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Effects Of Fire On Composition, Biomass, And Nutrients In Oak Scrub Vegetation On John F. Kennedy Space Center, Florida

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ABSTRACT

Oak scrub is a shrub vegetation type dominated by *Quercus myrtifolia*, *Q. chapmanii*, *Q. virginiana* var. *geminata*, *Serenoa repens*, and ericaceous shrubs occurring on well-drained sites on John F. Kennedy Space Center, Merritt Island, Florida.

Four stands of scrub vegetation, 2, 4, 8, and 25 years since fire, were sampled in 1983 with permanent 15 m line transects and percent cover by species was determined. Biomass was harvested on 1 m^2 plots associated with the line transects. Plant tissue samples were analyzed for total Kjeldahl nitrogen (TKN), total phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and aluminum (Al). Soil samples were taken from the 0 to 15 cm and 15 to 30 cm layers at each transect and analyzed for pH, conductivity, organic matter, cation exchange capacity (CEC), exchangeable Ca, Mg, K, Na, Al, nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N), available copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and P. Transects were resurveyed in 1985 for vegetation parameters.

Ordination analysis indicated that species were distributed along a gradient related to water table depth. Between the two sample periods some shifts in dominance in transects of the younger stands occurred with saw palmetto increasing in importance in some and oaks in others primarily due to height growth. Species richness changed little with time since fire. Mean total cover in the greater than 0.5 m stratum, mean height, and mean maximum height increased with time since fire. Mean total cover in the less than 0.5 m stratum decreased after year 2. Live biomass increased with time since fire. Litter biomass increased for at least 8 years after fire. Standing dead biomass formed a major component of total biomass but did not change significantly in total amount with time. Saw palmetto rhizomes were a significant and persistent component of scrub biomass.

Tissue concentrations in live biomass of TKN, total P, Ca, Mg, Na, K, and Al showed no trends with time since fire. Tissue concentrations were similar to those reported for other ericaceous shrubs and chaparral species. Litter concentrations of Ca, K, and total P were elevated in the 2 year old stand probably as a result of ash deposition.

Nutrient pools in biomass were calculated from biomass data and tissue nutrient concentrations. Litter, standing dead material, and saw palmetto rhizomes were major pools for many nutrients. Live stem biomass became important in the oldest stand. Standing crops were similar to those in other shrublands such as chaparral.

Soil chemical properties were closely related to water table depth. Wetter soils had higher organic matter content, greater cation exchange capacity, and higher concentrations of many nutrients. Effects of fire on scrub soils include increased pH and decreased organic matter, TKN, and available Zn.

Soil nutrient pools were calculated from nutrient concentrations and bulk density. Biomass pools of P, Ca, and K were greater than those of the soil in all stands. Biomass pools of TKN, Na, and Mg exceeded those in the soil except in wetter sites or where saw palmetto rhizomes were few. Aluminum pools were consistently greater in the soil than in biomass.

Deposition rates of nitrogen, Ca, P, and K in precipitation were low relative to biomass pools while the amounts of sodium and magnesium in precipitation were greater relative to biomass. Biological nitrogen fixation and mechanisms which retain and recycle nutrients in the system may be important to the persistence of oak scrub.

Long-term fire effects of a changed fire regime (e.g., the 3 yr cycle now being applied) could be greater than what is seen after recovery from a single fire event and could include shifts in dominance to the species best adapted to frequent fire and changes in nutrient cycling. The effects of frequent fire in oak scrub of most concern are the structural changes, particularly reduction in height. Burning on a 3 year cycle maintains shrub height in oak scrub less than 1 m but the endemic Florida scrub jay (dependent on oak scrub and related communities) prefers oak scrub greater than 1 m as habitat.

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INTRODUCTION

Scrub Vegetation Literature Review

Scrub has long been recognized as a distinctive plant community in Florida. (Harper 1914, 1921, 1927, Mulvania 1931, Webber 1935, Kurz 1942). However, considerable confusion exists about what specific communities should be designated scrub. Confusion also exists as to the fire ecology, relationship to environmental variables, and successional patterns of scrub. Sand pine scrub is endemic to Florida (Austin 1976, Christensen 1979); related oak scrub communities occur in adjacent states (Laessle 1967). Laessle (1942) used the designation scrub only for sand pine scrub which had a canopy of sand pine (_Pinus clausa_) and an understory of evergreen shrubs, particularly myrtle oak (_Quercus myrtifolia_), sand live oak (_Q. virginiana_ var. _geminata_), Chapman oak (_Q. chapmanii_), and saw palmetto (_Serenoa repens_) and referred to similar communities without the sand pine canopy as "scrubby flatwoods." This classification is also used by some recent workers (Abrahamson 1984a,b, Abrahamson et al. 1984, Givens et al. 1984). Kurz (1942) used the term scrub more broadly for various communities of evergreen shrubs on coastal and inland dunes. Webber (1935) emphasized the importance of the shrub layer rather than the pine overstory in defining scrub.

The Florida Natural Areas Inventory (FNAI) uses a broad classification defining eight scrub types: sand pine scrub, sand pine/turkey oak scrub, slash pine scrub, oak scrub, rosemary scrub, saw palmetto scrub, and tropical scrub (Duever 1983a, FNAI unpublished).

Sand pine scrub has received more study than other types. It occurs on xeric sand ridges which are low in nutrients (Mulvania 1931, Webber 1935). Laessle (1958b, 1967) established the relationship between inland scrubs and former shore lines; old dunes, beaches, and bars formed from washed and sorted sands were occupied by sand pine scrub. Laessle (1958b) suggested that nutrient deficiencies of the scrub soil were responsible for the occurrence and distinctness of this community; he later analyzed soils from sand pine scrub and adjacent sandhill (longleaf pine/turkey oak) vegetation and found no consistent differences in the soils (Laessle 1967). Kalisz and Stone (1984) found no consistent differences in soil profile morphology, particle size distribution, or extractable nutrients between longleaf pine islands and sand pine scrub in Ocala National Forest.

Fire is of major importance to scrub vegetation. Fires are infrequent in sand pine scrub; a return cycle of 20 to 40 or more years has been suggested (Austin 1976). Sand pine reproduces from seed following fire (Webber 1935) and frequent fire would eliminate it. Richardson (1977) and Peroni and Abrahamson (1986) have reported the transformation of sand pine scrub to "scrubby flatwoods" by frequent fire. However, sand pine is a short-lived species (ca. 75 years) and long exclusion of fire can also lead to its elimination (Laessle 1967).

Rosemary (Ceratiola ericoides) reproduces only from seed and requires a fire cycle of 10 to 40 years (Johnson 1982) indicating limits to the natural fire cycle of scrub in which rosemary is important. When fire does occur in sand pine scrub it is intense (Webber 1935). Several factors contribute to the low frequency of fire in scrub including the evergreen nature of the shrubs (which spreads out in time the accumulation of litter), the lack of grasses and herbs in the community, and lack of extensive litter buildup on the ground under the stand (Webber 1935). Over time, sufficient fuel builds up to carry fire, at least under dry conditions. After fire, the scrub oaks and other shrubs resprout (Webber 1935). These low frequency-high intensity fires contrast sharply with the frequent, low intensity fires typical of longleaf pine/turkey oak (sandhill or high pineland) vegetation (Webber 1935, Laessle 1967) and may be responsible for maintaining sand pine scrub and sandhill as distinct communities (Kalisz and Stone 1984, Myers 1985).

