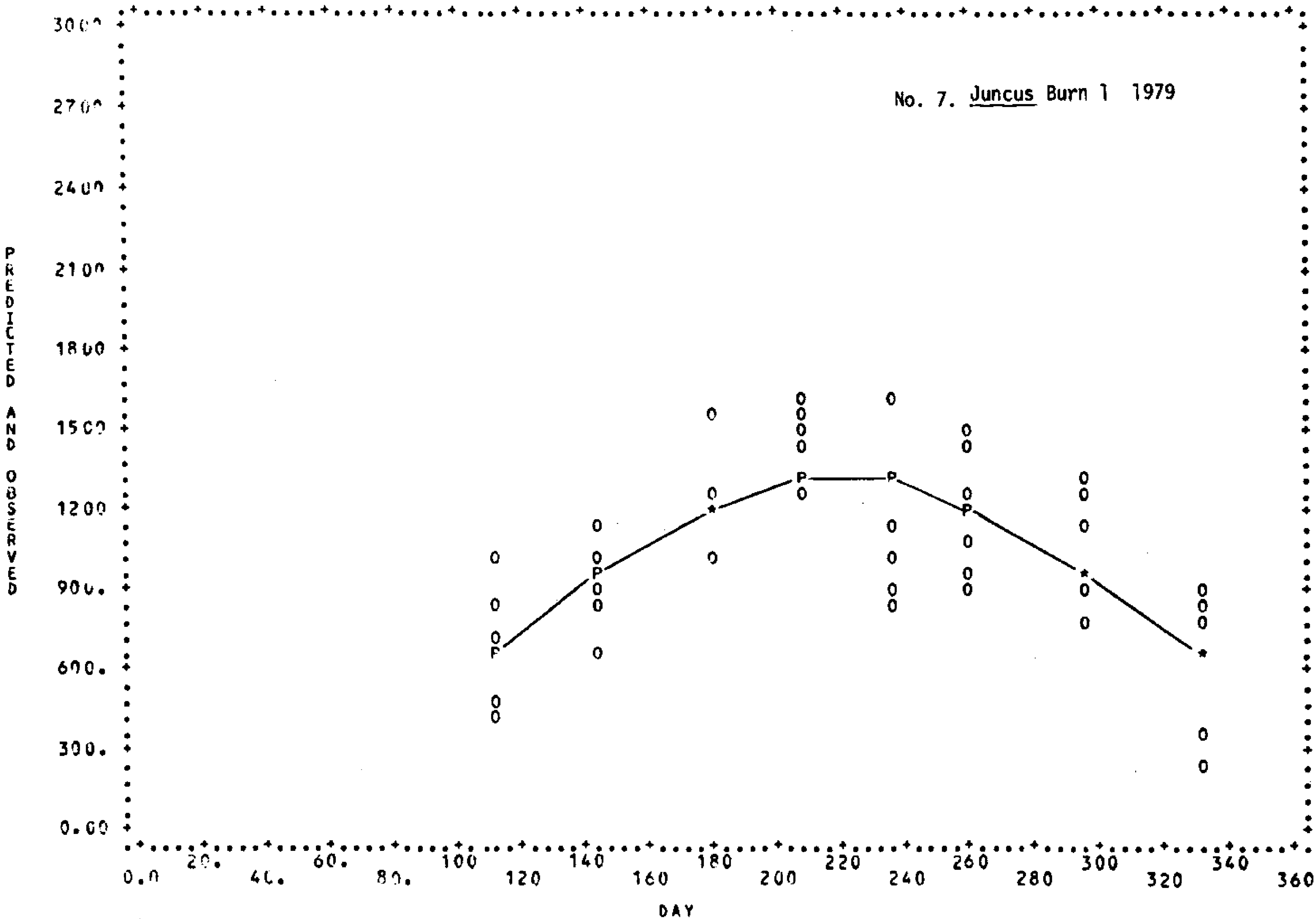
160
180
200
220
240
260
280
300
320
340
360
DAY


No. 6. Juncus Burn 2 1978
PREDICTED AND OBSERVED
DAY
120
160
200
240
280
320
360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PREDICTED AND OBSERVED
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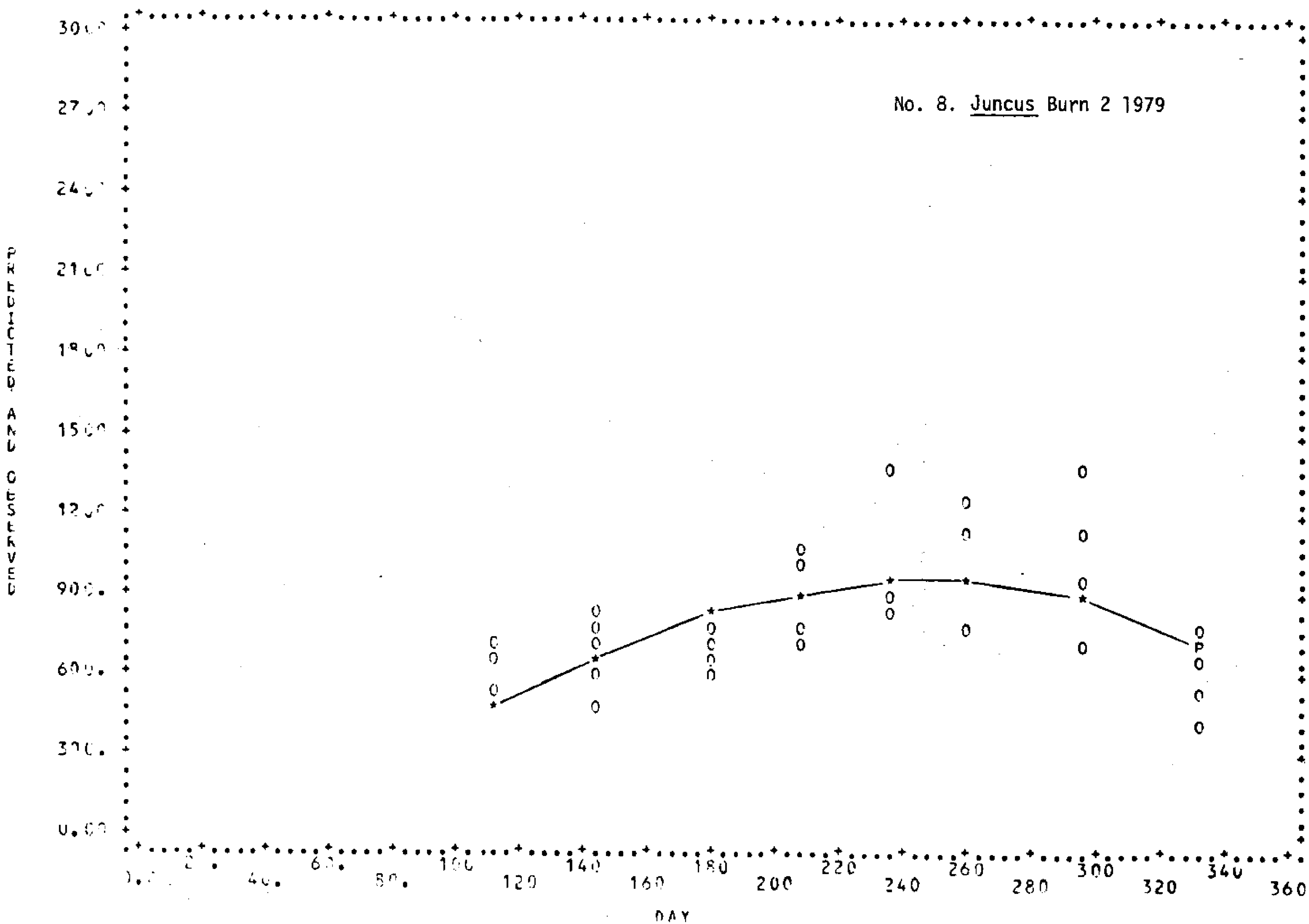
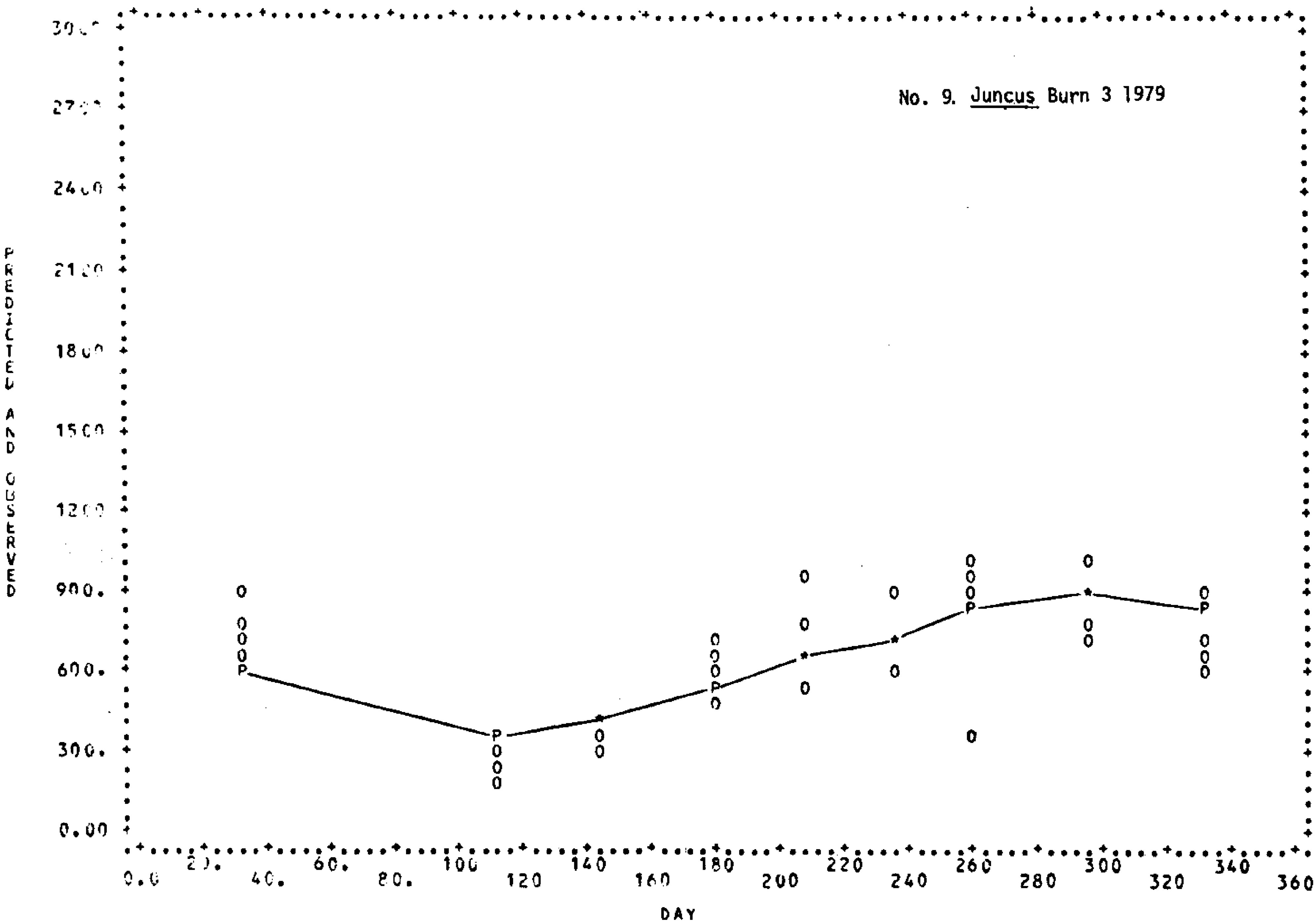
2100
1800
1500
1200
900.
600.
300.
0.00
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY

