SOUTH FLORIDA RESEARCH CENTER

Report T-640

Impact of 22 Years of Fire on Understory Hardwood Shrubs in Slash Pine Communities within Everglades National Park

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September 1981

Taylor, Dale L. and Alan Herndon. 1981. Impact of 22 years of Fire on Understory Hardwood Shrubs in Slash Pine Communities within Everglades National Park. South Florida Research Center Report T-640. 30 pp.

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INTRODUCTION

Everglades National Park, established in 1947, is a subtropical region that covers 566,300 hectares (ha) of land and water at the extreme southern tip of Florida. Terrestrial area, totaling 285,600 ha, is comprised of an estimated 133,000 ha of mangrove and saltmarsh, 148,000 ha of prairie, and 8,000 ha of pineland (Klukas 1973). The pinelands and prairies have the highest fire frequencies and account for most of the 182,000 ha that have burned since 1948.

The climate in south Florida is subtropical with alternating wet and dry seasons. Rainfall for 1979 totaled 134 cm (52.8 inches) at Royal Palm in Everglades National Park, but wide annual fluctuations between 76 cm and 254 cm (30 and 100 inches) may occur (Leach et al. 1972). June to October is the wet season when water covers the soil of most community types, except hammocks and pinelands, and when most cloud-to-ground lightning occurs. November into May is the dry season, and the time when most man-caused fires occur. Freezing temperatures may occur during January and February.

The south Florida slash pine forest, comprised of *Pinus elliotti* var. *densa*, has historically been maintained by fire (Robertson 1953). The forest once occupied an extensive area along the Miami oolite limestone rock ridge that parallels the east coast of Florida, extending southwest from Miami to below Florida City, then west into Long Pine Key of Everglades National Park. Vegetation maps from 1900, 1950, and 1970 show progressive urbanization occurring on these pineland areas. Shaw (1975) found only 4% of the original forest exists outside Everglades National Park. The less than 8,000 ha within the park is the only remaining area of large size. We anticipate that within a few years all pinelands outside the park will be urbanized or invaded by the exotic shrub, *Schinus terebinthifolius*.

The present Everglades National Park pinelands are primarily the result of natural regeneration from scattered cull pine trees left during logging in the late 1930's and early 1940's. Some poorly stocked pinelands on poor sites were not cut. Our unpublished data show pine density ranged from 523 to 1069 trees/ha in 1958 and from 501 to 943 trees/ha in 1979. Pine basal area ranged from 1.7 to 6.6 m^2/ha in 1958 and from 5.8 to 7.9 m^2/ha in 1979. Growth rates have averaged 1.8 mm/year diameter increase and 0.2 m/year height increase for the 22 years. Fires normally do not kill overstory pine trees, however, wildfires during drought can cause high mortality.

Approximately 125 tropical hardwood hammocks are interspersed within the Long Pine Key pine forest. Many of the hammock hardwood species are also present in the pine forest understory. These understory shrubs have the potential of becoming trees in the absence of fire, and will shade the understory herbs within 15-25 years (Robertson 1953) (Figs. 1 and 2). Height of the understory depends largely upon recent fire history. Without periodic fire, the pineland will become a hardwood forest (Figs. 1 and 2).

The herbaceous pine understory is composed of approximately 100 species, 32 of which are endemic to south Florida (Avery and Loope 1980). (An additional ten endemic species occur in pinelands subject to development outside the park). When fire is excluded these endemic species will disappear due to shading by the developing hardwood stand.

With National Park Service acquisition of Everlades National Park in 1947 came fire control. Service policy was the 10 a.m. rule, which stated that all efforts be devoted to control of every fire during the first afternoon, and failing that, every effort should be made daily to obtain control before 10 a.m. the following day (Taylor 1981). Robertson (1953) described fires as follows: "pineland fires remove the ground cover vegetation and prune back the hardwood understory leaving bare limestone. Recovery after fire is marked by an outburst of bloom of the herbaceous plants, and stands of tall broom grass on one-year old burns. A single fire kills few hardwoods because the roots are deeply embedded in the limestone and are protected by it. There is some evidence that hardwoods tend to be eliminated from the pineland by frequently recurring fires, and to be replaced by an understory of low palms, especially saw palmetto."

Robertson's (1953) work led to an attempt to amend National Park Service fire policy to allow for prescribed fire. Then Superintendent Beard stated (in 1956) that fire control was creating unnatural conditions with hammock vegetation rapidly dominating the rockland pine areas. Extensive areas of Long Pine Key (Fig. 4) had not burned in many years and in some places it was a solid mass of hardwood understory averaging 20 feet in height. Beard felt the advance of hardwood succession would ultimately result in the extinction of south Florida slash pine and other endemic species of pineland plants. He felt it extremely important that Long Pine Key be protected as a natural landscape of open pine woods embracing tropical hardwood hammocks and areas of everglades vegetation. The fire control policy was considered the chief threat to the pine forest and the alternative of prescribed burning was deemed necessary. A proposal to allow prescribed fire was approved by the Director of the National Park Service on October 9, 1957 (Taylor 1981).

During 1957, 20 miles of roads were constructed on Long Pine Key to be used as fire breaks and creating several pineland management blocks (Fig. 3). Block B was burned April 25, 1958, representing the first prescribed fire in a national park area, an historic landmark in National Park Service fire management.

W. B. Robertson, Jr. began a long-term study of the effects of fire on pineland vegetation in 1958. This study has been expanded and directed toward the overall goal of describing the Miami rock ridge pinelands in such a manner that the consequences of various management alternatives can be predicted. The management decision to continue prescribed fire to maintain the pineland forest within Everglades National Park is based upon Robertson (1953), the long-term study (Personal communication, W. B. Robertson, 1979), recommendations by Hofstetter and Parsons (1975), and writings of Craighead (1971, 1974).

Figure 1. Fire-scarred slash pine. Note the lack of tall shrubs in the background. Photo taken in 1952. Courtesy of W. B. Robertson, Jr. (Robertson 1953).

Figure 2. The same fire-scarred slash pine shown in Figure 1 after 27 years without fire. Photo by the senior author. March 1, 1979.

The objectives of this report are to measure impact of fire management on numbers of understory hardwood shrubs from 1958 to 1980, and to compare findings with stated fire management objectives of reclaiming the pinelands from hardwood invasion, and of maintaining the pinelands (Everglades Fire Management Plan 1979).

METHODS

North-south roads made during logging combined with new east-west roads made for these studies were used to establish pine management blocks A through J in 1957 (Fig. 3). Between 1958 and 1965 seventy-three 12 x 48 m permanent plots were established at intervals along roads in all blocks except D and G. The blocks have been burned, primarily by winter headfires since 1958 (Table 1). Sampling was done at irregular intervals, but blocks B, E, F, H, I, and J were all sampled during the intervals 1958-1961, 1963-1965, and 1978-1979. Blocks A and C were not sampled during 1958-1961, but they were sampled during the last two sample periods. For convenience, the sampling periods are referred to as 1958, 1964, and 1979. Table 1 shows years vegetation sampling occurred.

Shrubs were identified by species and stems tallied in height classes of 3-5 feet, 5-10 feet, or over 10 feet tall in one-fourth of each plot. Only pine trees were counted in the entire plot. Rate of hardwood recovery was determined by comparing numbers of hardwoods stems present before fire to numbers present at post-fire intervals. Recovery rate data were normalized by determining percentage recovery to the pre-fire condition. Scientific nomenclature follows Long and Lakela (1976).

RESULTS

During the 22 years of this study, eight wildfires and 26 prescribed fires occurred. After these 34 fires, 92% as many stems remained in 1979 as were present in 1958. Stem numbers in blocks B, E, F, H, I, and J averaged 14,549/ha in 1958, 16,797/ha in 1964 and 13,396/ha in 1979 (Table 2). The Wilcoxon-Mann-Whitney two sample test showed no significant change in stem numbers between 1958 and 1979 and between 1964 and 1978. Blocks C, E, F, H, I, and J were within ± 15% of the original number of stems after 22 years of burning (Table 1). Block A showed a 34% decrease in stems, but block B showed a 107% increase in stem numbers because a fire had occurred one year prior to the start of the study and recovery was not complete when the block was first measured. No major shift in stem numbers from one size category to another has occurred (Table 2).

Number of stems that occur in years following fire is presented for pine blocks B and H, the blocks with the greatest frequency of vegetative sampling. These blocks are located on either end of the study area (Fig. 3). The model shows recovery is similar on the two blocks (Fig. 4). Correlation coefficients between years post-fire and number of stems per hectare were .935 for block H and .712 for block B.