Natural fire frequency for oak scrub is not known with certainty. It is generally assumed that oak scrub burned more often than the 20 to 70 year cycle estimated for sand pine scrub but less often than the nearly annual cycle of longleaf pine/wiregrass sandhill community (Abrahamson et al. 1984). Davison and Bratton (1986) found a drought cycle of 23 ± 5 years for Canaveral National Seashore and suggested that oak scrub is only likely to experience major fires with summer drought conditions since only at this time would an ignition source (lightning) coincide with vegetation in a fire-prone condition.

Less information is available on the response of scrub types other than sand pine scrub to fire. Abrahamson (1984a,b) studied the response of several communities to fire on Lake Wales Ridge (Archbold Biological Station) including "scrubby flatwoods." A prescribed winter burn using headfires burned 30 to 62% of the vegetation along transects in "scrubby flatwoods" (Abrahamson 1984a). Species present in "scrubby flatwoods" before fire sprouted in response to the fire. Cover (measured as single stratum) returned to pre-burn values within 2 years and species composition was unchanged. However, height growth of the scrub oaks was slow; myrtle oak had a mean height of 50 cm at 5 years post-burn and sand live oak had a mean height of 30 cm at 5 years (Abrahamson 1984a). Saw palmetto returned to its pre-burn cover within 1 year after fire; it also exhibited faster height increase reaching 70 cm within 2 years after fire (Abrahamson 1984b).

Succession in the absence of fire has been the subject of much speculation. Kurz (1942) suggested that scrub species could invade adjacent sandhill vegetation. He also placed coastal strand, oak scrub, and sand pine scrub in the middle of the dune successional sequence between sea oats and hammocks. He noted, however, that most scrubs were stable and considered them an edaphic climax on sterile xeric sands. Laessle (1942, 1958b) thought that scrub would undergo succession through live oak hammock to a mesic hammock and that there was no successional relationship between scrub and sandhill. He later noted sand pine invasion of sandhills which had been protected from fire (Laessle 1967). He also observed that many scrubs showed no invasion by hammock species while some, particularly in coastal areas on less leached soils, did show such invasion (Laessle 1967).

Veno (1976) studied permanent quadrats established by Laessle (1958a) in communities of the Welaka Reserve which had been protected from fire since 1939. Scrub showed no change in species composition; density and basal area of the scrub species increased greatly and woody litter increased over the 20 year period of the study. Givens et al. (1984) also reported little change in species composition of sand pine scrub or "scrubby flatwoods" in 10 years in a section of Archbold Biological Station which had been protected from fire since 1927. Structural changes occurred including height and crown diameter growth; density of most shrubs decreased due to thinning mortality. Peroni and Abrahamson (1986) found that "scrubby flatwoods," sand pine scrub, and rosemary scrub on the southern Lake Wales Ridge remained relatively stable in the absence of fire. Myers (1985) showed that scrub species including sand pine, sand live oak, myrtle oak, Lyonia ferruginea (rusty lyonia), and scrub hickory (Carya floridana) increased greatly in density and basal area in a sandhill site at Archbold Biological Station protected from fire since 1929.

Kalisz and Stone (1984) suggested (based on soil opal data) that the boundary between sand pine scrub and sandhill may shift over time with differing fire frequencies and intensities. Myers (1985) suggested that fire frequency and intensity are the major determinants in the development and maintenance of sandhill, sand pine scrub, and xeric hardwood vegetation.

Paleoecological studies (Watts 1971, 1975, 1980) have shown that scrub vegetation has long been present in Florida. At Lake Annie at the south end of Lake Wales Ridge (Watts 1975), the pollen record suggests that rosemary scrub dominated from 37000 BP to 13000 BP, indicating xeric conditions. Oak scrub (or woodland) possibly with prairie openings dominated between 13000 BP and 4700 BP at which time the presettlement vegetation patterns were established. Oak scrub or woodland is also recorded in north and central Florida between about 8000 BP and 5000 BP (Watts 1971). These studies suggest much drier conditions at least in terms of soil moisture during the Wisconsin glaciation due to lower sea levels, dropping the regional water table, or to reduced precipitation (Watts 1980).

Effects of Fire on Soils

No detailed studies of the effects of fire on scrub soils exist. The effects of fire on soils varies with the type of soil, climate, vegetation, fuel load, physical attributes of the site (e.g., slope), temperature and duration of the fire, and other factors (Wells et al. 1979, Raison 1979, Rundel 1981). Effects occur from the direct action of heat on plants and soil and indirectly from the removal of vegetation and litter creating a new microclimate and from the redistribution and changed availability of nutrients. Changes in soil properties may be immediate or may occur subsequently through vegetation changes and the activities of soil organisms. Changes may be short term in response to a single fire event or long term in relation to a particular fire regime (Raison 1979).

Given the variability in vegetation, soils, and fire regimes, effects of fire on soils are highly variable (Wells et al. 1979). Raison (1979) suggested that fire is likely to have the most impacts on systems whose long term stability depends on efficient nutrient accumulation, retention, and recycling, and that these situations are often characterized by low soil nutrient reserves, a large portion of the nutrient capital in biomass, and rates of decomposition which limit productivity of the whole plant community. Boerner (1982) distinguished between oligotrophic ecosystems where nutrients are mainly aboveground and soil reserves are low and eutrophic ecosystems which occur on nutrient rich soils. Nutrient losses should be more significant for oligotrophic systems since the losses would be greater relative to the soil reserves.

Nutrient losses with fire occur by three mechanisms: direct volatilization of organic matter, wind and water erosion of the ash deposited by fire, and leaching to ground water of nutrients made available by fire (Raison 1979, Wells et al. 1979). Volatilization is most significant for nitrogen (Knight 1966, Raison 1979) and to a lesser extent for sulfur. Losses (if any) of other nutrients occur primarily through wind and water erosion and leaching.

Even within the coastal plain of the southeastern United States, the magnitude and significance of fire effects on soils varies. On the Santee Experimental Forest in South Carolina, prescribed fires produced atmospheric losses of up to 40 kg/ha nitrogen and 8 kg/ha sulfur but no changes in ground water or stream flow nutrients and only small effects on soil nutrients (Richter 1980, Richter et al. 1982). This site had clay soils with high cation exchange capacity (Richter 1980) and major nutrient pools in the mineral soil (Gilliam 1983). On sandy, infertile soils with low cation exchange capacity at the Savannah River plant, Lewis (1974) found losses of cations (Ca, Mg, Na, K) from the litter and increases of some (Ca, Mg, Na) in the ground water. In the Pine Barens of New Jersey, Boerner and Forman (1982) found that both hydrologic and mineral (Ca, Mg, K) outputs were greater in wildfires than in prescribed fires that were, in turn, greater than those from unburned sites.