No. 8. Juncus Burn 2 1979





No. 9. Juncus Burn 3 1979
PREDICTED AND OBSERVED
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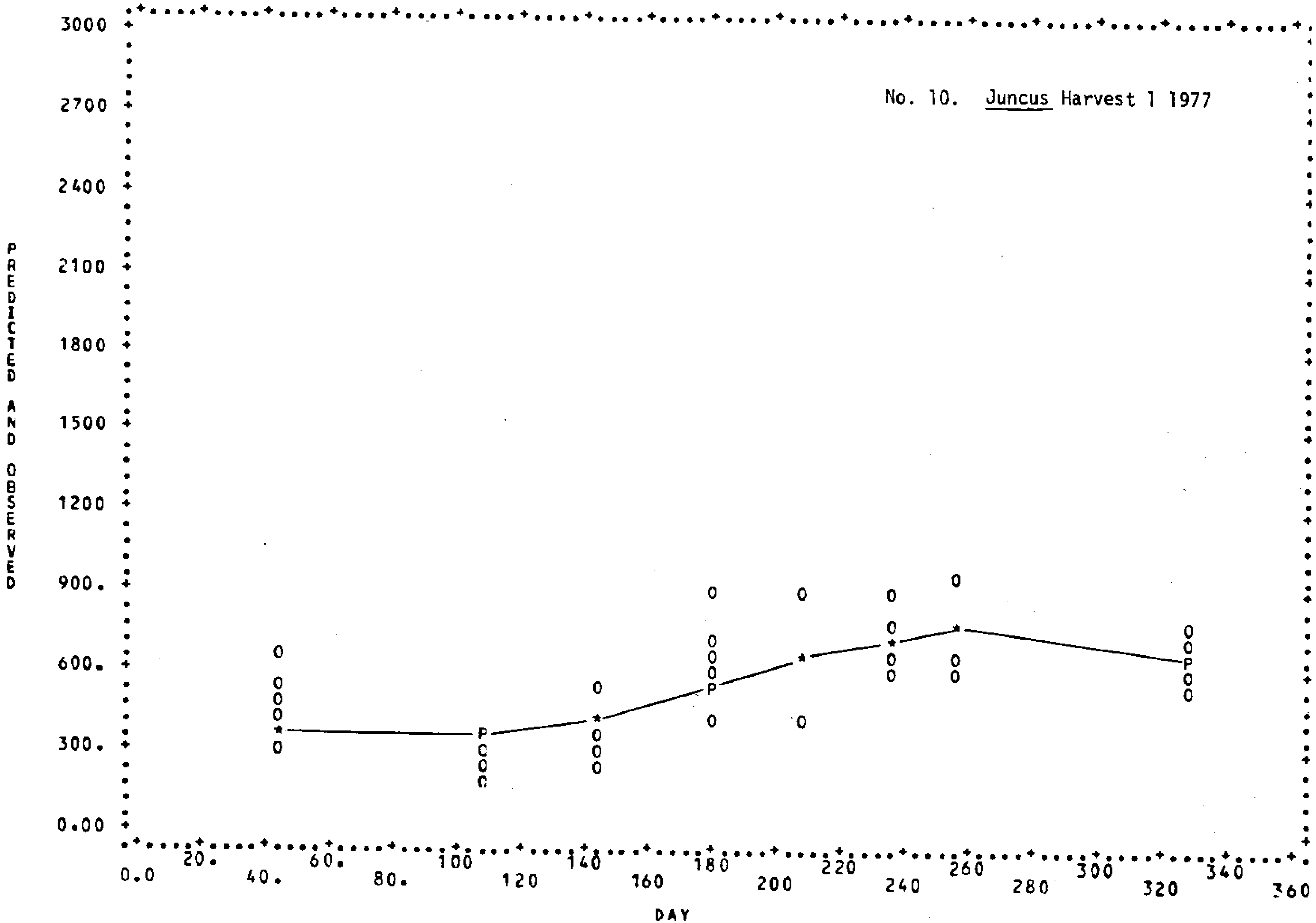
2700
2400
2100
1800
1500
1200
900.
600.
300.
0.00
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY


No. 10. Juncus Harvest 1 1977
PREDICTED AND OBSERVED
DAY
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2700
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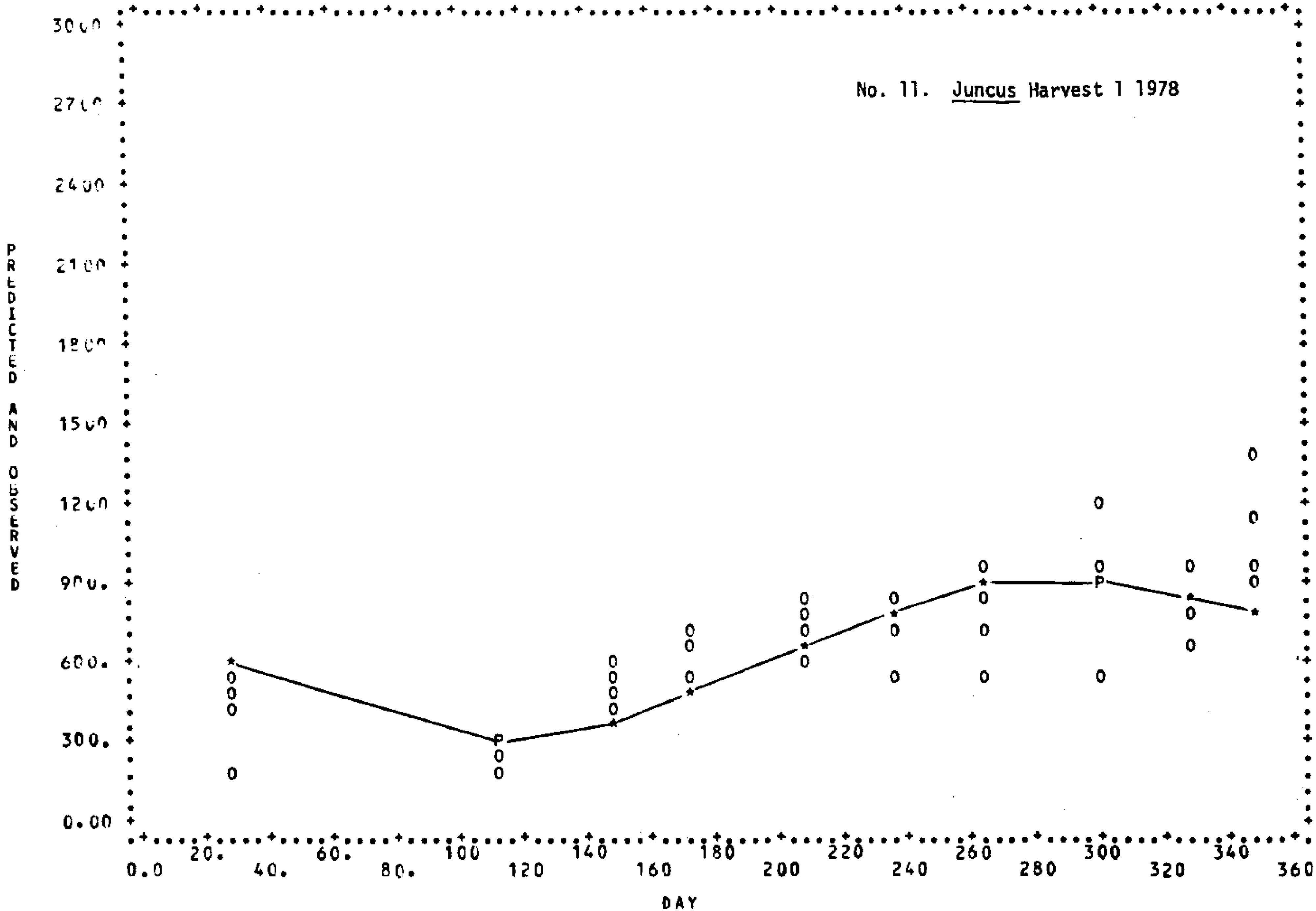
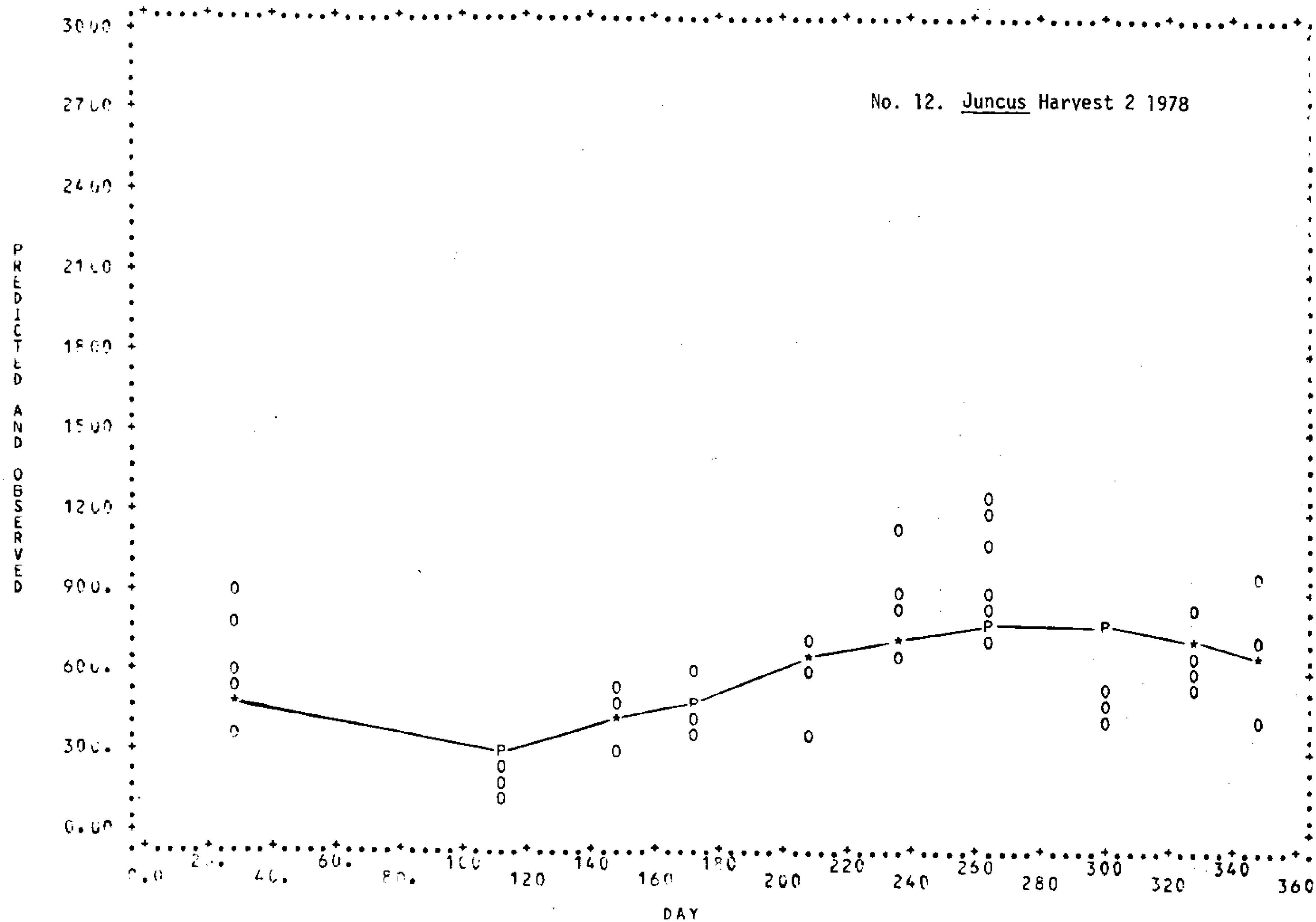
2100
1800
1500
1200
900.
600.
300.
0.00
0.0 20. 40. 60. 80. 100 120 140 160 180 200 220 240 260 280 300 320 340 360