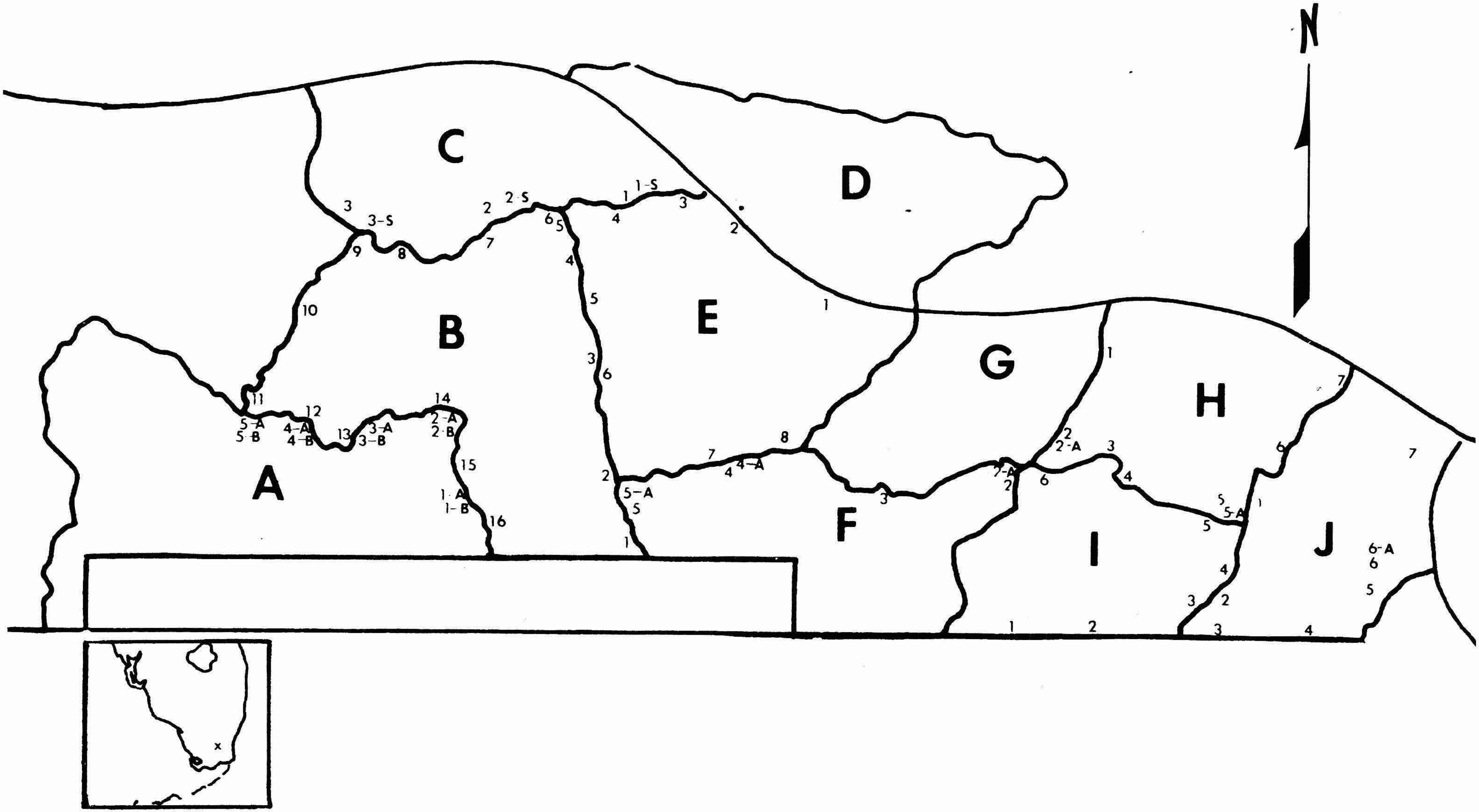

Figure 3. Long Pine Key pinelands showing pine blocks A - J. Small numbers show location of 12 X 48 meter plots. The X on the insert of south Florida shows the location of Long Pine Key.

Rate of stem recovery to the pre-fire level is about 4 years (Fig. 5). Number of stems continues to increase for at least 12 years post-fire. Hofstetter (1973), working in the same area, reported that hardwood succession past 13 years results in fewer stems produced and existing stems grow taller.

Out of the total of 50 hardwood shrub species that occurred, twenty-six had 100 or more stems per hectare at one or more sampling times (Table 2), 11 had 500 or more stems/hectare and 3 had 1000 or more stems/hectare (Table 2). The 3 most common shrubs were Serenoa repens, Guettarda scabra, and Myrsine guianensis (Table 2). None of these will get larger than a small tree.

Seven species, Acacia pinetorum, Hypericum hypericoides, Lysiloma latisiliqua, Magnolia virginia, Psychotria nervosa, Stillingia sylvatica, and Trema micrantha, appeared as new species in the study plots (Table 3). Only Lysiloma and Trema, with 25 and 36 stems/hectare, respectively, became very common (Table 2). Both Lysiloma and Trema are considered weedy species that pioneer into burned over pinelands (Tomlinson 1980). Magnolia is a low hammock or bayhead species (Tomlinson 1980) with only one stem/ha occurring in the plots in 1979. The other four species are pineland plants (Long and Lakela 1976).

Shannon-Weaver diversity index (Pielou, 1966) increased in blocks B, E, F, H, I and J between each successive sampling period, going from 2.8 in 1959 to 2.9 in 1964 and 3.0 in 1979. The significance of this index for rock reef pineland communities is unknown. For those periods when sampling occurred, diversity in blocks A and B remained stable while diversity in blocks C, E, F, H, I, and J increased (Fig. 6).

Species showing an increase in stem number of greater than 10% outnumbered those showing a decrease of greater than 10% only during the 1958-1964 sample period (Table 3). Approximately the same number of species increased by greater than 50% as decreased by greater than 50% (Table 3).

Two species, Hypelate trifoliata and Jacquinia keyensis have disappeared from the plots since burning began. In addition, Byrsonima lucida, Psidium longipes, and Ilex krugiana have decreased by more than 80% from original levels (Tables 2 and 3). Hypelate and Ilex krugiana are classified as threatened species in Florida (Ward 1979), and are of concern. Both species are present in areas outside the sample plots and attempts will be made to maintain viable populations. Jacquinia, Byrsonima, and Psidium are locally common in areas outside the plots. Chrysobalanus icaco decreased by 77% from 1958 to 1979, but the species is extremely common in thickets in moist areas outside the plots. The species is extremely susceptible to frost and the reduction in numbers may have been due to the severe frost that occurred in 1977.

Coccothrinax argentata, the rarest of the three palms and a threatened species (Ward 1979), increased by 82% from 1958 to 1979 (Table 3). Serenoa repens was within ± 7% of the original number during the three sample periods (Table 3). Hilmon (1968) reported coverages by Serenoa increased as the frequency of burning declined. This phenomenon is indicated by our data, but changes from +2 to -7% are probably within sampling error for this species, and we conclude the population