McKee (1982) compared four coastal plain pine sites subject to repeated prescribed burning. He found that the mass and nutrient content (N, P, K, Ca, Mg) of the forest floor was reduced on all burned sites. Available P and pH of the surface soil increased on all sites. Exchangeable Ca and Mg generally increased with burning in the surface soil while exchangeable K and Na were little changed. For the whole system (forest floor and soil), nitrogen increased slightly at two sites, decreased at one, and at the fourth site increased with annual winter burns, remained unchanged with periodic winter burns, and decreased with periodic or annual summer burns.

In prescribed fires on Miami Rock Ridge pineland, Snyder (1984) found nitrogen losses of 57 to 95 kg/ha but that other nutrients were transferred from live vegetation and litter to ash, standing dead vegetation, and the remaining litter. Resprouting vegetation was important in taking up available nutrients.

STUDY AREA

Location

John F. Kennedy Space Center (KSC) is located on the northern part of Merritt Island on the east coast of central Florida and consists of approximately 57,000 ha of land and lagoonal waters (Figure 1). The National Aeronautics and Space Administration (NASA) acquired the northern part of Merritt Island in 1962 to support the space program and provide a safety and security buffer area (NASA 1979). Management of part of the lands not actively used in the space program was transferred to the U.S. Fish and Wildlife Service (FWS) in 1963 with the establishment of Merritt Island National Wildlife Refuge (MINWR); in 1972 this management authority was expanded to include all areas except those with NASA facilities or directly used in the space program. In 1975 management of part of the coastal lands was transferred to the National Park Service (NPS) with the establishment of Canaveral National Seashore (CNS) (Hamilton et al. 1985).

Geology and Soils

Merritt Island together with the adjacent Cape Canaveral form a barrier island complex. Topographic relief is slight; elevation ranges from sea level to about 3 m (10 ft) in the inland areas of Merritt Island and to slightly over 6 m (20 ft) on Cape Canaveral and the recent dunes. The topography is marked

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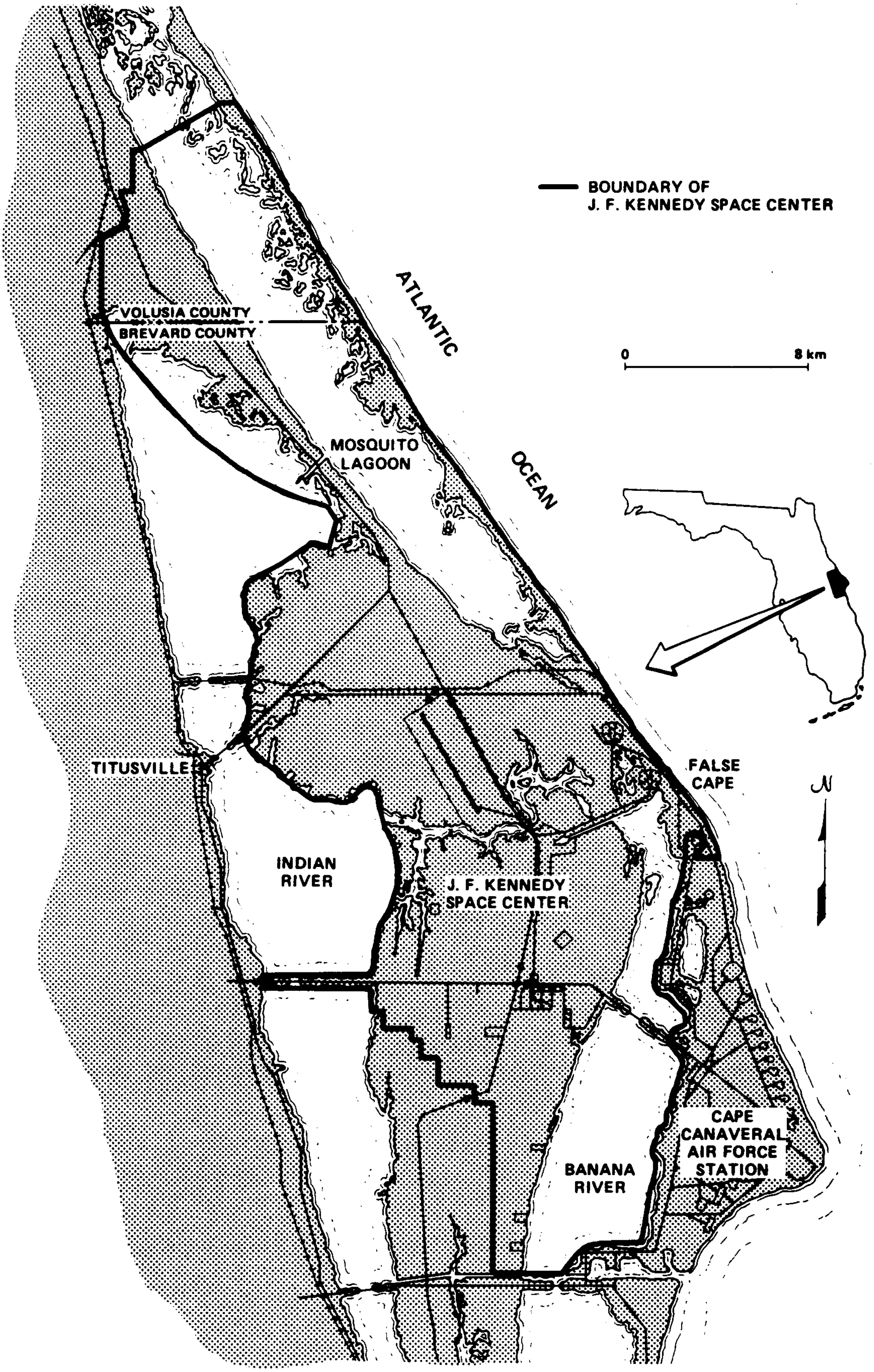


Figure 1. Map of the John F. Kennedy Space Center.

by a sequence of ridges and swales reflecting relict beach ridges. Brooks (1981b) mapped the area as the Cape Canaveral section of the Central Atlantic Coast Strip. Healy (1975) mapped Merritt Island and Cape Canaveral as belonging to the Silver Bluff Terrace while the Atlantic Coastal Ridge on the adjacent mainland belongs to the Pamlico Terrace.

Surficial deposits are of Pleistocene and Recent ages consisting primarily of sand and sandy coquina. These deposits are sometimes referred to as the Anastasia formation (Brooks 1981a). These overlay upper Miocene or Pliocene deposits of unconsolidated beds of fine sand, shells, clay, and calcareous clay. Under these are the Hawthorn formation of Miocene age composed of calcareous clay, sandy phosphatic limestone, phosphorite, and radiolarian clay. Below these are a series of limestones of Eocene age which also constitute the Florida aquifer (Brown et al. 1962).