No. 11. Juncus Harvest 1 1978
PREDICTED AND OBSERVED
DAY


No. 12. Juncus Harvest 2 1978
PREDICTED AND OBSERVED
DAY
3000
2700
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2100
1500
1200
900.
600.
300.
0.00
40.
60.
120
140
160
200
220
240
260
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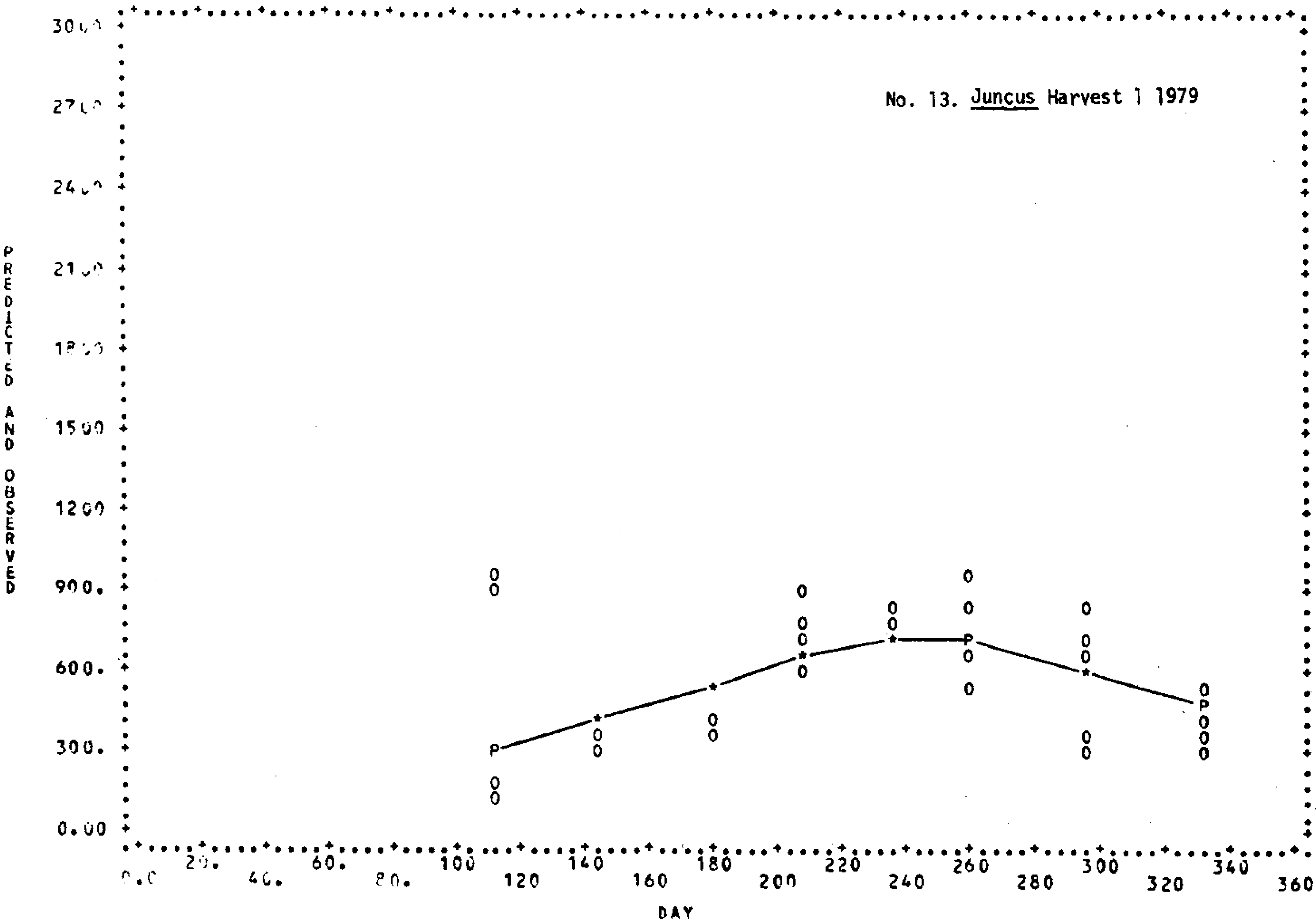
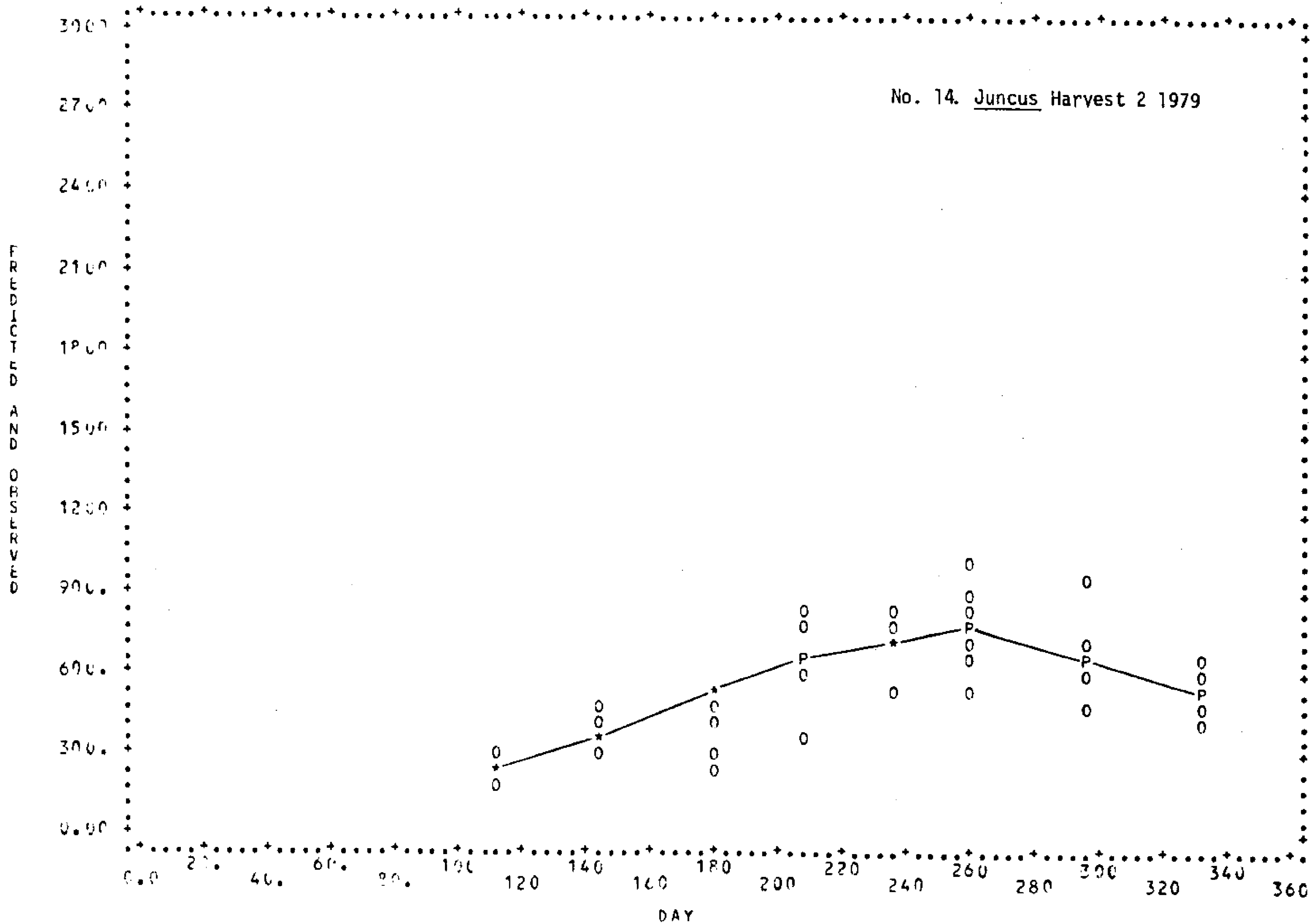
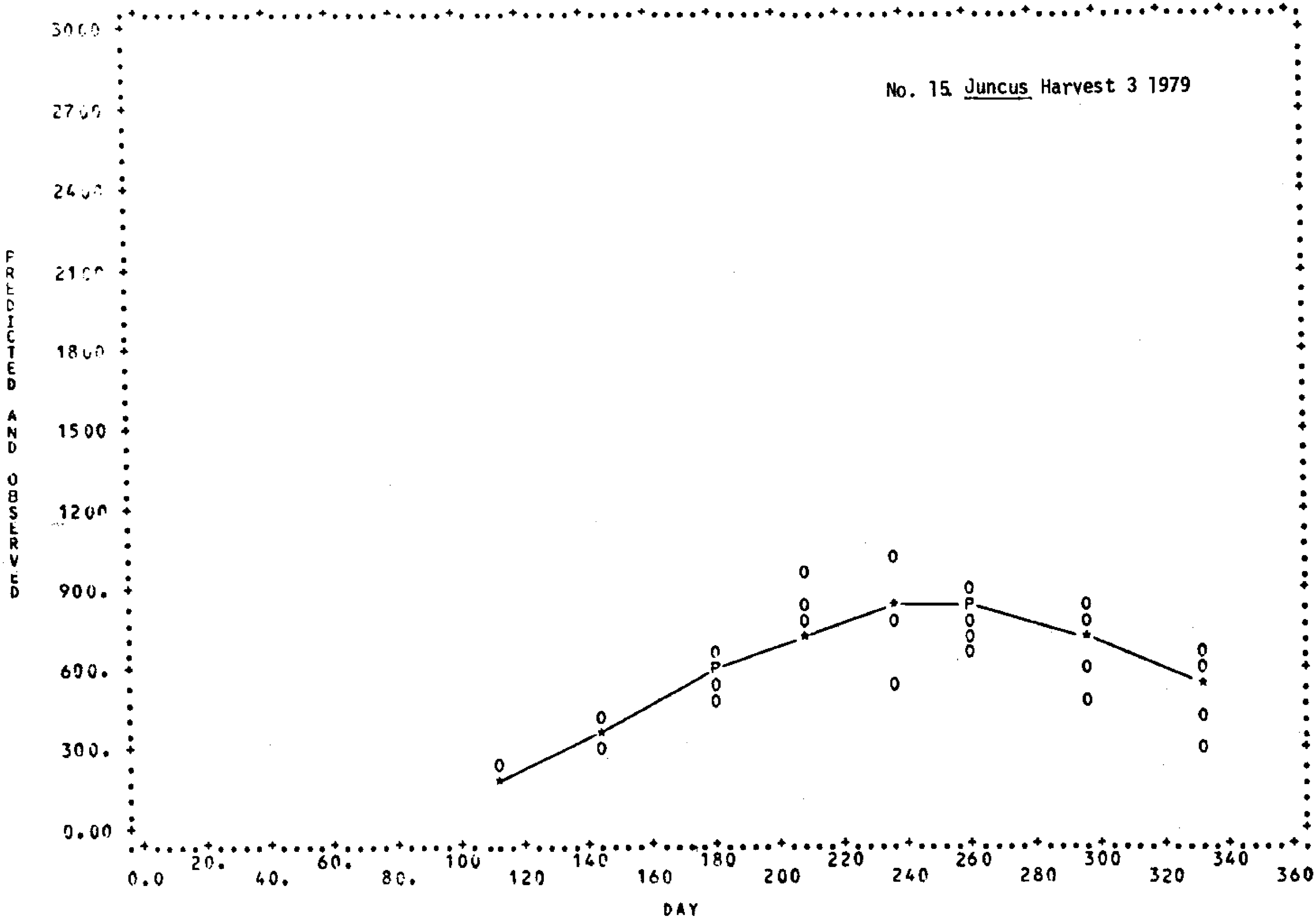
320
340
360



No. 13. *Juncus* Harvest 1 1979

No. 14. Juncus Harvest 2 1979




No. 15 Juncus Harvest 3 1979
PREDICTED AND OBSERVED
DAY
0.00
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600.
900.
1200
1500
1800
2100
2400
2700
3000
0.0
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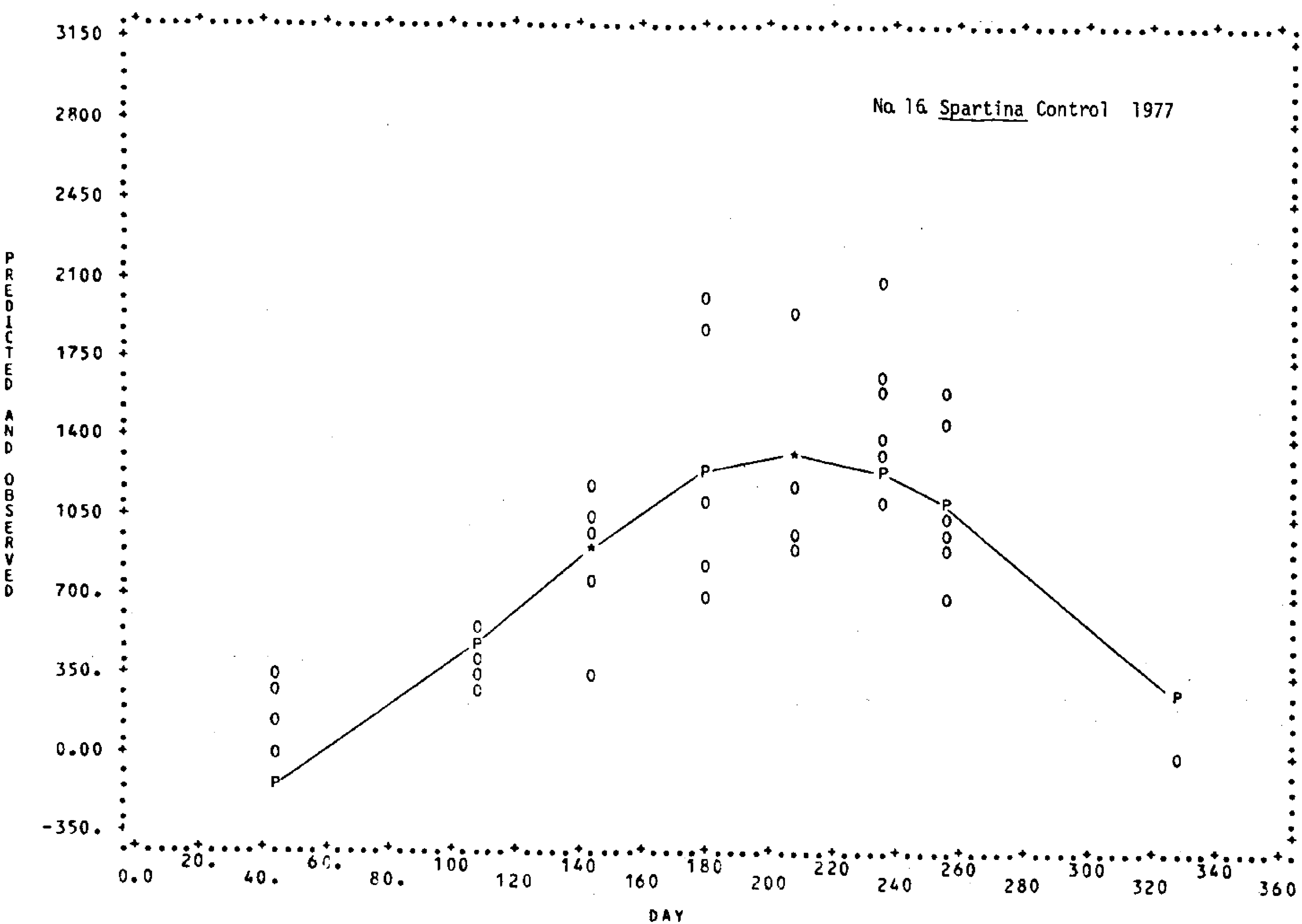
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360