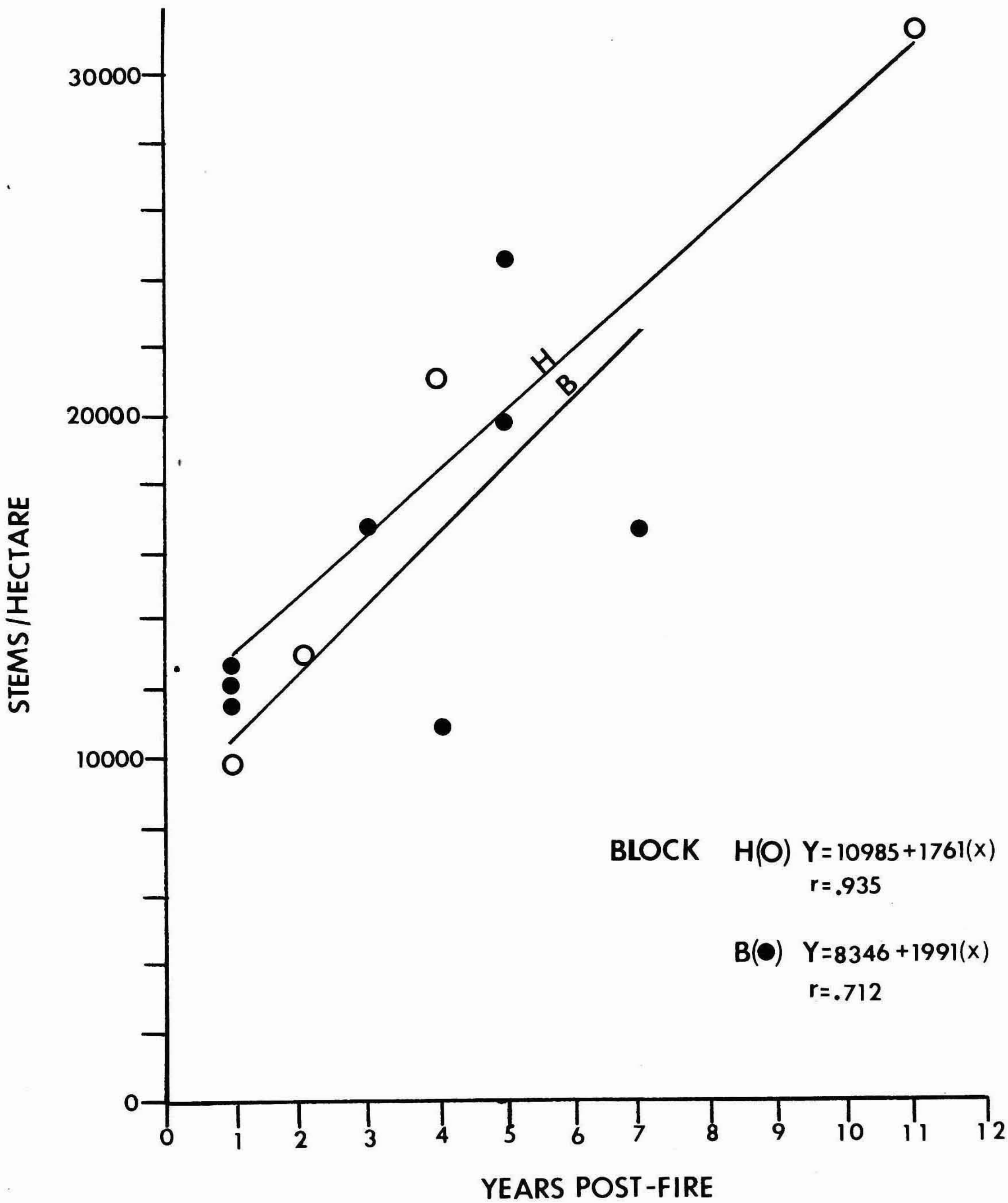

Figure 4. Number of stems/hectare relative to time since fire.

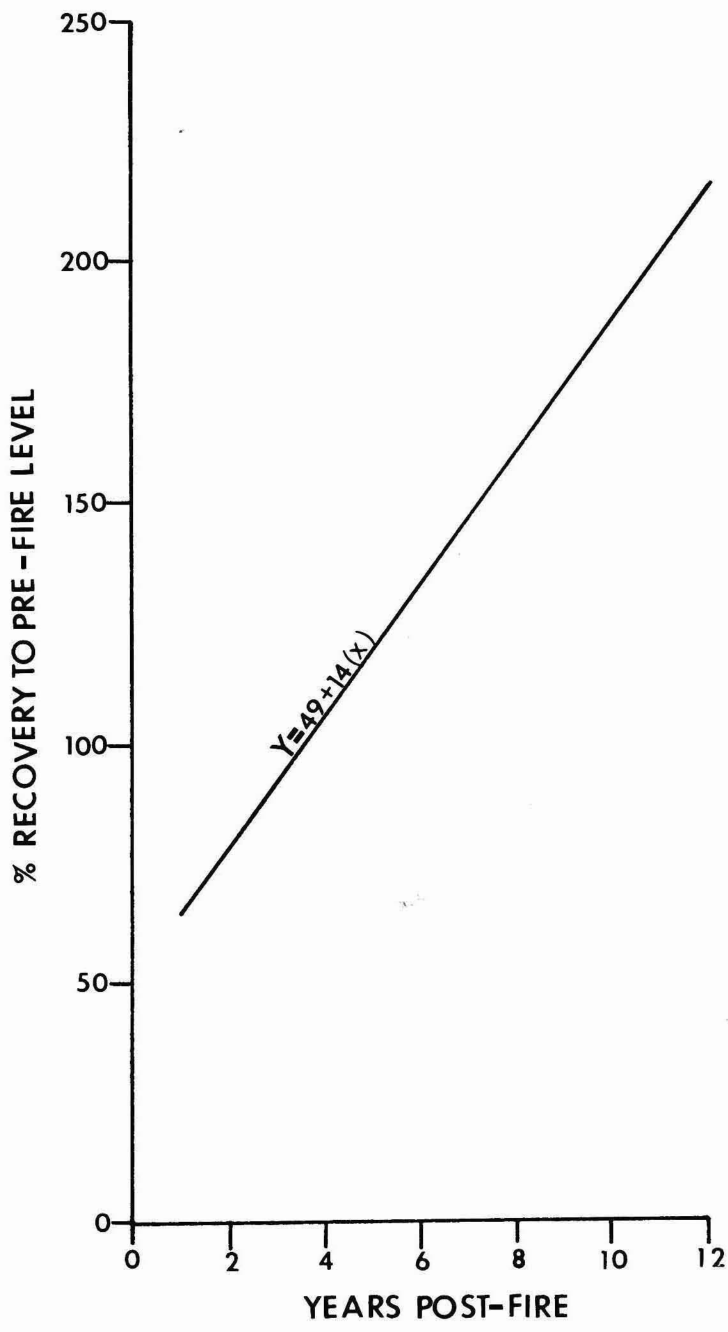

Figure 5. Years required for stem recovery following fire. (Correlation coefficient = .909).

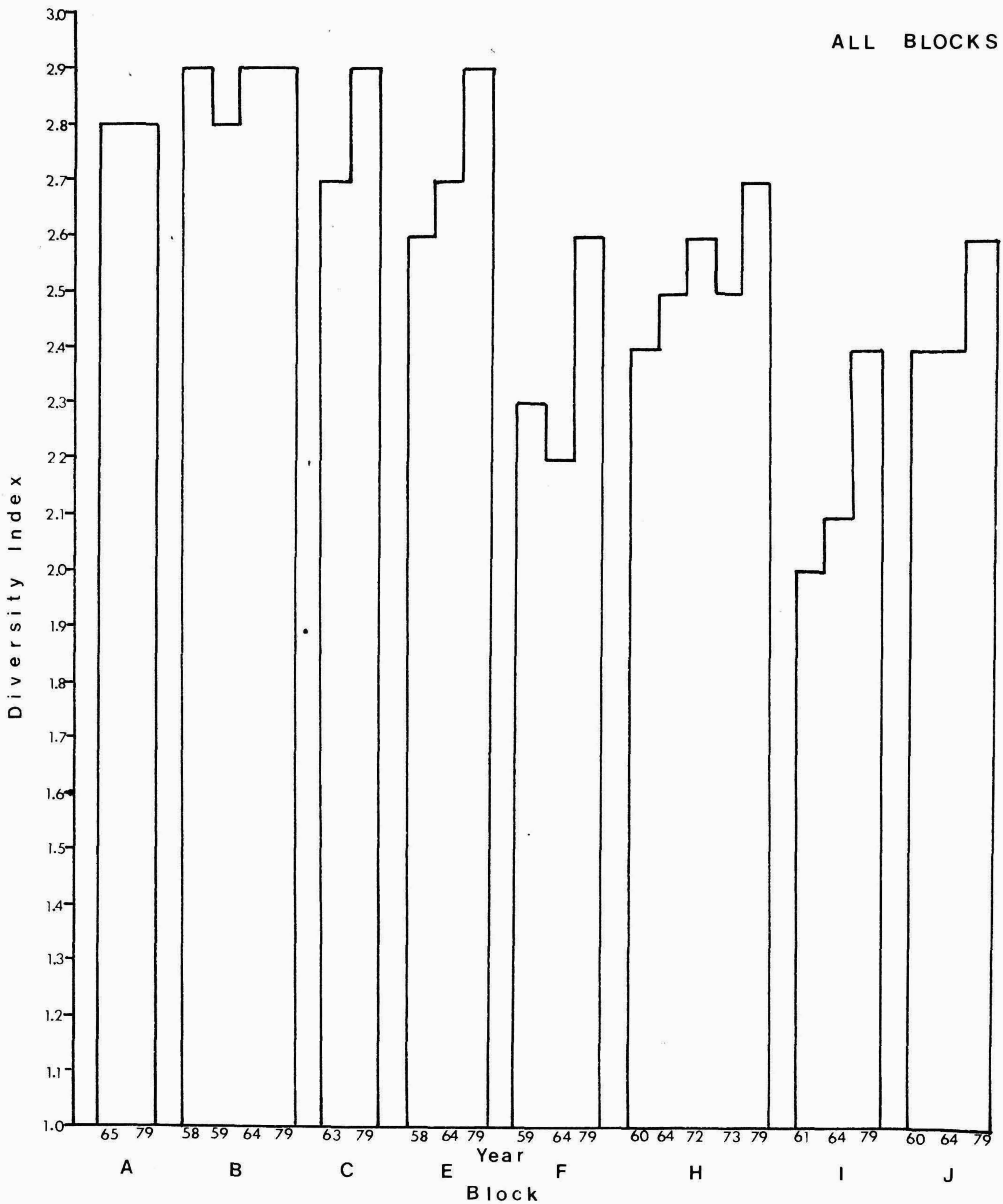

Figure 6. Shannon-Weaver diversity index for understory hardwood shrubs.

has remained stable. Numbers of sabal palms (Sabal palmetto) increased from 1958 to 1964, but the population declined when more frequent burning occurred (Table 3).

Most shrubs are top-killed by fire but they quickly recover to pre-fire levels. Examples for Metopium toxiferum, Ilex cassine, and Myrica cerifera are shown (Figs. 7 through 9). Even though Metopium showed an overall decline of 41% (Table 3) the species has the potential to spread without fire. Figure 7 shows a few trees of all sizes remained one year after fires in 1958 and 1972. High numbers of trees of all sizes, but especially of trees in the 5-10 foot and over 10 foot category, remained one year after the 1977 fire. Metopium is considered one of the easier trees to kill with fire.