The Cape Canaveral-Merritt Island barrier island complex is unique along the Florida coast; it is not associated with rivers or former deltas unlike capes on the coast of the Carolinas (Hoyt and Henry 1970). White (1958, 1970) described this as a prograding barrier island complex. He considered Cape Canaveral to be the result of southward (longshore) growth of an original cape at the site of the present False Cape. The eastern edge of Merritt Island at its contact with Mosquito Lagoon and the Banana River forms a relict cape coaxial with False Cape. Multiple dune ridges parallel to the present shore inland on Merritt Island apparently represent successive stages in this growth. White (1958, 1970) thought that this succession of cape formations was probably structurally controlled by some bedrock feature which influenced the southward movement of sediments along the coast. Brown et al. (1962) showed that the depth to the Eocene limestone formation below the land surface forms a ridge-like structure roughly conforming to the shape of Cape Canaveral, which may be the structure responsible for the cape formation. Chaki (1974) distinguished eleven distinct beach ridge sets on Cape Canaveral and suggested that periods of deposition and erosion have alternated.

Successively older landscapes occur westward on Merritt Island. Erosion has reduced the western side of Merritt Island to a nearly level plain (Brown et al. 1962). Brooks (1981a) mapped Cape Canaveral as of Holocene age, less than 4500 BP, but Merritt Island as Pleistocene. Dating of fossil beach rock, shells, or coquina (Osmond et al. 1970) gave recent ages on the current barrier beach, ca. 30,000 BP on Merritt Island, and ca. 100,000 BP on the adjacent mainland.

Soil development reflects the differing ages of the landscape as well as drainage and parent material influences. Numerous soil types occur (Huckle et al. 1974). Upland soils fall into several groups. On the current barrier beach and Cape

Canaveral, Canaveral sand (Aquic Udipsamment) and Palm Beach sand (Typic Udipsamment) are the major soils. Both are entisols formed in marine sand and shell deposits, with shell fragments still present in the profile and an alkaline to neutral reaction (Huckle et al. 1974). On the ridges on Merritt Island, the main soils are Pomello sand (Arenic Haplahumod) and Paolo sand (Spodic Quartzipsamment). Paolo sand, an entisol, is the better drained of these two series; Pomello sand is moderately well drained and has a spodic horizon. Both soils are acid and contain no shell fragments. On less well drained sites, Immokalee sand (Arenic Haplaquod), Myakka sand (Aeric Haplaquod), and associated series are the major soils. Both are spodosols with acid reaction; Immokalee is slightly better drained than Myakka.

Climate

Merritt Island has a warm, humid climate. Annual precipitation is about 125 cm and ranges from 4.01 cm in December to 22.48 cm in September. Mean daily maximum temperatures are 21°C for January and 31°C for July; mean daily minimum temperature are 11°C for January and 23°C for July. Freezing temperatures may occur in winter but persist for less than a full day (NASA 1979). Thunderstorms are common in the summer months; the average number of days per month with thunderstorms are: May, 8; June, 13; July, 16; August, 14; and September, 10 (Eastern Space and Missle Center 1982). Lightning strikes are common, averaging 3.9 ± 2.4 per square kilometer during June, July, and August; a total of approximately 1400 ± 840 strikes occurs in each of these months in the 350 km^2 KSC area (Eastern Space and Missile Center 1982). Long term precipitation data indicate a drought cycle of 23 ± 5 years (Davison and Bratton 1986).

Vegetation

Merritt Island contains a diverse flora; approximately 943 native or naturalized species and 124 exotics persisting at least 10 years after cultivation occur (Sweet 1976, Poppleton et al. 1977). This flora contains elements of tropical and subtropical distribution as well as temperate species.

Before the 1970's little detailed information is available on the vegetation of Merritt Island. Davison and Bratton (1986) have compiled and analyzed historical data on the vegetation history of Canaveral National Seashore. They note impacts to vegetation associated with logging of live oak and slash pine, drainage of wetlands, land clearing for agriculture, increased fire frequency, and grazing by cattle and hogs.

Harper (1921) surveyed Merritt Island and the adjacent mainland. He noted the presence of slash pine flatwoods, palm savannas, salt marsh, and mangrove swamp on Merritt Island.

Dunes near the ocean had thickets of saw palmetto behind the sea oats zone. Hammocks of a tropical nature occurred on shell mounds. "Low hammock" occurred on marly sites and graded into swamps. Old dunes (on the mainland) supported sand pine scrub.

Kurz (1942) described the sequence of vegetation on recent and inland (older) dunes on Cape Canaveral. He noted a sea oats zone followed by a zone dominated by saw palmetto with other shrubs grading into a zone of live oak, wax myrtle, tough buckthorn, and bay. Elsewhere on Cape Canaveral on more acid soils, he described areas dominated by sand live oak, myrtle oak, tallow wood (_Ximenia americana_), and blueberry (_Vaccinium_).

Sweet (1976) described and mapped the vegetation of northern Merritt Island between Banana Creek and Haulover Canal. He differentiated several types of scrub communities. He termed areas on the higher ridges of Merritt Island dominated by myrtle oak, saw palmetto, Chapman oak, and other shrubs "scrubby flatwoods." Less well drained sites dominated by saw palmetto, sand live oak, _Lyonia_ spp., and wiregrass (_Aristida_ spp.) but lacking a pine canopy, he termed "pineless flatwoods." More robust stands of saw palmetto around swales and ponds he termed "pond margins." In coastal areas, he described two types, "coastal flatwoods" dominated by saw palmetto, nakedwood (_Myrcianthes fragrans_), live oak, and wax myrtle and nearer to the shore "shrubless flatwoods" dominated by saw palmetto. These coastal types are more generally classified as coastal strand (Duever 1983b).

Stout (1980) mapped and described upland vegetation of KSC and Cape Canaveral Air Force Station (CCAFS). He used the term "coastal scrub" for scrub on Merritt Island dominated by myrtle oak, sand live oak, saw palmetto, and other shrubs. On the barrier beaches, he mapped and described as coastal strand the saw palmetto thickets inland from the sea oats zone. He used pine flatwoods for areas with pine overstory and also for similar sites with a shrub layer of saw palmetto but lacking a pine canopy.

Ongoing vegetation studies on KSC include the preparation of a detailed vegetation map at 1:9600 scale (Provancha et al. 1986). The classification used in association with this map recognizes two scrub types: oak scrub and saw palmetto scrub (Schmalzer and Hinkle 1985). Slash pine flatwoods are mapped only where there is a pine canopy. Oak scrub is dominated by myrtle oak, sand live oak, Chapman oak, saw palmetto, and other shrubs. It corresponds to the "coastal scrub" of Stout (1980) and to the "scrubby flatwoods" of Sweet (1976) and other authors (Abrahamson et al. 1984, Laessle 1942). Saw palmetto scrub is dominated by saw palmetto with lesser amounts of oaks and other shrubs. It corresponds to the "pineless flatwoods" of Sweet (1976) and to the part of the pine flatwoods of Stout (1980) lacking a pine canopy. On the basis of this vegetation map, it has been estimated that 6830 ha (16876 ac) of scrub occur on KSC of which 1284 ha (3173 ac) are oak scrub and 5546 ha (13703 ac) are saw palmetto scrub; additionally, 505 ha (1247 ac) of disturbed scrub and 5010 ha (12380 ac) of slash pine flatwoods occur.

STUDY OBJECTIVES

This study has the major objectives of examining the following topics:

1. Characterization of oak scrub vegetation on Merritt Island compared to related vegetation throughout Florida in terms of species composition and structure.