No. 16 Spartina Control 1977
PREDICTED AND OBSERVED
DAY
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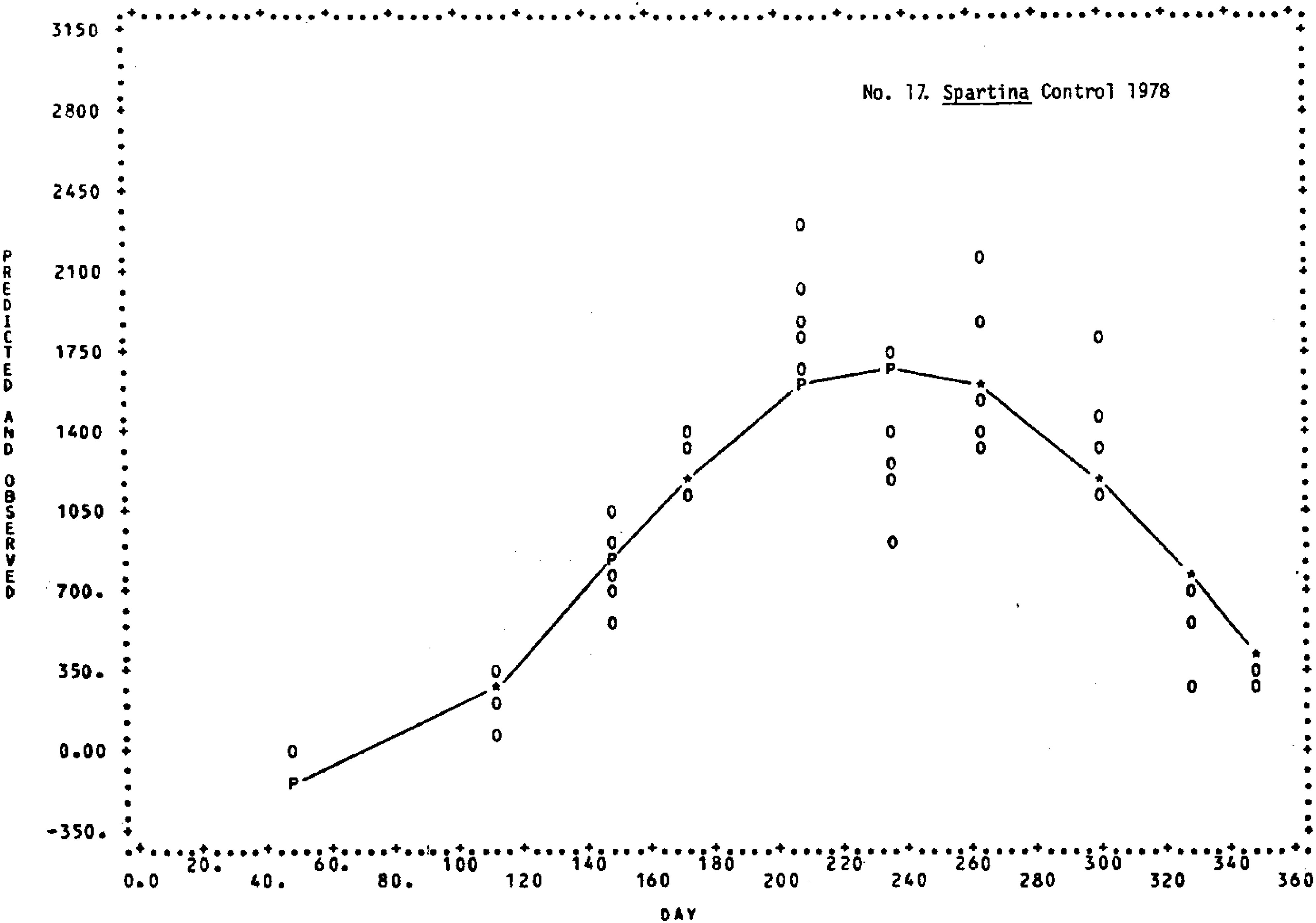
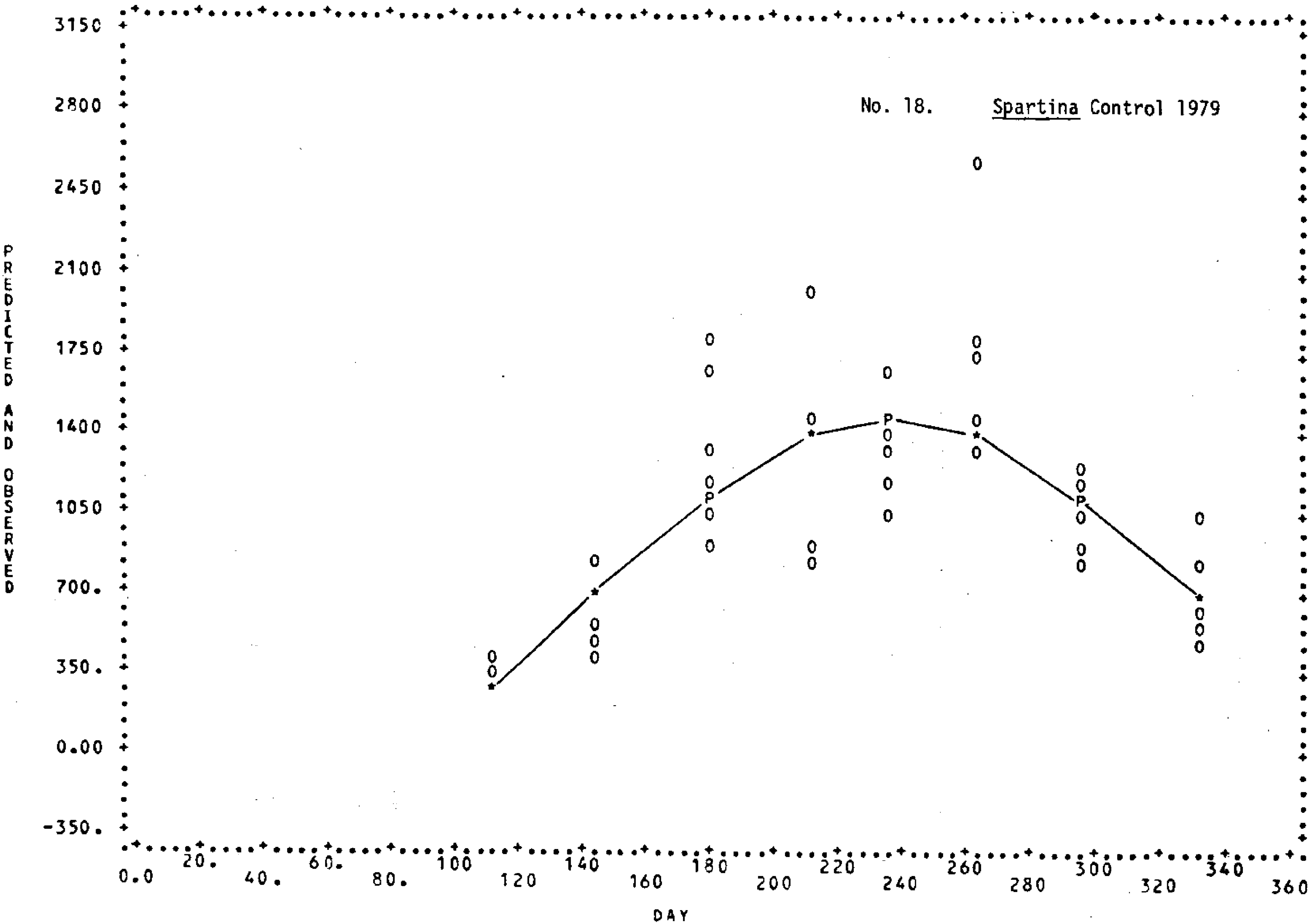
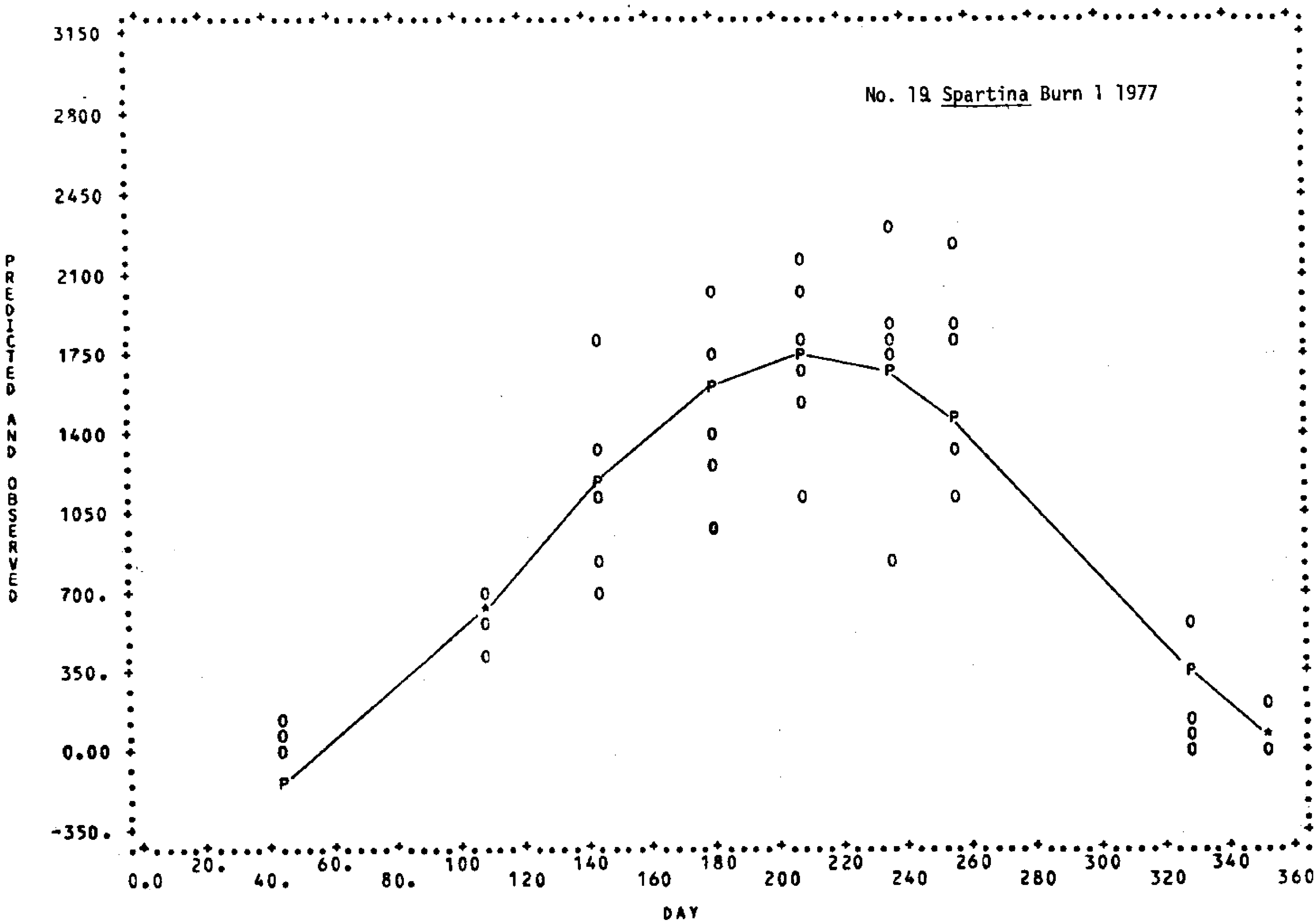
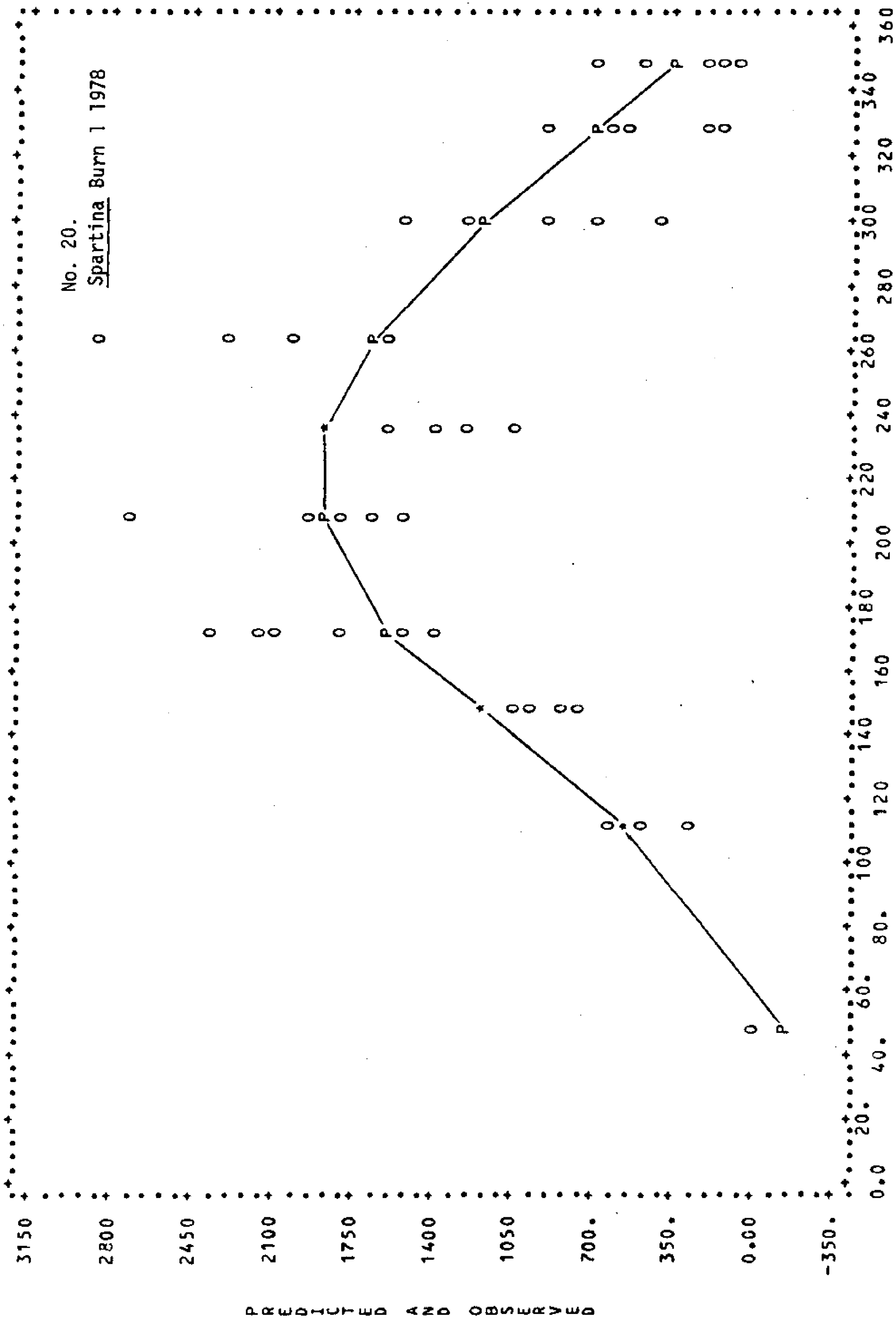
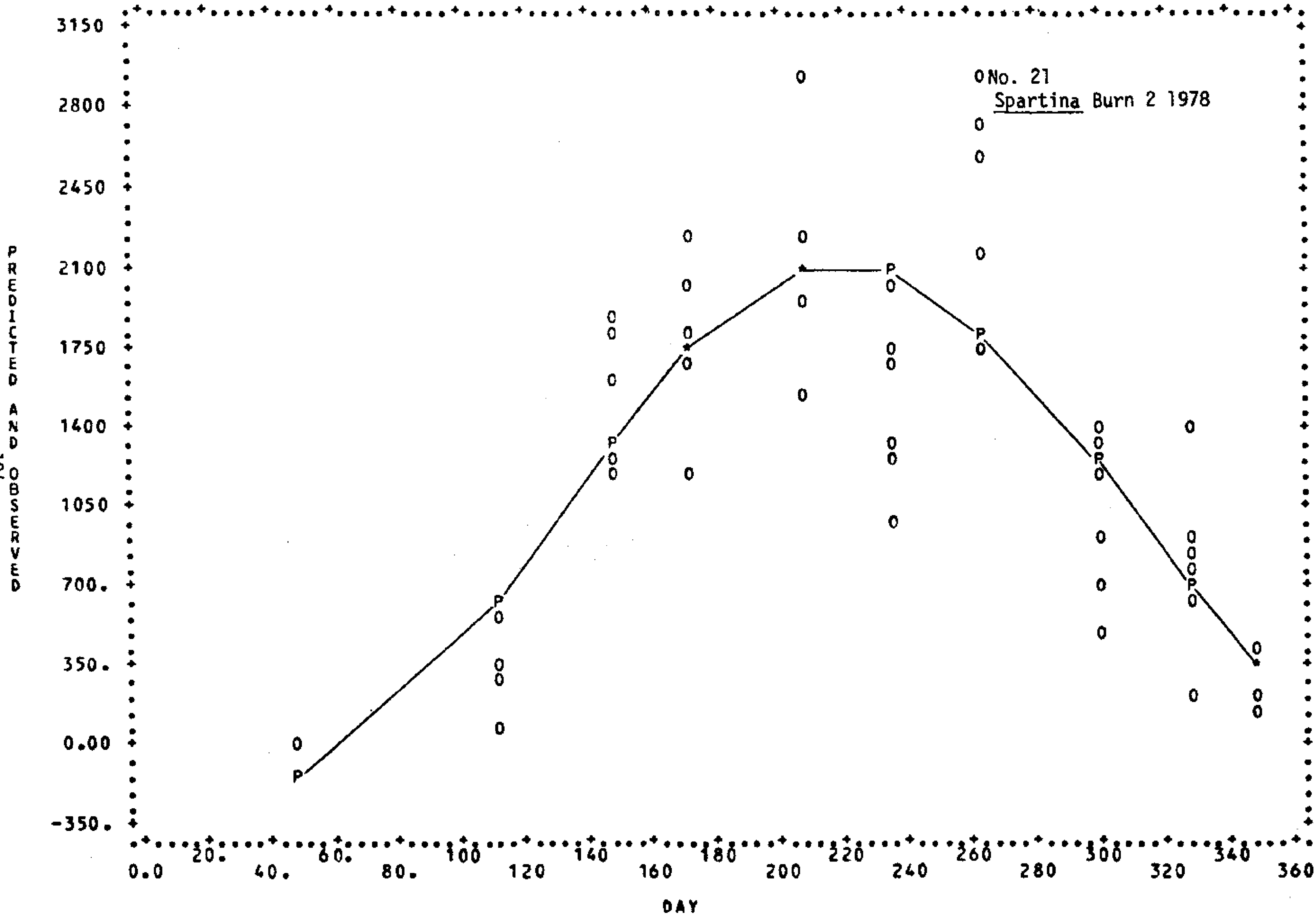
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360