The only species to show a statistically significant change in stem numbers was Rhus copallina. The Wilcoxon-Mann-Whitney two sample test showed changes to be significant ($p = .05$) for 1958 compared to 1979 and for 1964 compared to 1979. All other species showed non-significant changes occurred in stem numbers.

Dodonaea viscosa, Rhus copallina, and Tetrazygia bicolor increased by 121% to 659% from 1958 through 1979 (Table 3). The sixth most common shrub, Myrica cerifera, increased by 35%. Examples of post-fire recovery for Myrica, Dodonaea, and Rhus are shown in Figs 9, 10 and 11. These species, especially Rhus copallina, have the potential of becoming the major dominants in the hardwood understory because they continue to increase with frequent winter fires.

DISCUSSION

Some of the factors that could influence hardwoods in south Florida include fire frequency, fire intensity, season of fire occurrence, fire type, succession, freezing temperature, and hurricanes.

Hurricanes

Hurricanes are unlikely to have much long-term effect on understory hardwoods in south Florida pinelands. Craighead and Gilbert (1962) report the 1960 Hurricane Donna resulted in water covering the ground in lower pineland areas for more than two weeks. This may have caused a temporary impact, but the phenomenon is not unusual as seasonal water level fluctuations often cause the ground to be covered for longer periods of time. Criaghead and Gilbert (1962) noted hardwood trees, denuded by high winds from the hurricane, refoliated within a few weeks. Hurricane-generated overwash on gulf coast barrier islands described by Stoneburner (1978) does not occur in most south Florida pinelands.

Freezing Temperatures

Damaging frosts may occur in south Florida every other year (Craighead 1971), but most frosts do little damage inside a pine forest. One of the most damaging freezes in south Florida history occurred in February 1977, but no measurements of

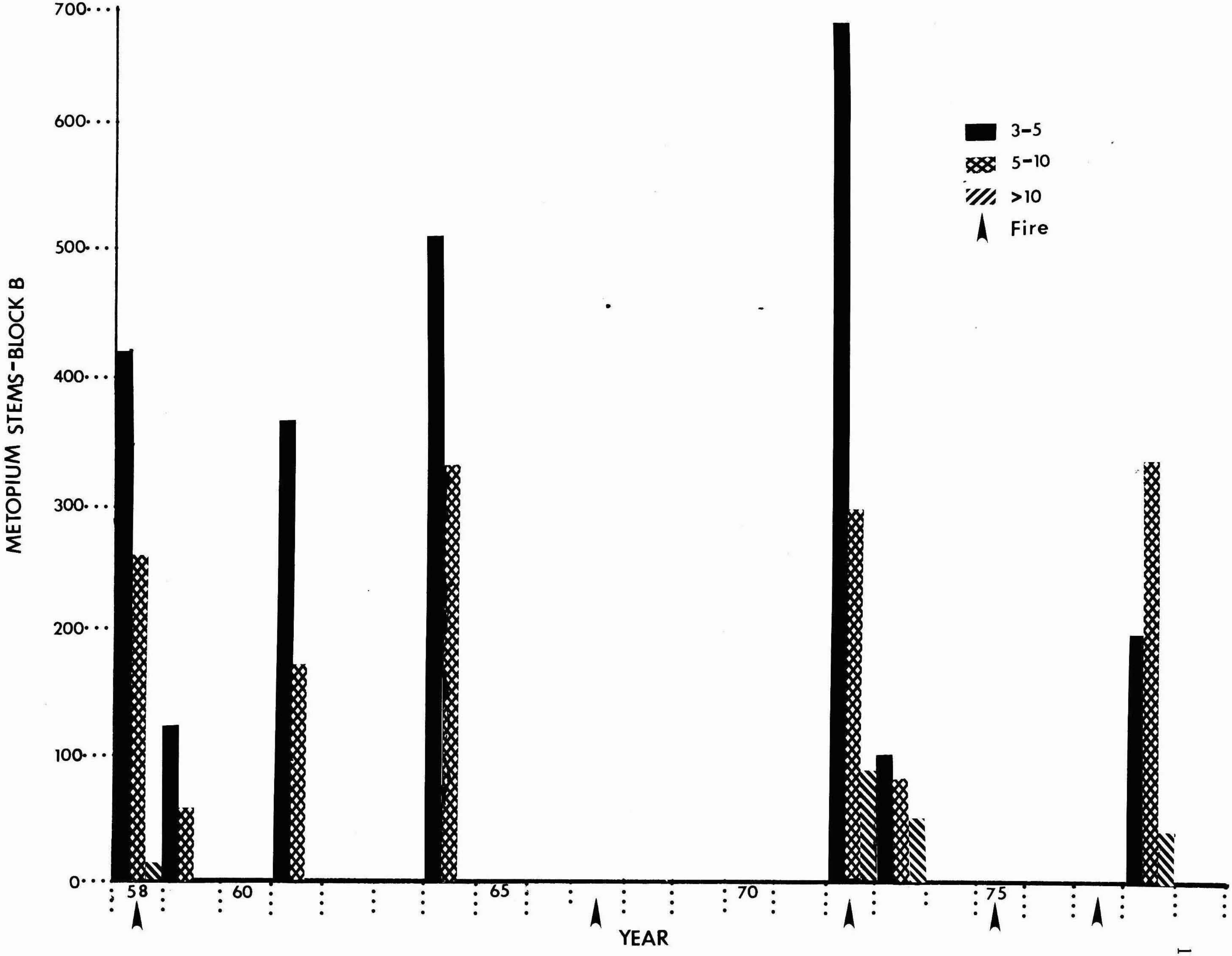

Figure 7. The number of stems of Metopium toxiferum in Block B.

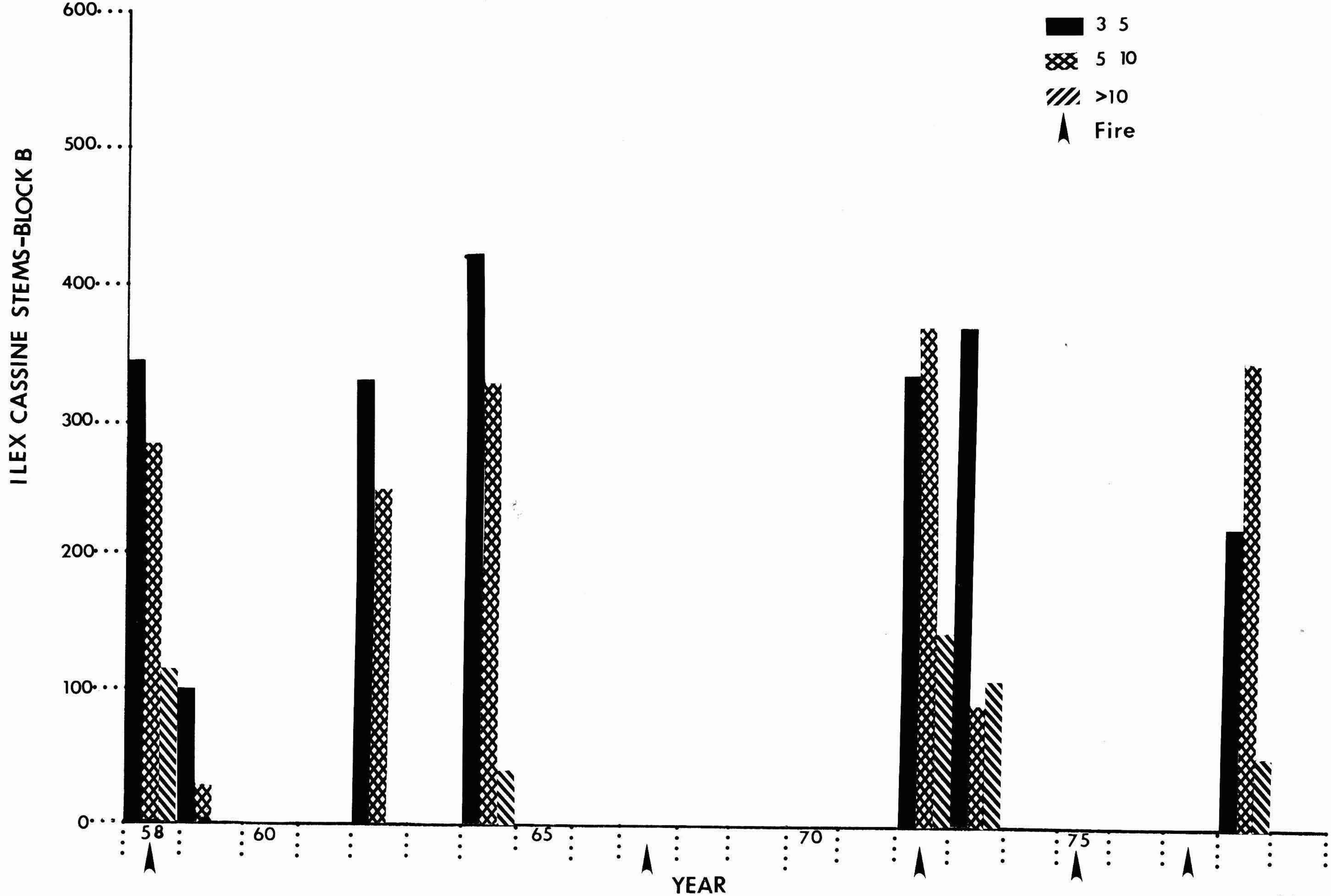

Figure 8. The number of stems of Ilex cassine in Block B.

effect on hardwoods were made. Smaller size classes of some species such as cocoplum (Chrysobalanus icaco), buttonwood (Conocarpus erecta) and poisonwood (Metopium toxiferum), may have been affected by this freeze (Table 2).