2. Response of oak scrub vegetation on Merritt Island to fire and the effects of fire on stand composition and structure.

3. Effects of fire-caused changes on habitat quality for certain endemic scrub animals.

4. Dynamics of biomass changes in relation to litter and fuel accumulation as compared to different aged stands and to other similar community types.

5. Dynamics of nutrient standing crops in relation to soils and biomass pools in different aged stands and in comparison to other community types.

These objectives are considered important for the following reasons:

1. Scrub vegetation on Merritt Island is important as habitat for animal species of special concern including Florida scrub jay (*Aphelocoma coerulescens coerulescens*), Florida mouse (*Peromyscus floridanus*), gopher tortoise (*Gopherus polyhemus*), and eastern indigo snake (*Drymarchon corais couperi*). KSC contains the largest single remaining population of the endemic Florida scrub jay (Cox 1984). Threatened or endangered plants occurring in scrub include Curtis's milkweed (*Asclepias curtissii*), nodding pineweed (*Lechea cernua*), brown-haired snoutbean (*Rhynchosia cinerea*), dwarf redbay (*Persea borbonia* var. *humilis*), and sand spikemoss (*Selaginella arenicola*) (Schmalzer and Hinkle 1985).

2. Effects of fire on composition and structure of oak scrub vegetation are not well known. Structural changes may be extremely important to species of concern such as the Florida scrub jay.

3. Biomass data on oak scrub vegetation have not been reported. Information on nutrient concentration in scrub

vegetation is also limited. Vickers et al. (1975) provided concentrations of K, Na, Ca, Mg, Fe, Mn, Zn, Cu, and Al in leaf tissue of selected species from Merritt Island. Biomass and nutrients in the saw palmetto/gallbery understory of slash pine stands have been studied (Hough 1981, 1982, McNab et al. 1978, McKee 1982). Effects of fire on nutrient standing crops in biomass and soil of oak scrub vegetation are unknown.

4. A general policy of fire suppression was in effect between 1963 and 1975 when FWS began a limited prescribed fire program (Lee et al. 1981). The fire suppression policy was not completely successful during this period and some wildfires did occur (FWS, unpublished records). After severe wildfires during the 1981 drought, a more extensive prescribed fire program was instituted providing a three year fire cycle for most upland habitats (Lee et al. 1981, Adrian et al. 1983).

METHODS

Community Composition and Structure

Four stands of oak scrub were selected for study in January 1983. These stands occurred in the same general area of Merritt Island on what were considered similar sites. They differed in the time since the last fire. Stand 1 was a reasonably well developed scrub with oaks 1 to 2 m tall whose age was not known initially. Stand 2 had been burned 4 years ago and Stand 3 was 2 years old (FWS/MINWR fire records). Stand 4 was an old stand with oaks several meters high.

Stands were sampled using permanent line transects. Five 15 m transects were placed in Stand 1 and six each in the other three stands. Transects were oriented north-south and both ends of each were marked with metal poles. Percent cover was recorded by species in two separate height classes, 0 to 0.5 m height and greater than 0.5 m height (Mueller-Dombois and Ellenberg 1974).

Height of the vegetation was determined at four intervals along the transects, 0, 5, 10, and 15 m. The maximum height of any vegetation along the transect was also determined. Vegetation sampling along these permanent line transects was repeated in January 1985. The stands did not burn during this interval.

Environmental Variables

Transects were located on topographic maps (Orsino and Wilson 7.5' quadrangles) and elevation was estimated for each transect. Only 5 ft contours are available on these maps, however. Transects were also located on soils maps (Huckle et al. 1974). Soil type, association, and parent material were determined from the maps and associated survey.

Age Determination

In Stand 4 some entire trunks of myrtle oaks were harvested during the biomass sampling. These were sectioned near the base, sanded, and examined under a dissecting microscope in order to count growth rings. Although growth rings were small they were distinguishable. Representative individuals of live oak and myrtle oak were harvested from Stand 1 and similarly dated.

Biomass and Biomass Chemistry

Biomass samples were harvested on one square meter plots located 10 m east of the vegetation sampling transects. All above ground biomass, living and dead, and litter on these plots were collected. Samples were separated into appropriate plant parts; leaves, stems, trunks, rhizomes, were oven dried at 105°C to constant weight. Dry weights were determined. For chemical analyses, subsamples were taken from each transect within a stand in which the taxa occurred and pooled. These samples were ground in a Weber pulverizing mill to pass through a #50 mesh screen. Ground material was oven dried at 105°C. For metals and phosphorus analyses, 1 g of oven dried material was dry ashed at 450°C in a muffle furnace (Wolfe 1962) and taken up in hydrochloric acid. Analyses were performed on a Perkin-Elmer Model 3030 atomic absorption spectrophotometer using Perkin-Elmer methods #11.1 (Na), #12.1 (Mg), #13.1 (Al), #19.1 (K) and #20.1 (Ca) (Perkin-Elmer Corporation 1982). Total phosphorus was analyzed on a Technicon Autoanalyzer using method 696.82W (Technicon Industrial Systems 1983d). For the determination of TKN, a 0.25 g sample was digested in 2 ml concentrated H_2SO_4, 2 ml 30% H_2O_2, and 4 ml of K_2SO_4-$CuSO_4$ digestion mixture in a model BD-40 block digester. The analysis was performed on a Technicon Autoanalyzer using method 696-82W (Technicon Industrial Systems 1983b).

Standing crops of nutrients in biomass per stand were calculated by multiplying the mean biomass of the plant part of a particular species or other biomass category such as litter or standing dead by its nutrient concentration.

Soil Sampling

Soil samples were taken from the 0 to 15 cm and 15 to 30 cm depths near each transect. Depth and type of the litter layer were recorded. Depth to the water table was determined by coring with a soil auger until saturated soil was reached. Transects were revisited seasonally (spring, summer, autumn) and the determination of water table depth was repeated.

Soil Chemistry

Soil samples were air dried. Analyses of all parameters except organic matter were made in the NASA/KSC Environmental Chemistry Laboratory. pH was determined on a 1:1 soil to water slurry (McLean 1982) using an Orion pH meter. Conductivity was measured on a 1:5 soil to water solution using a conductivity meter (Rhoades 1982). Exchangeable cations, Ca, Mg, Na, and K, were extracted in 1N ammonium acetate (Knudsen et al. 1982, Lanyon and Heald 1982) and analyzed by atomic absorption spectrophotometer using the same methods as for biomass samples (Perkin-Elmer Corporation 1982).

Available metals, Cu, Fe, Mn, and Zn, were extracted in diethylenetriaminepentaacetic acid (DTPA) (Olson and Ellis 1982, Gambrell and Patrick 1982, Baker and Amacher 1982) and analyzed by atomic absorption spectrophotometer using methods #29.1 (Cu), #26.1 (Fe), #25.2 (Mn), and #30.1 (Zn). Exchangeable aluminum was extracted in 1N potassium chloride (Barnhisel and Bertsch 1982) and analyzed by atomic absorption spectrophotometry using method #13.1 (Perkin-Elmer Corporation 1982).