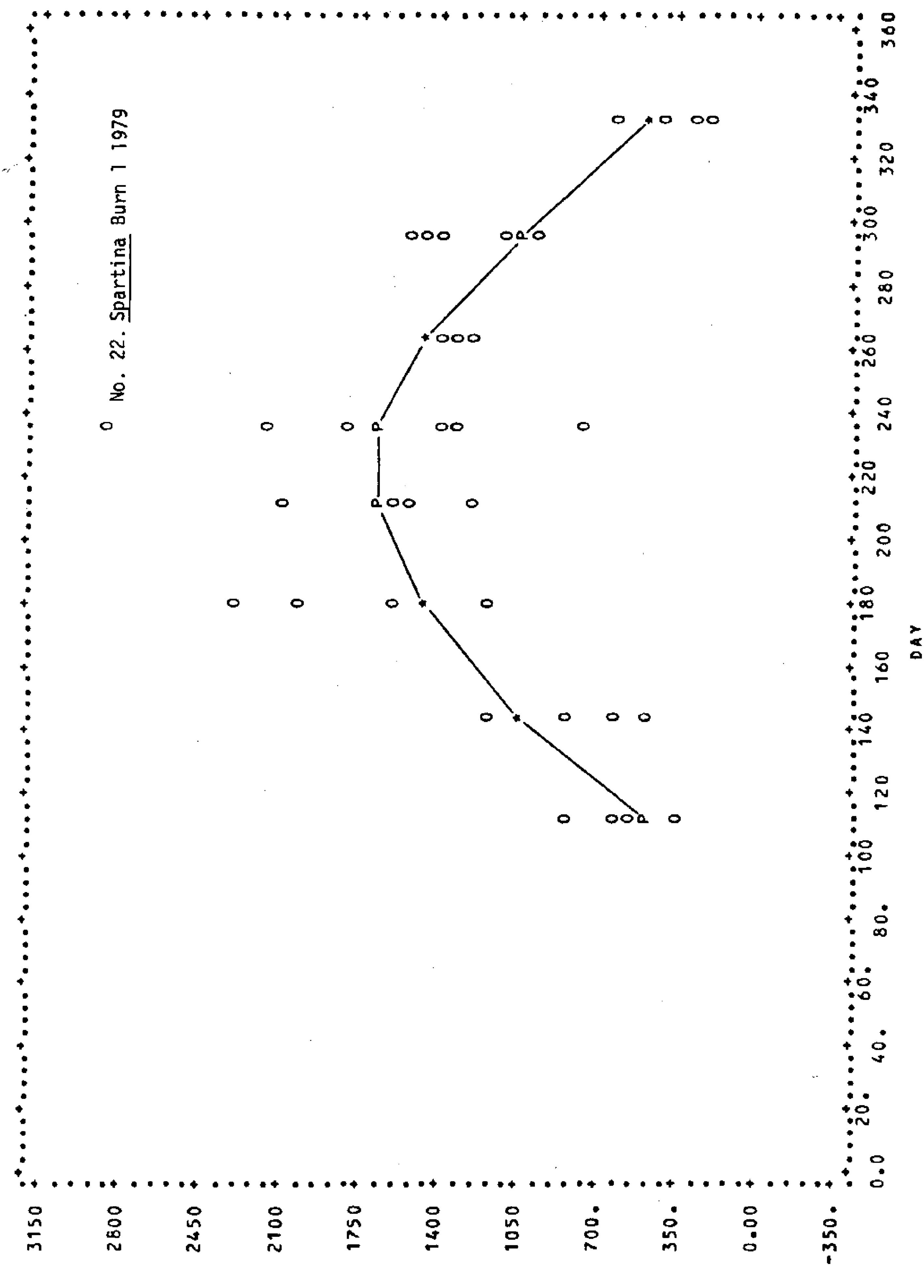

No. 17. Spartina Control 1978
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
PREDICTED AND OBSERVED
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY

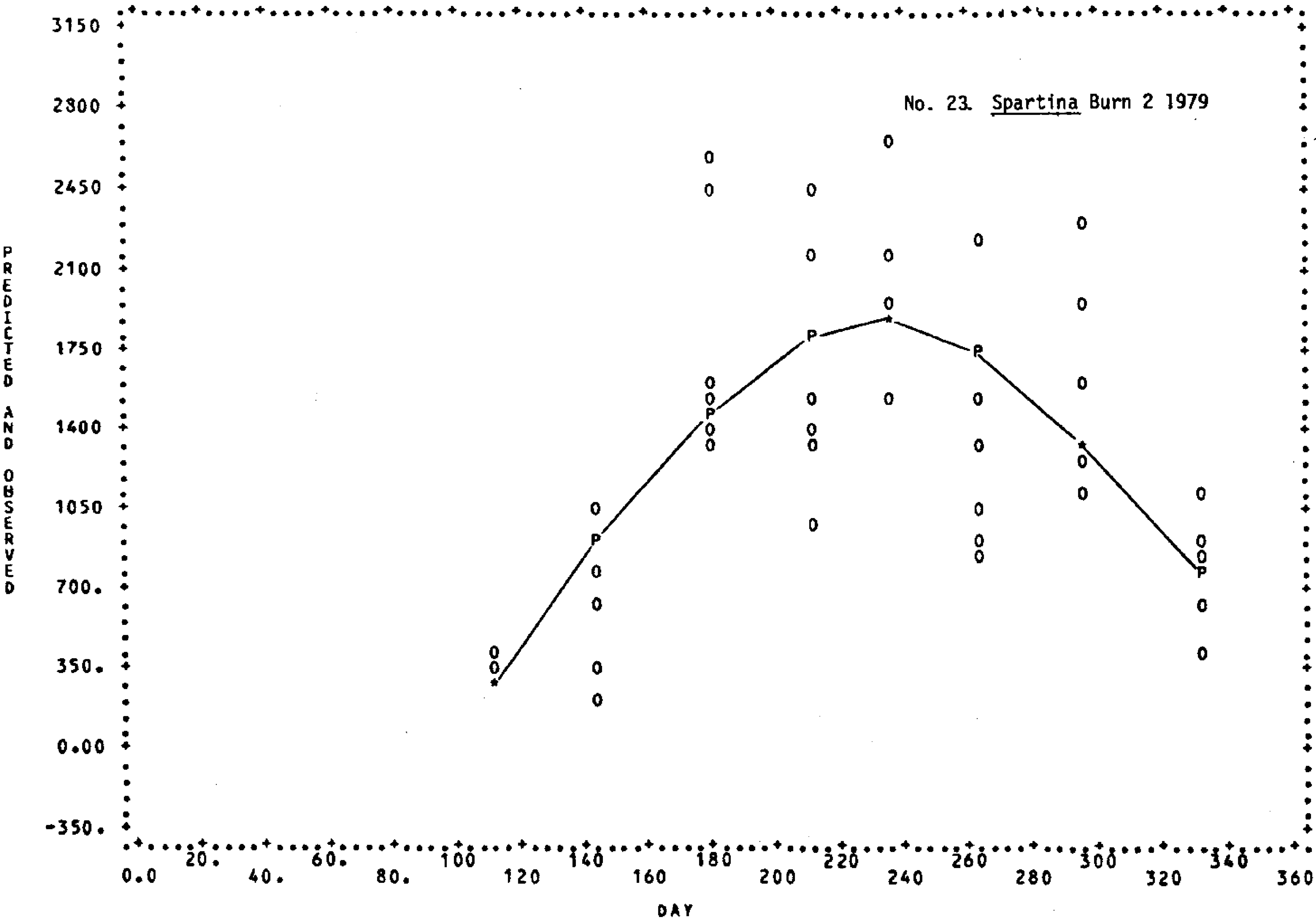

No. 18. Spartina Control 1979
PREDICTED AND OBSERVED
DAY
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360

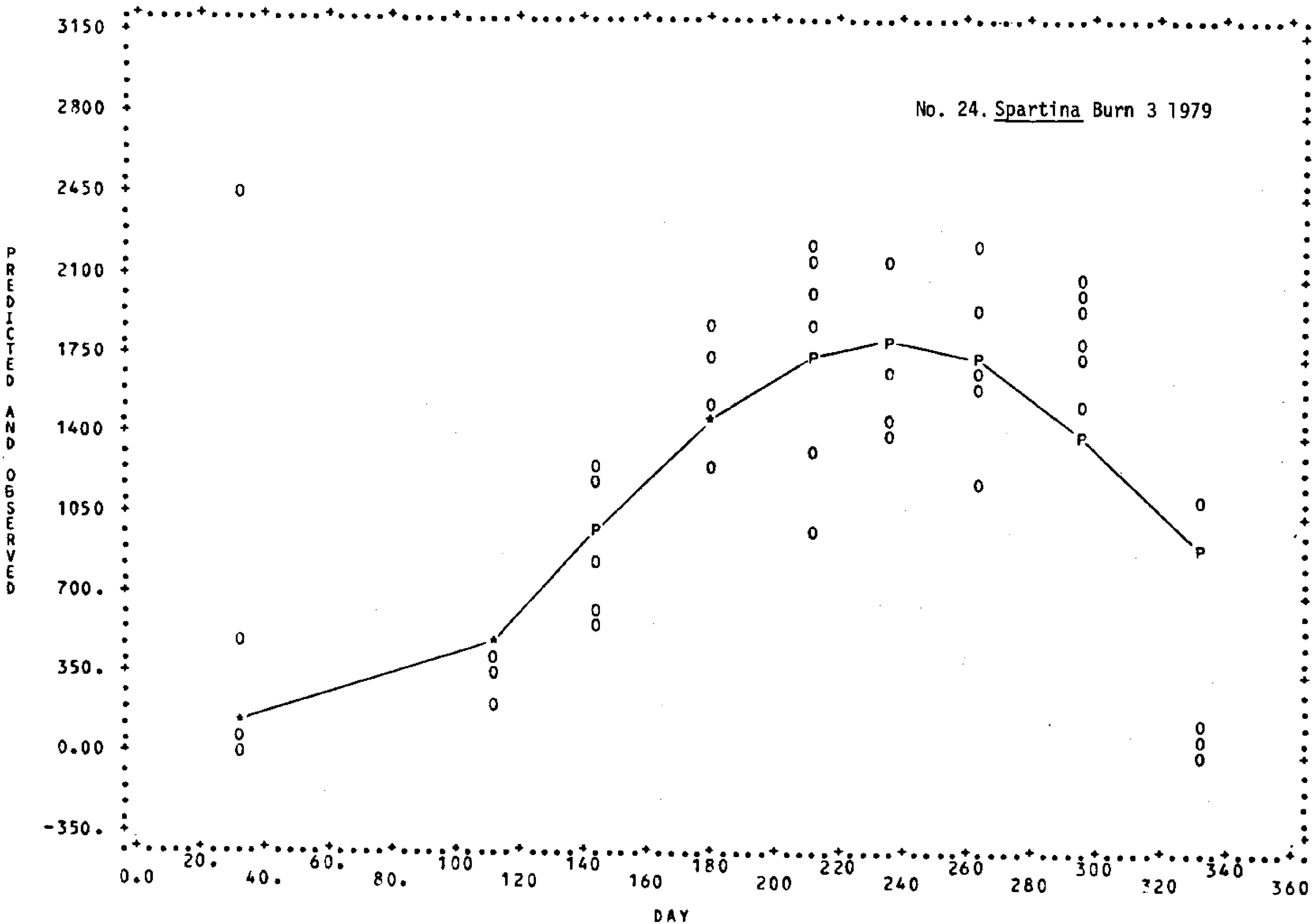

No. 19 Spartina Burn 1 1977
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
PREDICTED AND OBSERVED
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY


No. 20.
Spartina Burn 1 1978
DAY
0.0 20. 40. 60. 80. 100 120 140 160 180 200 220 240 260 280 300 320 340 360
PREDICTED AND OBSERVED
3150 2800 2450 2100 1750 1400 1050 700. 350. 0.00 -350.

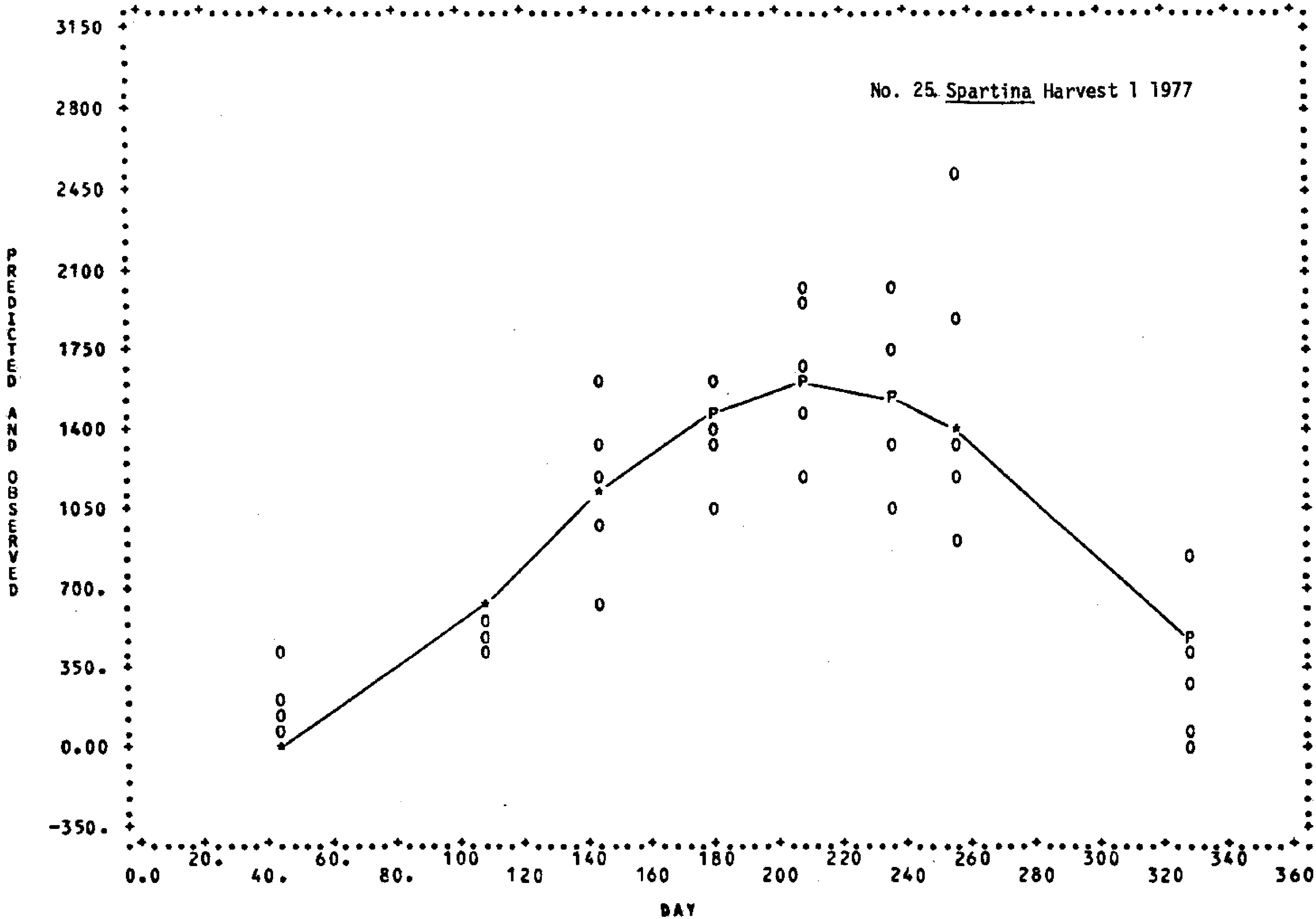

No. 21
Spartina Burn 2 1978
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY

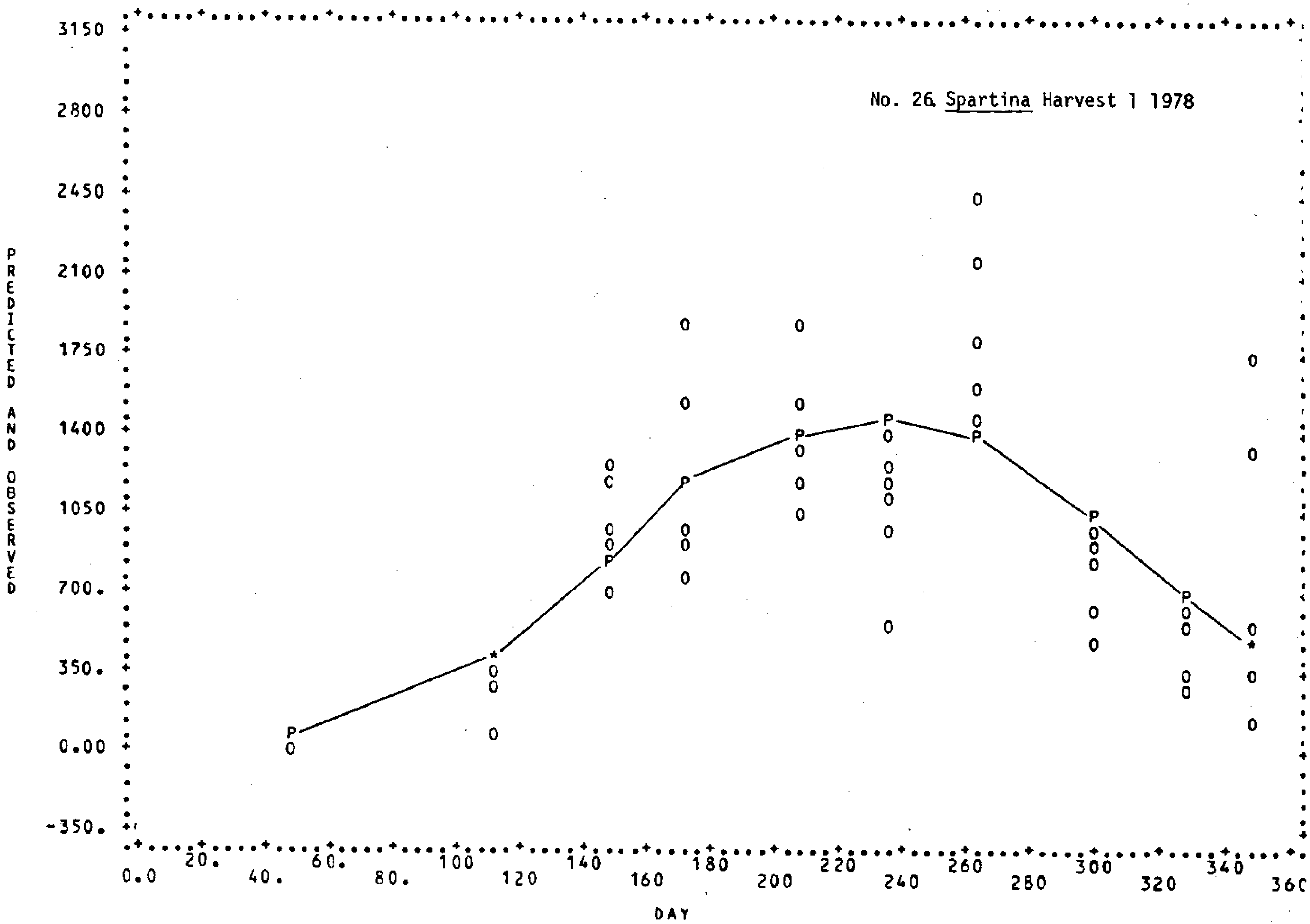

No. 22. Spartina Burn 1 1979
DAY
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360