Succession

The pinelands were lumbered about 35 years ago, therefore, the possibility that observed species changes are due in part to natural succession following clearing, irrespective of such disturbances as frost and fire should be explored.

Robertson (1953) observed pineland hardwoods to have a fire-pruned growth form with several stems per plant rising from the surface of the limestone. Both hardwoods and perennial herbaceous plants were observed to have large root masses deep in fissures and solution pockets in the limestone from which they resprout following fire. All plants listed in Table 2 show this pattern, consequently, almost all changes in number of stems would be a result of fire effects rather than succession (Table 2). Hofstetter (1973) concluded succession resulted only in an increase in height of hardwood stems in the absence of fire.

Of the seven new species that appeared during the 22 years only Lysiloma and Trema became common (Table 2). Both are weedy species that pioneer into burned pinelands (Tomlinson 1980). The remaining species are typical pineland plants. Magnolia is a low hammock or bayhead species and occasional stems present in the pinelands should not be unexpected.

Fire Type (Headfire vs Backfire)

The original (1958) prescribed burning plan recommended burning be done into the wind (backing fire), with severe burning (headfires) used where hardwood succession was more advanced (Taylor 1981). In 1968 it was concluded light backing fires develop sufficient heat to kill most hardwoods up to 3/4 inch basal stem diameter, but backing fires were considered impractical for large areas because of the time required. Short running headfires were determined to be the best burning method (Taylor 1981).

Records, although incomplete, indicate backing fires were used on some early burns, but almost all fires from 1973 through 1978 were headfires or were short running headfires. Headfires were often the method of choice because hardwood succession was considered to be advanced and because the burns could be completed in less time than it takes for backing fires.

Comparative kill results from headfires versus backing fires described in the literature on southeastern forests are inconclusive for any one fire type, but tend to support headfires as being the most effective. Davis and Martin (1960) show that headfires reach higher temperatures at the 1 and 4 foot level above ground, but backing fires maintained their temperatures for a longer time period. Langdon (1971) reported that headfires, because of their greater intensity, generally topkill more stems of all species than backfires. Ferguson (1957) reported headfires killed back significantly more stems of all species than backfires. Ferguson (1957) also reported complete kill of rootstocks of a relatively small number of hardwoods was achieved by all fires regardless of intensity. Bender and Cooper (1968) found strip headfires were no better in killing hardwoods than backfires. They were cheaper and could be used under a greater variety of weather and fuel conditions. Bender and Cooper (1968) recommended a single strip headfire in the summer (in Georgia) for best hardwood kill. Lotti (1956) used backfires because of the ease of control compared to headfires. Cushwa, Bender and Cooper (1966) reported significantly more legumes present on plots burned with backing fires, but no reason for the difference was apparent. Economic considerations apparently were as important in choosing fire type as ecological factors, but the effect on pine trees must also be considered. Grusehow (1951) reported north central Florida winter headfires cause a marked reduction in the subsequent height and diameter growth of slash pine (P. e. var. elliotti), but prescribed burning by backfires has little or no effect, providing the trees are more than about 12 feet high.

Season of Fire

The season when a fire occurs is important in trying to match prescribed fires to the natural fire season. In Everglades National Park, the natural fire season must be from May through September when 94% of all lightning-caused fires occur (Taylor 1981). From 1958 through 1979, 94% of all prescribed fires or wildfires that burned the pinelands occurred from November through April, the winter dry season. Fires during this season are out of sequence with the natural fire season, and have the potential for allowing the exotic shrub Schinus terebinthifolius to invade (Taylor 1980). Schinus is frequently observed in the pinelands, but it has not yet occurred in the study plots.

Season when a fire occurs also has an important bearing upon recovery by certain plants. Most investigations in the southeastern United States conclude that repeated summer fires provide greater and longer lasting shrub control than repeated winter burns (Grano 1970; Bender and Cooper 1968; Chaikin 1952; Ferguson 1957; Hughes and Knox 1964; Langdon 1971; Lotti 1956; Grenlen 1975; Hughes and Knox 1964; Lewis and Harshbarger 1976).

Lotti et al. (1960) stated little is to be gained by a series of annual winter fires. Most rootstocks survive, and when the treatment is stopped the understory will regain its competitive position in a few years. They recommended incorporating summer fire into the treatments in South Carolina. Hughes and Knox (1964) reported gallberry (Ilex glabra) may be checked temporarily by late summer burning, but measures other than fire were needed for permanent control. They found the species thrives with frequent winter burning. Lotti (1956) reported winter fires will topkill Myrica cerifera, but a short series of annual summer fires will practically eradicate the species. Annual and biennial summer fires caused Myrica to significantly increase coverage according to Lewis and Harshberger (1976). They reported Rhus copallina had slightly greater cover following annual summer fires than occurred on the control. Single summer burns do not completely kill hardwoods (Langdon 1971), but a succession of annual summer fires practically eliminated the understory in a South Carolina study (Lotti et al. 1960, Lewis and Harshbarger 1976). Understory control adequate for pine regeneration was obtained with a few successive annual summer fires (Lotti et al. 1960). In Arkansas, repeated summer burns at 1-or-2-year intervals reduced sprouting to any desired degree (Grano 1970).

Summer growing-season fires reduced the hardwood understory more than fires during the winter dormant season, but summer fires were more than twice as damaging to overstory pine (Ferguson 1957; Grenlen 1975). Lewis and Harshbarger (1976) concluded that conditions for producing combinations of grazing and wildlife can be maintained by burning every 2 or 3 years during the winter, but annual summer burns eliminated most shrubs.

Apparently, higher ambient air temperatures in summer compared to winter, and consequent exposure of hardwoods to higher fire temperatures, were partially responsible for increased hardwood kill (Ferguson 1957). Higher ambient temperatures do occur in summer in Everglades National Park. From June through September average temperatures are 2°F to 18°F higher than November through May, and 15°F to 18°F higher than temperatures that occur during January, February and March (U.S. Department of Commerce, Climatological Data for Florida 1979). These higher temperatures affect growth rates, and although some evergreen hardwoods may continue to grow throughout the winter months in south Florida, growth rate is slower than in summer. For example, Rhus copallina becomes dormant in winter. Food reserves in the root are lowest during the summer, and exposure of the plants to repeated summer burns will gradually reduce vigor and kill the plant (Langdon 1971). Food reserves seem to have a direct effect on heat resistance as well as on sprouting capacity (Hare 1961).

The above studies were conducted in North and South Carolina, Texas, Georgia, Arkansas, and various parts of Florida, but several understory species have common occurrence. These are: Rhus copallina, Myrica cerifera, and Serenoa repens, as well as species of holly (Ilex sp.), and oak (Quercus sp.). Fire effects on these species are similar in the different areas.

Fire Frequency and Fire Intensity

Fire frequency and fire intensity are treated together because the more frequently pineland fires occur the less fuel will be available resulting in a lower fire intensity under normal prescribed burning conditions. Coppicing is stimulated if the plant is not killed, consequently, more stems could be produced by each fire.

Species have responded differently to burning practices (Tables 2 and 3, and Figs. 7 through 11). Metopium toxiferum is fire sensitive and has experienced a decrease in stem number with higher fire frequency (Table 3). However, Metopium has the capacity to recover quickly after fire (Fig. 7). Ilex cassine (Table 2 and Fig. 8) recovers to approximately original levels within two to three years following fire. Serenoa repens is affected little by fire (Table 2). This observation is confirmed by others, for example, Hughes (1975), working in south Florida reported frequent burning checks Serenoa repens without affecting its vigor. He found the trend similar for other shrubs. Hilmon (1968) reported a trend toward greater crown coverage and fewer stems of Serenoa with 6-10 years protection from fire.