Exchangeable nitrate (NO_3-N) and ammonia (NH_3-N) were extracted in 2N potassium chloride (Keeney and Nelson 1982) and then analyzed on a Technicon Autoanalyzer using methods 100-70W (NO_3-N) (Technicon Industrial Systems 1973) and 696-82W (NH_3-N) (Technicon Industrial Systems 1983a). Total Kjeldahl nitrogen was determined by micro-Kjeldahl digestion (Schuman et al. 1973) followed by analysis on a Technicon Autoanalyzer using method 696-82W (Technicon Industrial Systems 1983b).

Available phosphorus was determined by extraction in deionized water (Olsen and Sommers 1982) followed by analysis on a Technicon Autoanalyzer using method 696-82W (Technicon Industrial Systems 1983c).

Cation exchange capacity was determined by an ammonium saturation method (Chapman 1965) followed by determination of ammonium by using a Technicon Autoanalyzer (method 696-82W) (Technicon Industrial Systems 1983a).

Organic matter was determined by the combustion method (Nelson and Sommers 1982). Organic matter determinations were made by Post, Buckley, Schuh, and Jernigan, Inc., Orlando, Florida.

Nutrient Standing Crops in Soil

Standing crops of nutrients in the soil were calculated from nutrient concentrations and soil bulk density. Bulk density data are given in soil surveys of Brevard County (Huckle et al. 1974) and Volusia County (Baldwin et al. 1980). For typical scrub and flatwoods soil series a range of bulk densities are given. Typical values are Paola (0-6") 1.21 to 1.39 g/cm^3, Paola (6-15") 1.43 to 1.50 g/cm^3, Immokalee (0-6") 1.20 to 1.50 g/cm^3, Immokalee (6-15") 1.37 to 1.70 g/cm^3, Myakka (0-6") 1.09 to 1.27 g/cm^3, Myakka (6-15") 1.43 to 1.54 g/cm^3, Wabasso (0-7") 1.44 g/cm^3, and Wabasso (7-12") 1.43 g/cm^3. For nutrient standing crop calculations, a value of 1.20 g/cm^3 was used for the 0 to 15 cm (0-6") layer and a value of 1.50 g/cm^3 was used for the 15 to 30 cm (6-12") layer. Calculations were made of the nutrient standing crops per m^2 for the 0 to 15 cm and 15 to 30 cm layer.

Statistical Analyses

Descriptive statistics and correlations were calculated using STAT80 programs (Fullerton 1985) on a Hewlett-Packard 1000 computer. Multivariate analysis of variance (MANOVA) using a repeated measures design was performed on an IBM PC/XT computer using the MGLH procedure in the SYSTAT program package (Systat 1984). Univariate analysis of variance (ANOVA) using a repeated measures design was performed using the same procedures. Multivariate analysis of variance and univariate analysis of variance of soils data were performed using SPSS programs (Norusis 1986a, b) on an IBM PC/AT computer. Reciprocal averaging ordination used the ORDIFLEX package (Gauch 1977) as adapted to run on the HP-1000 computer (G. Markwell pers. com.). Community beta diversity was estimated from the first axis eigenvalue of the reciprocal averaging ordination using the formula

$HC = \sqrt{12EV/(1-EV)}/1.349$ (Whittaker et al. 1979b) where HC is beta diversity in half-change units and EV is the first axis eigenvalue.

RESULTS

Age Determination

The time since fire of Stand 1 was determined to be 8 years at the 1983 sampling and for Stand 4 was approximately 25 years.

Environmental Variables

Environmental variables varied betweem the four stands (Table 1). In particular, the water table was closer to the surface in three of four seasons in Stand 2 than the other stands. It should also be noted that Stand 2 had the only transects in soils classified as Immokalee or Myakka (Table 2).

Table 1. Selected environmental variables in the scrub stands.

Variable	All Plots N=23		Stand 1 N=5		Stand 2 N=6		Stand 3 N=6		Stand 4 N=6	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Elevation (m)	2.0	0.2	2.1	0.0	1.9	0.3	2.1	0.0	2.1	0.0
0 Horizon Thickness (cm)	0.5	0.6	0.9	0.4	0	0	0.2	0.4	1.1	0.5
Spring Water Table Depth (cm)	-79.2	41.5	-53.8	11.5	-34.5	27.0	-93.2	11.9	-131.2	9.2
Summer Water Table Depth (cm)	-102.6	43.5	-82.0	21.4	-64.7	47.7	-114.0	23.0	-146.2	23.9
Fall Water Table Depth (cm)	-77.0	32.2	-108.2	22.9	-37.2	23.0	-72.8	9.1	-95.2	15.6
Winter Water Table Depth (cm)	-98.0	35.0	-55.4	9.7	-82.3	15.8	-111.7	18.8	-135.8	25.4

Table 2. Categorical environmental variables in the scrub stands[1].

Environmental Variable	All Plots	Stand 1	Stand 2	Stand 3	Stand 4
Soil Type					
Immokalee	8.7	---	33.3	---	---
Myakka	8.7	---	33.3	---	---
Paola	13.0	---	---	---	50.0
Pomello	69.6	100.0	33.3	100.0	50.0
Soil Association					
Paola-Pomella-Astatula	82.6	100.0	33.3	100.0	100.0
Myakka-EuGallie-Immokalee	17.4	---	66.7	---	---
Soil Parent Material					
Marine Sands	87.0	100.0	100.0	100.0	50.0
Eolian Sands	13.0	---	---	---	50.0
Litter Type					
Thin or Scattered Mor	73.9	100.0	100.0	100.0	---
Mor	26.1	---	---	---	100.0

[1]Data are percentages of plots.

Community Composition

Species composition of the greater than 0.5 m layer was generally similar across the four stands at the initial sampling (Table 3). Myrtle oak, sand live oak, Chapman oak, saw palmetto, fetterbush (Lyonia lucida), staggerbush (Lyonia fruticosa), and rusty lyonia were the most important species. In the less than 0.5 m layer, the most common species were sprouts of the larger shrubs, small shrubs such as shiny blueberry (Vaccinium myrsinites), and wiregrass (Aristida stricta) (Table 4). The four stands exhibited some differences in composition; saw palmetto had greater dominance in Stand 2 (Table 3).

Reciprocal averaging ordination (Figures 2, 3) of the greater than 0.5 m layer data for 1983 arrayed the transects along a first axis along which saw palmetto had greatest importance to the left while oaks increased in importance to the right. Ordination scores on the first axis were correlated to water table depths in all four seasons (Table 5).

Species composition was similar in 1985 to that in 1983 (Tables 3, 4). In the younger stands (2 and 3), percent cover of many species in the greater than 0.5 m layer increased (Table 3) due to height growth and canopy spread. In the older stands (1 and 4), minor changes occurred (Table 3). Conversely, in the younger stands (2 and 3) many species decreased in cover in the less than 0.5 m layer as they grew into the higher layer or as thinning occurred.

Reciprocal averaging ordination of the 1985 greater than 0.5 m data gave a similar pattern to the 1983 ordination (Figures 4, 5). These first axis ordination scores were also most highly correlated to water table depths (Table 6).