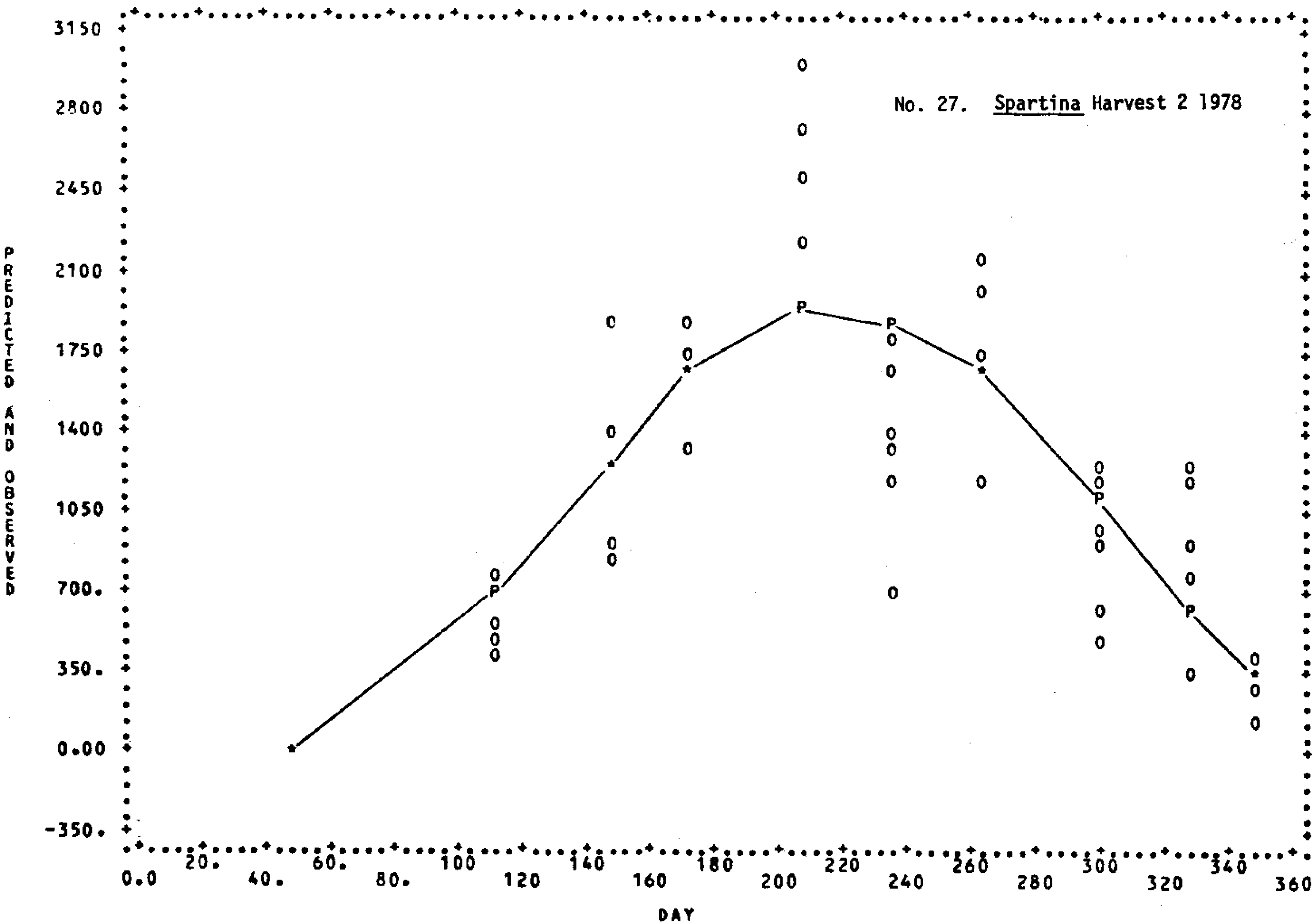

No. 23. Spartina Burn 2 1979
PREDICTED AND OBSERVED
DAY
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360

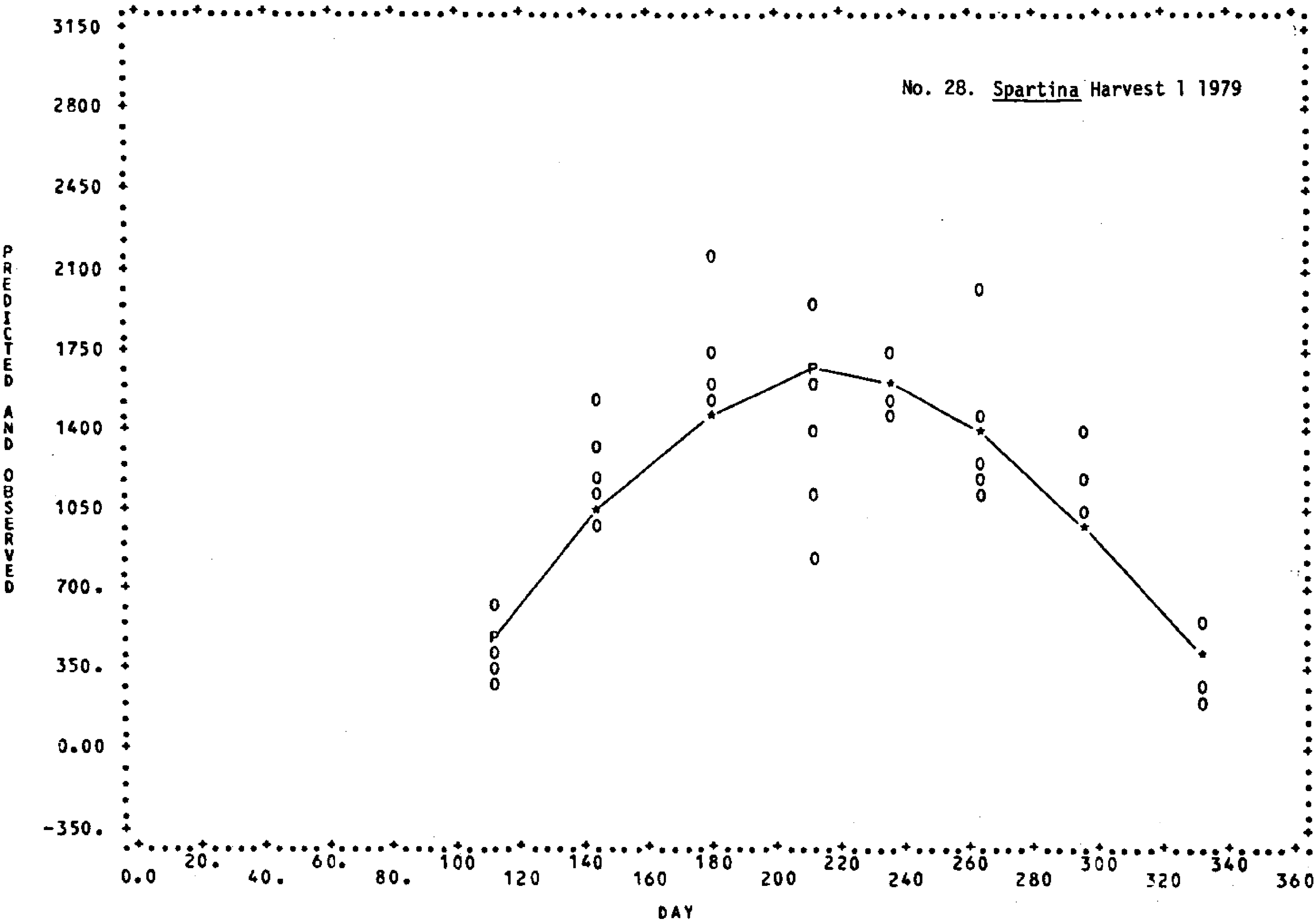


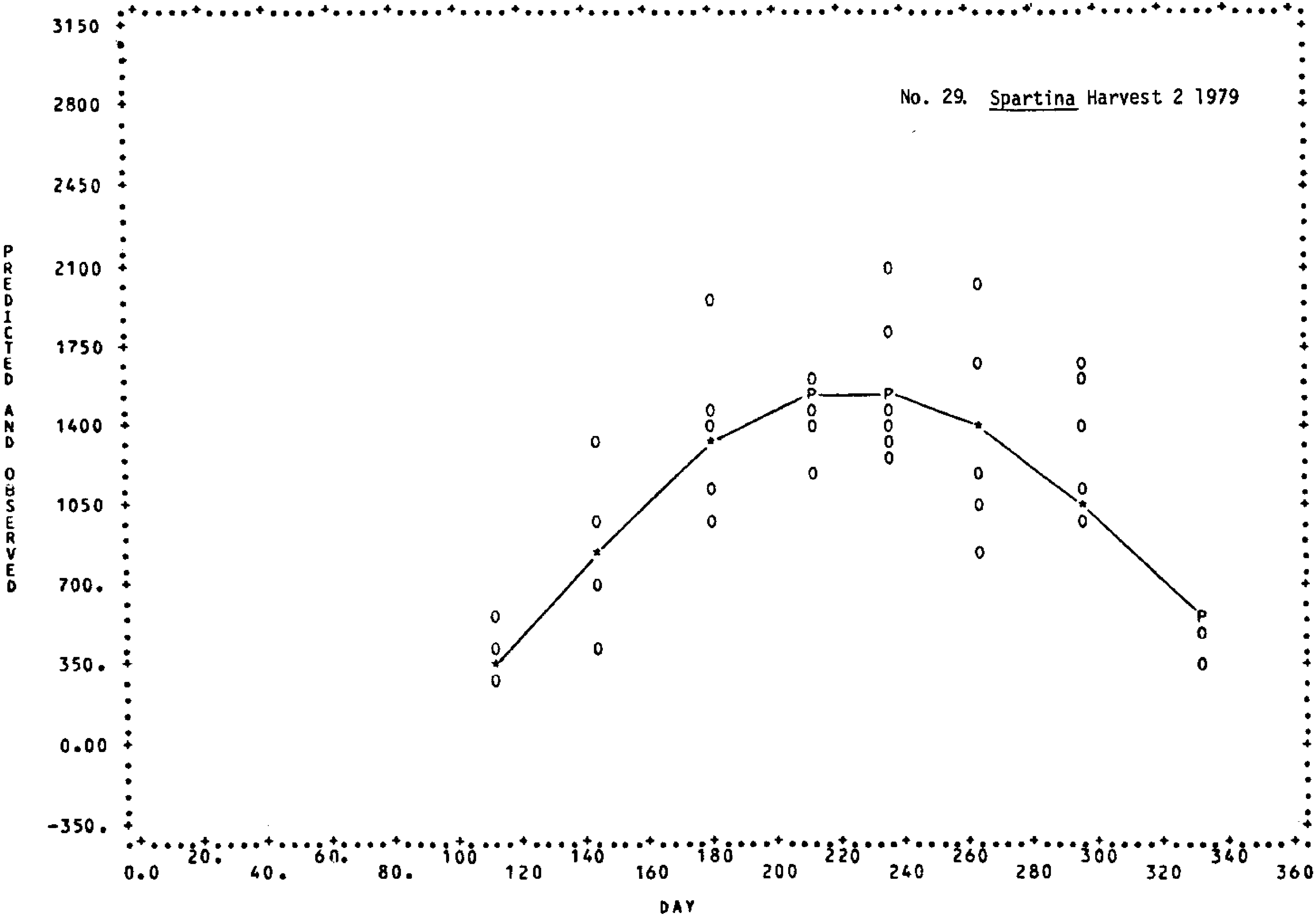
No. 24. Spartina Burn 3 1979


No. 25 Spartina Harvest 1 1977
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY