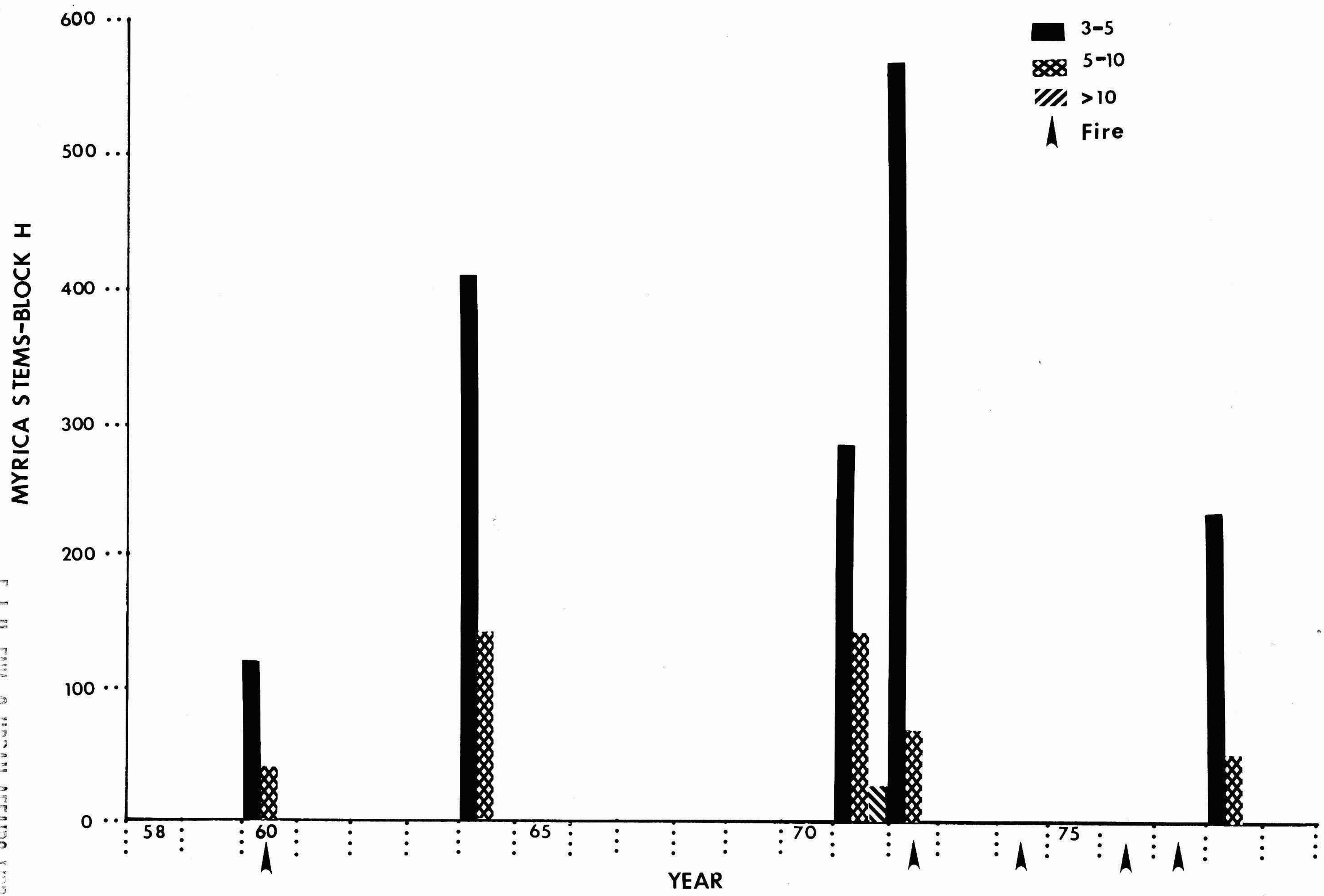

Figure 9. The number of stems of <u>Myrica cerifera</u> in Block H.

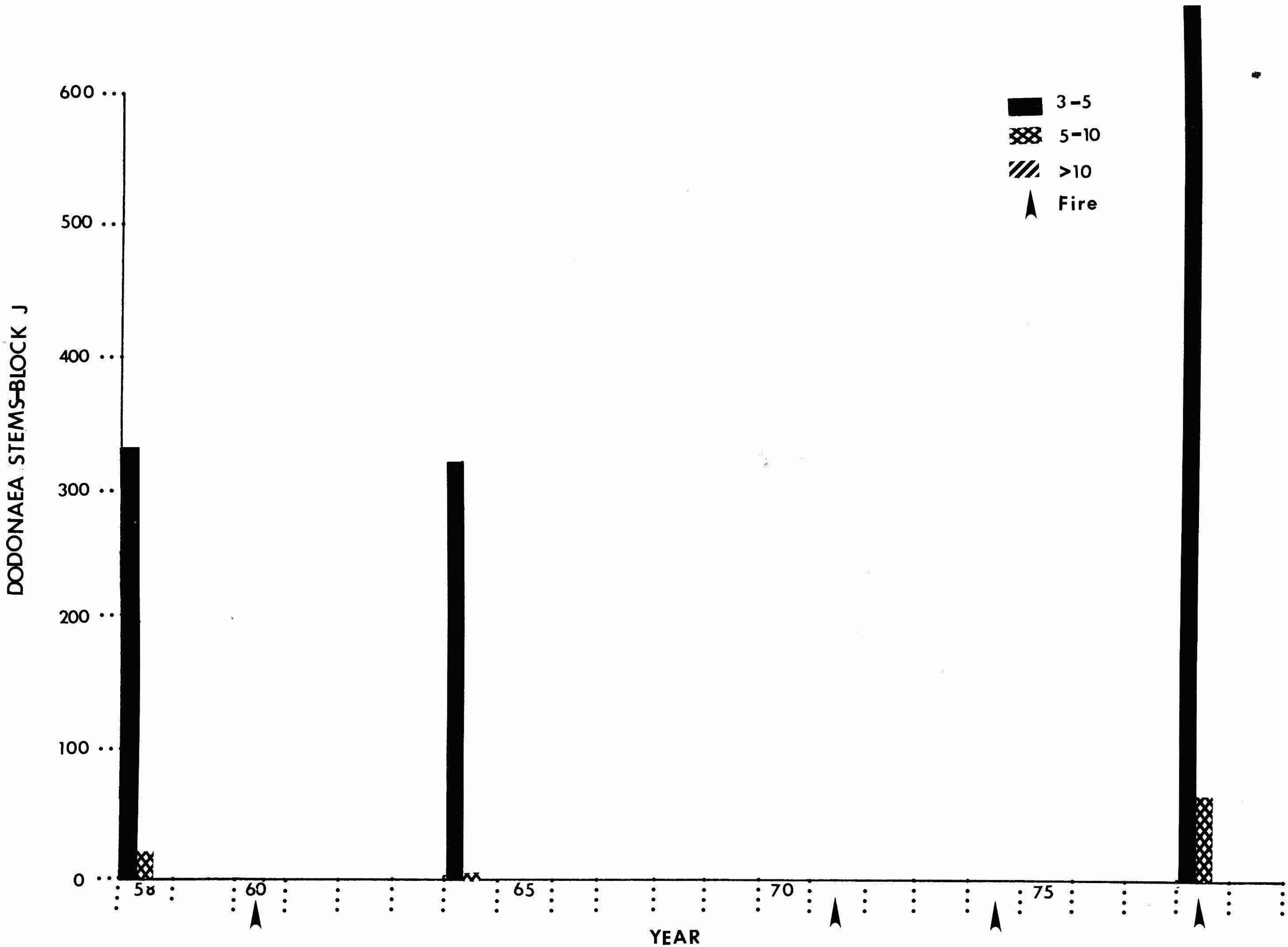

Figure 10. The number of stems of Dodonaea viscosa in Block J.