Ordination of the 1983 and 1985 data combined produced a similar pattern (Figures 6, 7). Stands in 1983 and 1985 occurred in the same general position along the ordination axes. Some changes did occur. Two plots in Stand 2 shifted to the left on the first axis from 1983 to 1985 as the dominance of saw palmetto in them increased. The other four plots in Stand 2 shifted to the right as the scrub oaks grew into the greater than 0.5 m height class. Plots in Stand 3 also tended to shift rightward with time as oak cover in the greater than 0.5 m height class increased.

Species richness varied little between stands and changed little between the two samplings of the same stand. There was an increase in number of species in the greater than 0.5 m layer in the younger stands from 1983 to 1985 (Figure 8) and a decrease in the less than 0.5 m layer (Figure 9) (Tables 3, 4). Considering both strata together, there was no significant change in species richness with time (Figure 10).

Table 3. Composition in percent cover of the greater than 0.5 m height class of the scrub stands in 1983 and 1985.

	ALL PLOTS				STAND 1				STAND 2				STAND 3				STAND 4			
	1983 N=23		1985 N=23		1983 N=5		1985 N=5		1983 N=6		1985 N=6		1983 N=6		1985 N=6		1983 N=6		1985 N=6	
Species	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Aristida stricta	1.4	3.6	0.5	1.3	5.6	6.3	1.7	2.2	0.6	1.1	0.6	1.1	—	—	—	—	—	—	—	—
Befaria racemosa	0.5	1.2	1.2	2.2	1.0	1.4	0.9	1.3	0.6	1.3	1.8	2.4	0.6	1.5	1.5	3.6	—	—	0.4	1.1
Ilex glabra	0.3	1.4	1.2	3.9	—	—	—	—	1.1	2.7	4.6	7.1	—	—	—	—	—	—	—	—
Lyonia ferruginea	3.2	5.8	4.0	6.2	—	—	—	—	0.3	0.7	—	—	1.0	1.2	3.8	3.5	11.1	6.7	11.4	7.4
L. fruticosa	0.8	1.4	1.2	2.2	2.5	1.6	3.1	2.7	—	—	1.8	2.9	—	—	—	—	0.9	1.4	0.3	0.8
L. lucida	7.3	9.1	6.8	9.1	17.8	7.0	14.7	7.1	12.6	7.9	13.1	10.7	—	—	0.3	0.8	0.5	0.8	0.4	1.1
Myrica cerifera	0.3	1.1	0.8	1.7	—	—	0.7	0.7	0.9	2.2	1.7	2.9	—	—	0.1	0.3	0.1	0.3	0.7	1.6
Persea borbonia	0.06	0.2	0.2	0.8	—	—	—	—	0.2	0.5	0.7	1.6	—	—	—	—	—	—	—	—
Pteridium aquilinum	0.03	0.1	—	—	—	—			0.1	0.3	—	—	—	—	—	—	—	—	—	—
Quercus chapmanii	4.5	6.3	7.1	6.8	9.1	5.2	7.1	3.3	0.7	1.0	1.3	1.7	1.6	2.4	8.1	4.5	7.5	9.3	12.1	10.1
Q. myrtifolia	26.3	21.4	37.4	19.1	36.9	8.9	42.4	8.1	4.6	5.4	17.7	22.2	12.8	5.6	37.3	13.1	52.6	12.7	53.2	9.6
Q. virginiana var. geminata	14.4	20.7	15.4	17.5	14.9	21.9	12.6	19.1	4.4	7.9	9.3	14.2	3.2	5.6	11.6	9.9	35.0	25.1	27.8	22.5
Serenoa repens	26.2	20.6	23.9	21.5	34.0	12.0	30.0	14.1	47.1	20.3	47.3	22.9	12.4	10.8	10.6	8.2	12.6	14.0	8.9	10.1
Smilax auriculata	1.6	3.0	0.9	1.9	0.7	1.5	—	—	—	—	—	—	—	—	1.8	2.8	4.1	4.2	1.8	2.3
Vaccinium myrsinites	0.06	0.3	0.06	0.3	0.3	0.6	0.3	0.6	—	—	—	—	—	—	—	—	—	—	—	—
V. stamineum	—	—	0.1	0.4	—	—	—	—	—	—	—	—	—	—	0.3	0.8	—	—	0.1	0.3
Ximenia americana	—	—	0.06	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	0.5
Total Cover	87.6	41.8	100.9	19.1	122.7	15.7	113.4	11.9	73.1	21.7	99.7	8.3	32.9	10.7	75.3	8.3	124.3	14.9	117.5	8.8
Total Number of Species per Stand	15	—	16	—	10	—	10	—	12	—	11	—	6	—	10	—	9	—	12	—
Mean Number of Species per Transect	5.2	1.8	6.2	1.9	7.0	1.7	7.4	2.1	4.7	1.5	6.0	2.1	3.7	1.2	5.5	1.4	5.8	1.0	6.0	1.8

Table 4. Composition in percent cover of the less than 0.5 m height class of the scrub stands in 1983 and 1985.