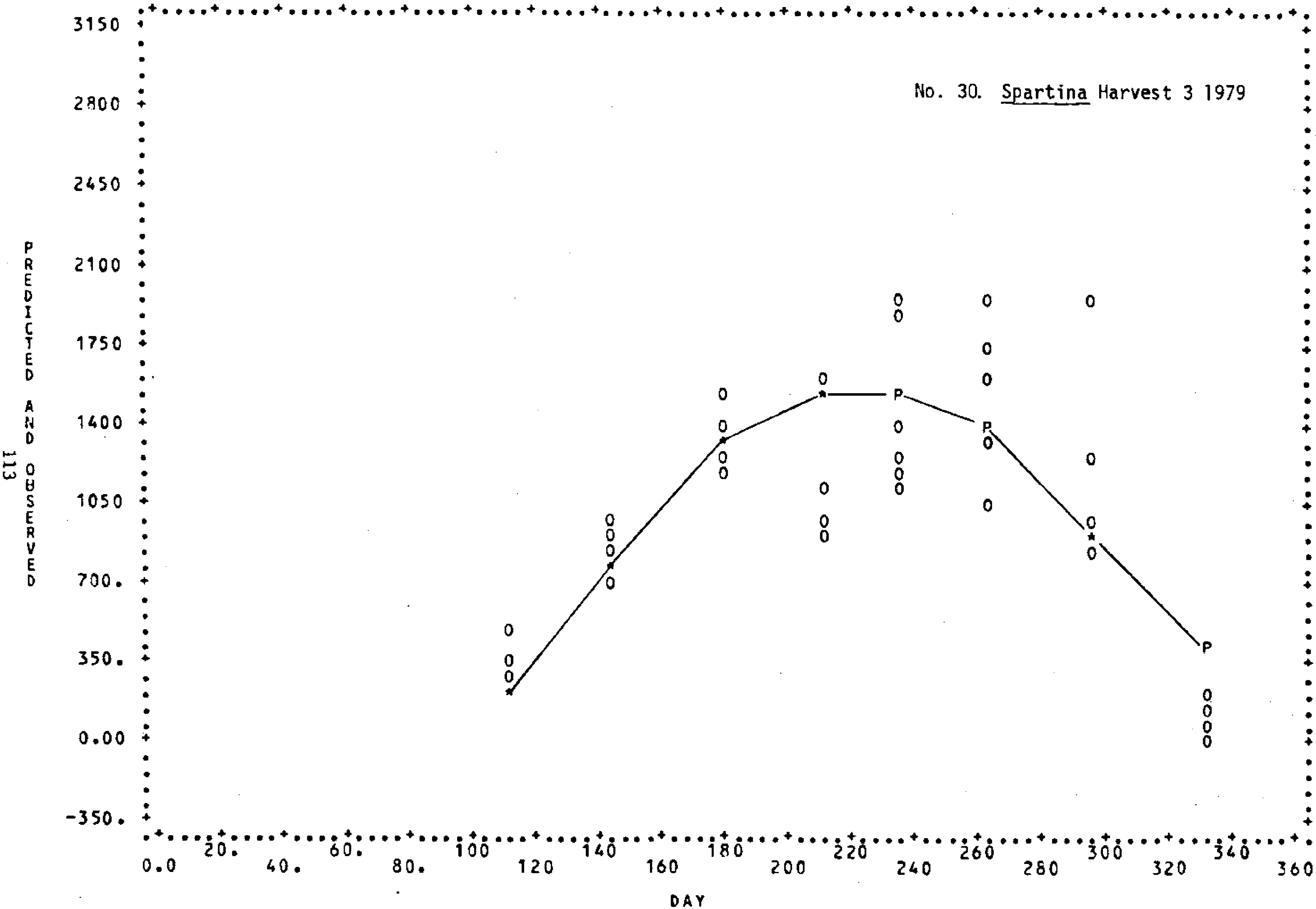

No. 26 Spartina Harvest 1 1978
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY

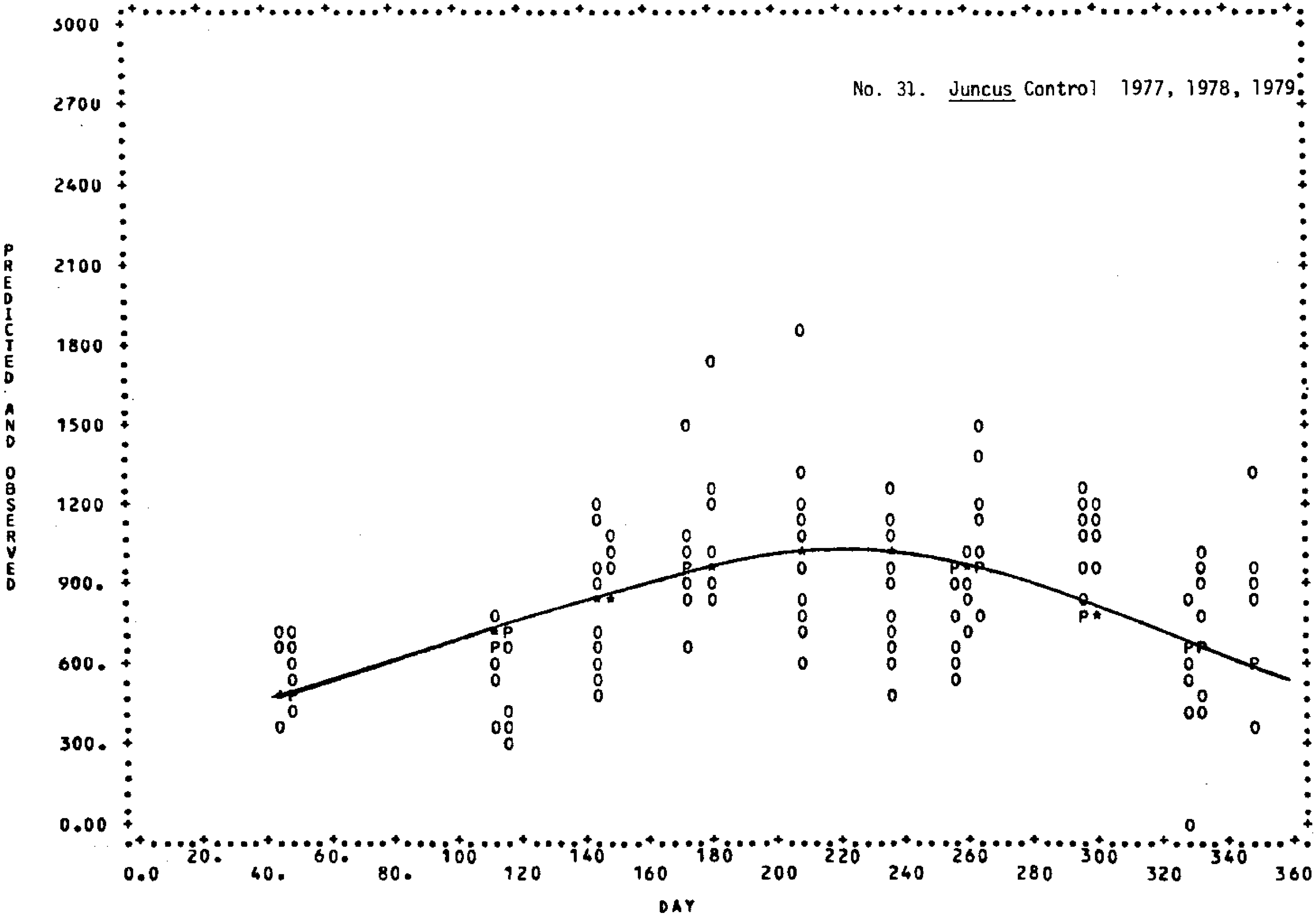

No. 27. Spartina Harvest 2 1978
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY

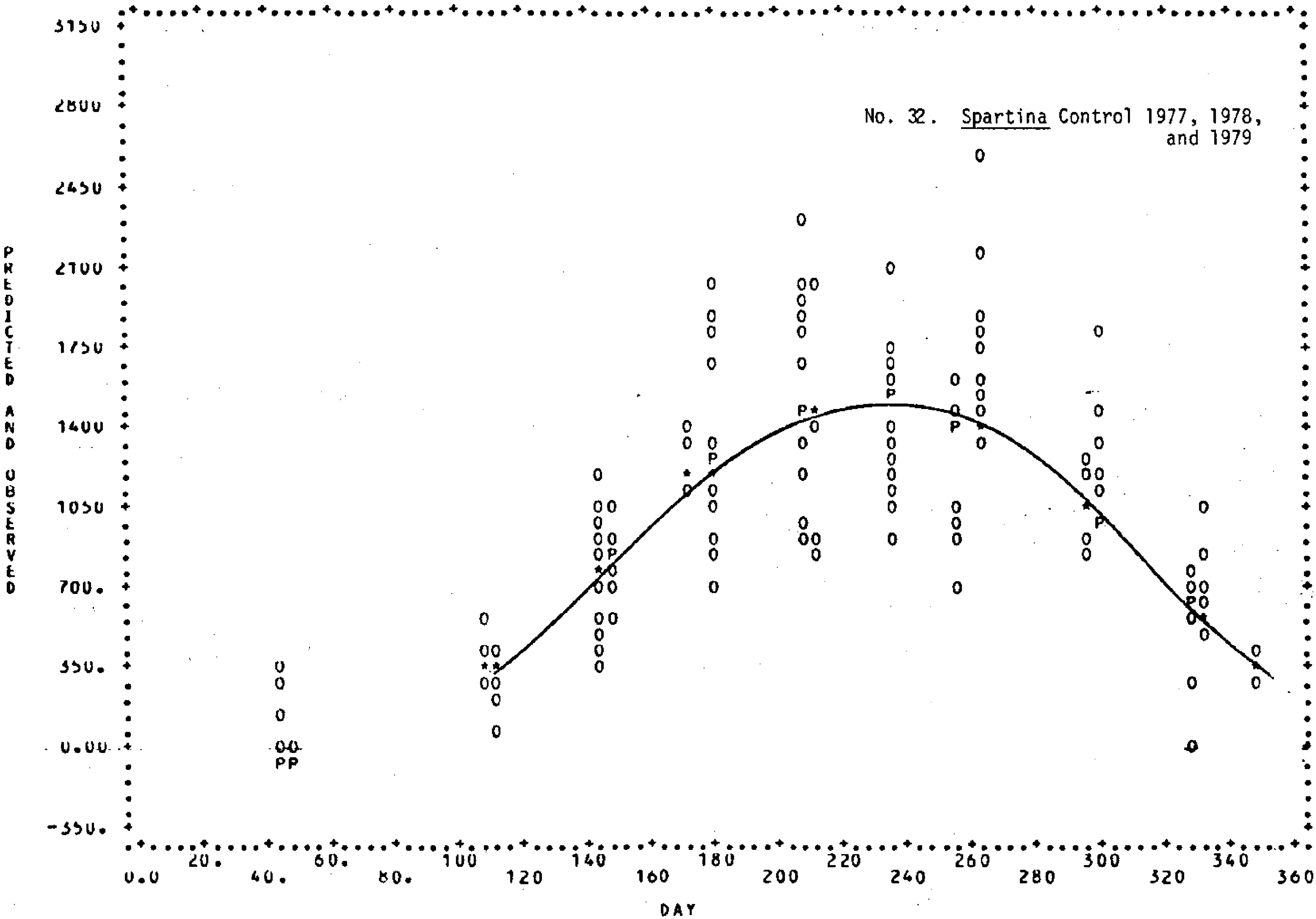

No. 28. Spartina Harvest 1 1979
PREDICTED AND OBSERVED
DAY
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360



No. 29. Spartina Harvest 2 1979
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY


No. 30. Spartina Harvest 3 1979
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY


No. 31. Juncus Control 1977, 1978, 1979
PREDICTED AND OBSERVED
3000
2700
2400
2100
1800
1500
1200
900.
600.
300.
0.00
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DAY


No. 32. Spartina Control 1977, 1978, and 1979
PREDICTED AND OBSERVED
3150
2800
2450
2100
1750
1400
1050
700.
350.
0.00
-350.
DAY
0.0
20.
40.
60.
80.
100
120
140
160
180
200
220
240
260
280
300
320
340
360