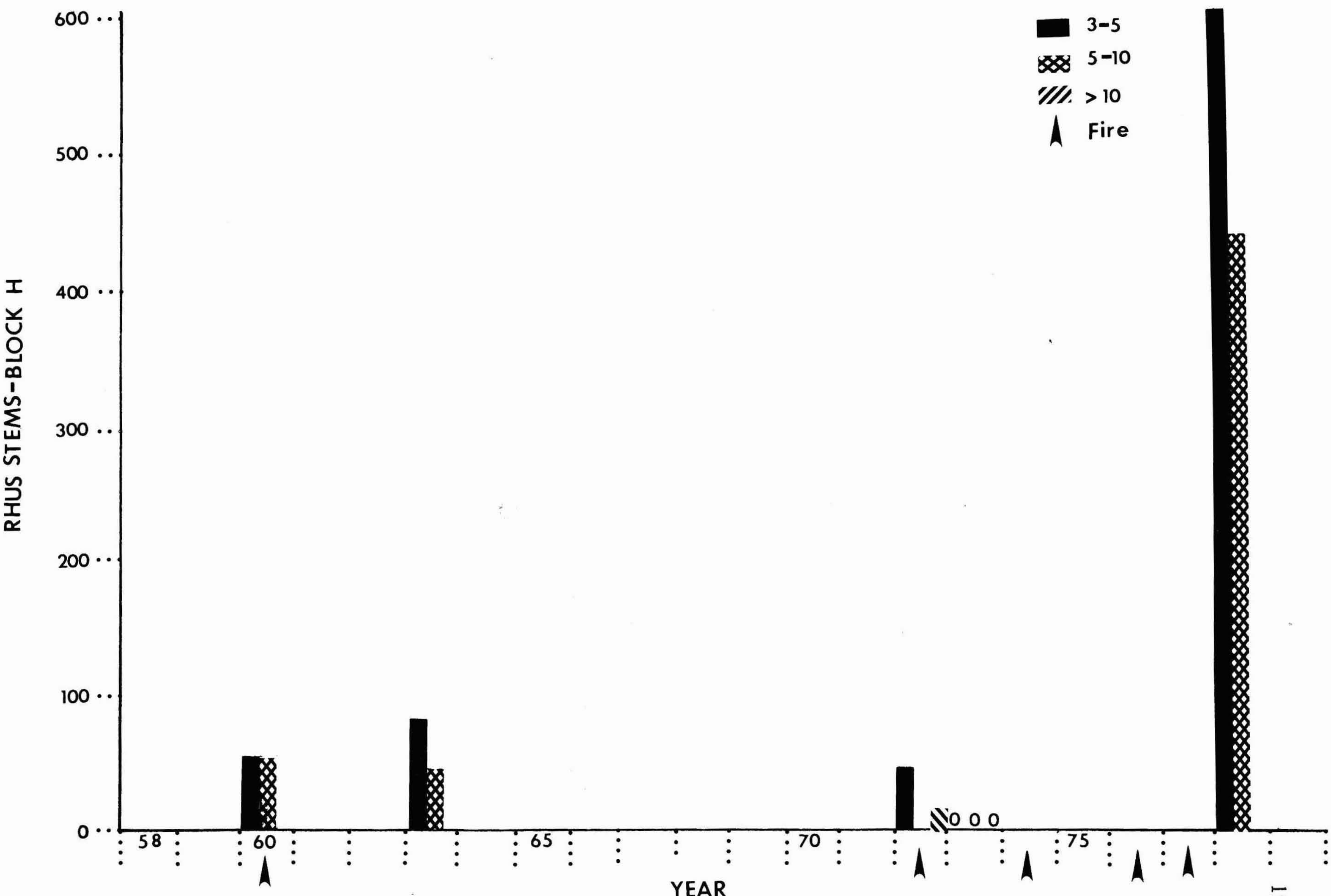

Figure 11. The number of stems of Rhus copallina in Block H. No stems were recorded during 1973.

Rhus copallina, Dodonaea viscosa, and Myrica cerifera increased in stem number in response to fire (Tables 2 and 3, and Figures 9, 10 and 11). Rhus copallina shows the most dramatic change of any species (Table 3) with increases in stems coming after more frequent burning (Fig. 11). For example, stem numbers in block H were relatively low after 12 years without fire. Block H was burned in 1972 and a year later Rhus was not recorded from the plots, but some stems less than 3 feet tall could have been present. By 1978 the population had increased dramatically (Fig. 11) following fires in 1974, 1976, and 1977. Most of the increase could have followed the 1974 wildfire that burned during March. Apparently, these fires stimulated root sprouting and sprouting from the stem collars. Germination from seed has been observed in Blocks E and I (James Snyder, personal communication). Marks (1979) reported fire stimulated germination of Rhus typhina seeds in New York.

Increase of 121% in Dodonaea viscosa stems is thought to be associated with fire frequency (Fig. 10). Following the 1958 block J burn, it took about 5 years for the species to recover, to pre-fire stem numbers. Two fires in succession apparently stimulated the increase observed in 1978 (Fig. 10).

Stems of Myrica cerifera increased at each sampling period, apparently in response to the frequent winter fires (Tables 2 and 3). High populations one year following the 1972 burn shows the rapid recovery possible following fire (Fig. 10). Stems greater than 10 feet tall were eliminated, and stems 5-10 feet tall remained at pre-fire levels, but stems in the 3-5 foot category increased dramatically. After fires in 1974, 1976, and 1977, almost as many stems remained as were present in 1972 when fire had been absent for 12 years (Fig. 9).

Lotti (1956) and Terry and White (1979) showed Myrica to be easily top killed by a single winter fire, but most plants survived through basal sprouts and repeated fires were recommended for control. Lotti et al. (1960) recommended a succession of annual summer burns for control of Myrica and other hardwoods.

SUMMARY AND CONCLUSIONS

Prescribed fire has been used in Everglades National Park pinelands since 1958 to control pineland understory hardwood shrubs. Additional purposes are to control fuel levels and to prevent hardwood shrubs from shading understory endemic plant species.

Seventy-three permanent plots established from 1958 through 1964 to study impact of prescribed fire show 92% as many shrub stems remain in 1979 as were present at the start of the study. Most shrubs are top-killed by fire, but they recover to pre-fire levels in about 4 years. Post-fire succession of species was not observed.

Approximately 50 species of hardwoods occur in the pinelands. The three most common are Serenoa repens, Guettarda scabra, and Myrsine guianensis. Twenty-six species had 100 or more stems per hectare. Seven species were recorded in the study plots in 1979 that were not present at the start of the study, but they also occur throughout the pinelands. Of the new species, only Lysiloma and Trema became very common.

Hypelate trifoliata and Jacquinia keyensis disappeared from the plots after burning began. Brysonima lucida, Psidium longipes, and Ilex krugiana decreased by more than 80%. These species remain outside the plots, and populations vary from rare to locally common.

Numbers of three species of palms, Coccothrinax argentata, Sabal palmetto, and Serenoa repens increased from burning activity, or remained at relatively constant levels. Dodonea viscosa, Rhus copallina, and Tetrazygia bicolor increased by 121% to 659% from 1958 to 1979. These species and Myrica cerifera have the potential of becoming major dominants as they increase in response to frequent winter fires.

Hurricanes, freezing temperatures, and succession appear to have little influence on composition of hardwood understory species. Localized effects, such as freezing, have a temporary impact on shrub height by top-killing some species.

The weight of observations seem to show that summer season fires provide greater and longer-lasting shrub control than repeated winter burns.

Comparative effects of headfires versus backing fires are inconclusive, but tend to support headfires as being most effective in hardwood kill. Effect on pines is much more severe with headfires than with backing fires, and backing fires are more easily controlled.

After 22 years of prescribed fire, the management objective of reclaiming the pinelands from hardwood invasion has not been achieved, but hardwood presence has been held in check.

ACKNOWLEDGEMENTS

W. B. Robertson, Jr. established the plots and made data collections at the beginning of the study. Ron Hofstetter collected data from blocks B, H, and J during 1972 and 1973. Burns were conducted by the Resources Management Division. Lynette McLamb, Jim Craig, and Ken Vernick did field investigations during the 1979 sample period. James Snyder and Dale Wade were especially helpful with the manuscript.

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Table 1. Years when pine blocks were sampled and burned. Asterisk indicates a wildfire and P represents a prescribed fire. Numbers represent hardwood stems per hectare.

	A	B	C	E	F	H	I	J
1958		5773 P		11183 P				
1959				P	12721 P			
1960						15384 P		18321 P
1961		10881					16037 P	
1962								
1963			7802 P		12412	21144	12444	
1964		16681		14450			P	22420
1965	15185 P							
1966								
1967		P						
1968								
1969				P	P		*	
1970								
1971	P		P					P
1972		24634 P				31342 P		
1973		11444				9855		
1974					*	*	*	*
1975	P	P	P	P	P			
1976						P		
1977		P				P	P	
1978							16252	18311 P
1979	10033	11941	8981 P	9664	14431 P	13300		
Number of times fires occurred prior to 1979	4	6	3	3	4	5	6	3
% Change in stem number from first to last measurement	-34%	+107%	+15%	-14%	+13%	-14%	+1%	0%

Note: Prescribed burning began in 1958. Prior to that, wildfires burned blocks A in 1957, B in 1951 and 1957, C in 1954, E and F in 1950, and I in 1957.

Table 2. Average stem numbers (per hectare) by height class for three sample periods.

	3 - 5'			5 - 10'			10'			Total Stems		
	1958	1964	1979	1958	1964	1979	1958	1964	1979	1958	1964	1979
Acacia pinetorum	0	0	3	0	0	0	0	0	0	0	0	3
Annona glabra	0	0	1	0	1	0	3	0	0	3	1	1
Ardisia escallonioides	415	505	302	92.	111	53	1	0	1	508	616	356
Baccharis halimifolia	68	36	65	40	14	33	3	0	0	111	50	98
Bumelia celastrina	1	22	0	0	0	0	0	0	0	1	22	0
Bumelia salicifolia	373	537	366	211	299	235	21	3	42	605	839	643
Bumelia reclinata	111	143	172	59	42	52	1	0	1	171	185	225
Bursera simaruba	1	4	4	1	1	1	0	0	0	2	5	5
Byrsonima lucida	319	142	43	15	8	0	0	0	0	334	150	43
Chrysobalanus icaco	294	392	90	153	185	14	1	0	0	448	577	104
Chrysophyllum oliviforme	75	107	63	26	54	31	0	0	1	101	161	95
Citharexylum fruticosum	14	38	19	16	31	13	0	0	0	30	69	32
Coccoloba diversifolia	11	8	3	8	4	6	1	0	0	20	12	9
Coccothrinax argentata	22	28	40	-	-	-	-	-	-	22	28	40
Conocarpus erecta	166	285	134	208	310	107	49	13	10	423	608	251
Croton linearis	42	42	28	1	0	0	0	0	0	43	42	28
Dodonaea viscosa	602	811	1248	36	42	161	0	0	0	638	853	1409
Eugenia axillaris	97	95	99	40	6	19	0	0	0	137	101	118
Ficus citrifolia	59	136	36	20	24	22	1	1	1	80	161	59
Forestiera segregata	12	14	15	3	3	25	0	0	0	15	17	40
Guapira discolor	566	712	338	154	141	143	11	3	3	731	856	484
Guettarda elliptica	316	476	307	3	10	18	0	0	0	319	486	325
Guettarda scabra	2759	3343	2354	635	451	257	1	2	0	3395	3796	2611
Hypericum hypericoides	0	1	1	0	0	0	0	0	0	0	1	1
Hypelate trifoliata	7	4	0	0	3	0	0	0	0	7	7	0
Ilex cassine	126	182	104	136	146	159	46	26	33	308	354	296
Ilex krugiana	38	40	7	12	17	0	0	0	0	50	57	7
Jacquinia keyensis	13	1	0	0	0	0	0	0	0	13	1	0
Lantana involucrata	18	18	25	0	6	3	0	0	0	18	24	28

	3 - 5'			5 - 10'			10'			Total Stems		
	1958	1964	1979	1958	1964	1979	1958	1964	1979	1958	1964	1979
Lysiloma latisiliqua	0	0	11	0	0	11	0	0	3	0	0	25
Magnolia virginiana	0	0	1	0	0	0	0	0	0	0	0	1
Mastichodendron foetidissimum	1	4	1	1	4	0	1	1	0	3	9	1
Metopium toxiferum	246	419	213	257	370	117	66	28	4	569	817	334
Morinda royoc	28	57	116	8	4	6	0	0	0	36	61	122
Myrica cerifera	263	291	256	145	167	301	8	6	6	416	464	563
Myrcianthes fragrans	16	1	0	15	0	0	0	0	1	31	1	1
Myrsine guianensis	798	986	843	232	186	106	11	0	1	1041	1172	950
Persea borbonia	80	79	92	78	79	90	18	3	3	176	161	185
Psidium longipes	236	257	35	22	22	1	3	0	0	261	279	36
Psychotria nervosa	0	0	6	0	0	0	0	0	0	0	0	6
Quercus virginiana	21	31	18	30	15	7	3	0	0	54	46	25
Randia aculeata	70	11	31	0	0	0	0	0	0	70	11	31
Rhus copallina	41	45	232	18	31	182	0	0	3	59	76	417
Sabal palmetto	899	996	810	0	-	-	0	-	-	899	996	810
Salix caroliniana	0	0	3	1	7	22	4	4	1	5	11	26
Serenoa repens	2081	2114	1968	-	-	-	-	-	-	2081	2114	1968
Solanum donianum	103	70	36	0	8	6	0	0	0	103	78	42
Stillingia sylvatica	0	4	8	0	0	0	0	0	0	0	4	8
Tetrazygia bicolor	163	327	415	49	93	82	0	0	0	212	420	497
Trema micrantha	0	0	24	0	0	11	0	0	1	0	0	36
Total Species	41	43	47	33	35	32	20	9	12	43	44	48
Total Stems	11571	13814	10987	2725	2895	2294	253	90	115	14549	16797	13396

Table 3. Percent change in stem numbers by height classes for three sample periods where 10 or more stems per hectare were present.

	3 - 5'			5 - 10'			10'			Total Stems		
	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979
Acacia pinetorum	-	New	New	-	-	-	-	-	-	-	New	New
Annona glabra	-	-	-	-	-	-	-	-	-	-	-	-
Ardisia escallonioides	22	-27	-40	21	-42	-52	-	-	-	21	-30	-42
Baccharis halimifolia	-47	-4	80	-65	-18	135	-	-	-	-55	-12	96
Bumelia celastrina	-	-	-	-	-	-	-	-	-	-	-	-
Bumelia salicifolia	44	-2	-32	42	11	-21	-	100	-	39	6	-23
Bumelia reclinata	29	55	20	-29	-12	24	-	-	-	21	32	9
Bursera simaruba	-	-	-	-	-	-	-	-	-	-	-	-
Byrsonima lucida	-55	-87	-70	-	-	-	-	-	-	-55	-87	-71
Chrysobalanus icaco	33	-69	-77	21	-91	-92	-	-	-	29	-77	-82
Chrysophyllum oliviforme	43	-16	-41	108	19	-43	-	-	-	59	-6	-41
Citharexylum fruticosum	171	36	-50	94	-19	-58	-	-	-	130	7	-54
Coccoloba diversifolia	-	-	-	-	-	-	-	-	-	-40	-55	-25
Coccothrinax argentata	27	82	43	-	-	-	-	-	-	27	82	43
Conocarpus erecta	72	-20	-53	49	-49	-65	-73	-79	-23	44	-41	-59
Croton linearis	0	-33	-33	-	-	-	-	-	-	-2	-35	-33
Dodonaea viscosa	35	213	54	17	347	283	-	-	-	34	121	65
Eugenia axillaris	-2	2	4	-	-52	-	-	-	-	-26	-14	17
Ficus citrifolia	130	-40	-74	20	10	-8	-	-	-	101	-26	-63
Forestiera segregata	17	25	7	-	-	-	-	-	-	13	166	135
Guapira discolor	26	-41	-53	-8	-7	1	-	-	-	17	-34	-43
Guettarda elliptica	50	-3	-36	-	-	80	-	-	-	52	2	-33
Guettarda scabra	21	-15	-30	-29	-60	-43	-	-	-	12	-23	-31
Hypericum hypericoides	New	New	-	-	-	-	-	-	-	New	New	-
Hypelate trifoliata	-	-	-	-	-	-	-	-	-	-	-	-
Ilex cassine	44	-17	-43	7	9	9	-43	-28	27	15	-4	-17
Ilex krugiana	5	-	-	42	-	-	-	-	-	14	-86	-

	3 - 5'			5 - 10'			10'			Total Stems		
	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979
Jacquinia keyensis	-	-	-	-	-	-	-	-	-	-	-	-
Lantana involucrata	0	39	39	-	-	-	-	-	-	33	56	17
Lysiloma latisiliqua	-	New	New	-	New	New	-	New	New	-	New	New
Magnolia virginiana	-	New	New	-	New	New	-	New	New	-	New	New
Mastichodendron foetidissimum	-	-	-	-	-	-	-	-	-	-	-	-
Metopium toxiferum	165	-13	-49	44	-54	-68	-58	-	-	44	-41	-59
Morinda royoc	104	314	104	-	-	-	-	-	-	69	238	100
Myrica cerifera	106	3	-12	-13	107	80	-	-	-	12	35	21
Myrcianthes fragrans	-	-	-	-	-	-	-	-	-	-	-	-
Myrsine guianensis	23	6	-15	-47	-54	-43	-	-	-	13	-9	-19
Persea borbonia	-1	15	16	1	15	14	0	0	0	-9	5	15
Psidium longipes	9	-85	-86	0	-	-	-	-	-	7	-86	-87
Psychotria nervosa	-	New	New	-	-	-	-	-	-	-	New	New
Quercus virginiana	48	-14	-42	-50	-77	-53	-	-	-	-15	-43	-33
Randia aculeata	-84	-56	182	-	-	-	-	-	-	-84	-56	182
Rhus copallina	10	466	416	72	911	487	-	-	-	29	659	489
Sabal palmetto	11	-10	-19	-	-	-	-	-	-	-11	-10	-19
Salix caroliniana	-	-	-	-	-	-	-	-	-	-	-	136
Serenoa repens	2	-5	-7	-	-	-	-	-	-	2	-5	-7
Solanum donianum	-32	-65	-49	-	-	-	-	-	-	-24	-59	-46
Stillingia sylvatica	New	-	-	-	-	-	-	-	-	New	-	-
Tetrazygia bicolor	101	155	27	90	67	-12	-	-	-	98	134	18
Trema micrantha	-	New	New	-	New	New	-	New	New	-	New	New
Number of new species	2	6	5	0	3	3	0	3	3	2	6	5
Number of species with change from 0 to ± 10%	8	8	3	3	3	3	0	0	0	4	8	2

	3 - 5'			5 - 10'			10'			Total Stems		
	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979	1958-1964	1958-1979	1964-1979
Number of species increasing: >10%-50%	22	10	10	12	6	7	0	1	1	24	9	13
>50%	8	6	5	4	4	4	0	1	0	6	6	7
Number of species decreasing: >10%-50%	4	15	20	6	11	11	3	2	1	7	17	21
>50%	2	5	7	2	6	6	2	1	0	3	6	7