	ALL PLOTS				STAND 1				STAND 2				STAND 3				STAND 4			
	1983 N=23		1985 N=23		1983 N=5		1985 N=5		1983 N=6		1985 N=6		1983 N=6		1985 N=6		1983 N=6		1985 N=6	
Species	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Andropogon spp.	0.1	0.5	—	—	—	—	—	—	0.4	0.9	—	—	—	—	—	—	—	—	—	—
Aristida stricta	2.2	3.6	1.6	2.6	2.3	3.3	1.6	2.2	5.4	4.9	3.8	3.5	1.1	2.4	0.9	1.9	—	—	—	—
Bare ground	0.8	2.1	0.2	0.5	—	—	—	—	—	—	—	—	3.2	3.2	0.5	0.8	—	—	0.2	0.5
Befaria racemosa	0.1	0.2	0.1	0.4	0.3	0.4	0.3	0.6	0.1	0.3	0.2	0.5	0.05	0.1	—	—	—	—	—	—
Hypericum reductum	0.06	0.2	0.06	0.2	—	—	—	—	0.2	0.4	0.2	0.4	—	—	—	—	—	—	—	—
Ilex glabra	0.09	0.4	0.03	0.1	—	—	—	—	0.3	0.8	0.1	0.3	—	—	—	—	—	—	—	—
Lyonia ferruginea	1.0	1.4	0.2	0.7	—	—	—	—	1.0	1.9	—	—	1.5	1.4	0.7	1.3	1.3	1.1	0.05	0.1
L. fruticosa	0.2	0.7	0.4	0.6	0.9	1.2	0.9	1.0	—	—	0.4	0.5	—	—	0.3	0.5	0.2	0.5	—	—
L. lucida	2.7	3.2	1.0	1.2	6.7	4.3	1.6	0.7	3.1	1.8	1.5	1.5	0.8	0.6	0.3	0.4	0.9	1.4	0.8	1.3
Myrica cerifera	1.4	2.2	0.9	1.2	2.0	1.6	0.9	1.1	2.5	3.2	0.9	1.6	0.1	0.3	0.2	0.5	1.2	2.4	1.4	1.3
Paronychia americana	0.03	0.1	0.01	0.06	—	—	—	—	—	—	—	—	0.1	0.3	0.05	0.1	—	—	—	—
Piloblephis rigida	0.06	0.3	—	—	—	—	—	—	—	—	—	—	0.2	0.5	—	—	—	—	—	—
Pteridium aquilinum	1.2	2.1	0.09	0.3	1.2	2.3	—	—	1.8	2.8	—	—	0.9	1.7	0.2	0.5	1.0	1.7	0.1	0.3
Quercus chapmanii	3.1	4.4	2.1	2.1	1.9	2.5	1.6	0.7	0.2	0.4	0.8	1.9	8.8	4.8	4.6	2.2	1.3	1.5	1.4	1.0
Q. myrtifolia	13.6	9.6	6.6	7.0	8.9	4.7	3.1	1.6	6.1	8.9	1.9	2.9	22.3	9.9	13.5	9.6	16.5	3.7	7.3	3.9
Q. virginiana var. geminata	6.1	7.2	1.8	2.0	2.3	1.7	1.3	1.1	2.8	3.1	1.1	2.0	11.7	11.0	3.2	2.8	6.8	5.3	1.6	1.4
Serenoa repens	0.7	1.4	0.2	0.5	1.3	2.0	0.5	0.7	0.7	1.2	—	—	0.7	1.6	0.3	0.6	—	—	—	—
Smilax auriculata	0.1	0.6	0.03	0.1	0.1	0.3	0.1	0.3	—	—	—	—	0.4	1.1	—	—	—	—	—	—
Vaccinium myrsinites	1.2	1.3	1.2	1.3	2.0	1.9	1.7	1.7	0.7	0.8	0.7	1.3	0.3	0.7	0.9	1.0	2.1	0.9	1.5	1.2
V. stamineum	—	—	0.2	0.5	—	—	—	—	—	—	—	—	—	—	0.5	0.8	—	—	0.1	0.3
Ximenia americana	—	—	0.06	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	0.5
Total Cover	34.9	13.9	16.6	8.6	29.9	7.1	13.8	4.1	25.3	12.9	11.5	6.7	52.4	9.5	26.0	10.1	31.3	5.8	14.7	4.0
Total Number of Species per Stand	19	—	19	—	12	—	11	—	14	—	11	—	15	—	14	—	9	—	11	—
Mean Number of Species per Transet	6.4	2.1	5.8	2.2	7.8	1.5	7.2	1.1	6.2	2.6	4.5	2.6	6.2	2.5	6.2	2.9	5.7	1.0	5.5	0.8

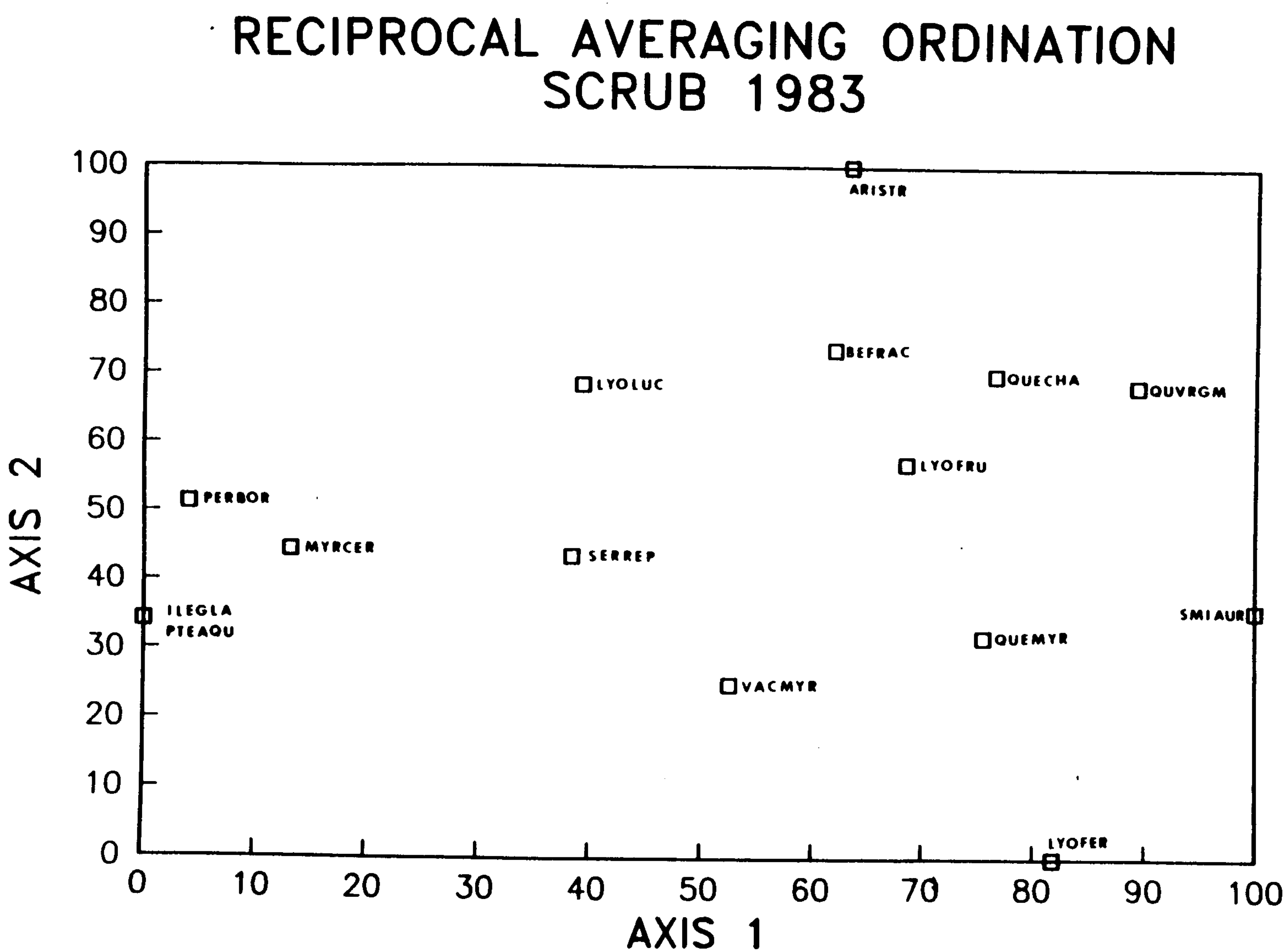


Figure 2. Reciprocal averaging species ordination of scrub vegetation sampled in 1983. Species are ARISTR *Aristida stricta*, BEFRAC *Befaria racemosa*, ILEGLA *Ilex glabra*, LYFER *Lyonia ferruginea*, LYOFRU *Lyonia fruticosa*, LYOLUC *Lyonia lucida*, MYRCER *Myrica cerifera*, PERBOR *Persea borbonia*, PTEAQU *Pteridium aquilinum*, QUECHA *Quercus chapmanii*, QUEMYR *Quercus myrtifolia*, QUVRGM *Quercas virginiana* var. *geminata*, SERREP *Serenoa repens*, SMIAUR *Smilax auriculata*, VACMYR *Vaccinium myrsinites*.

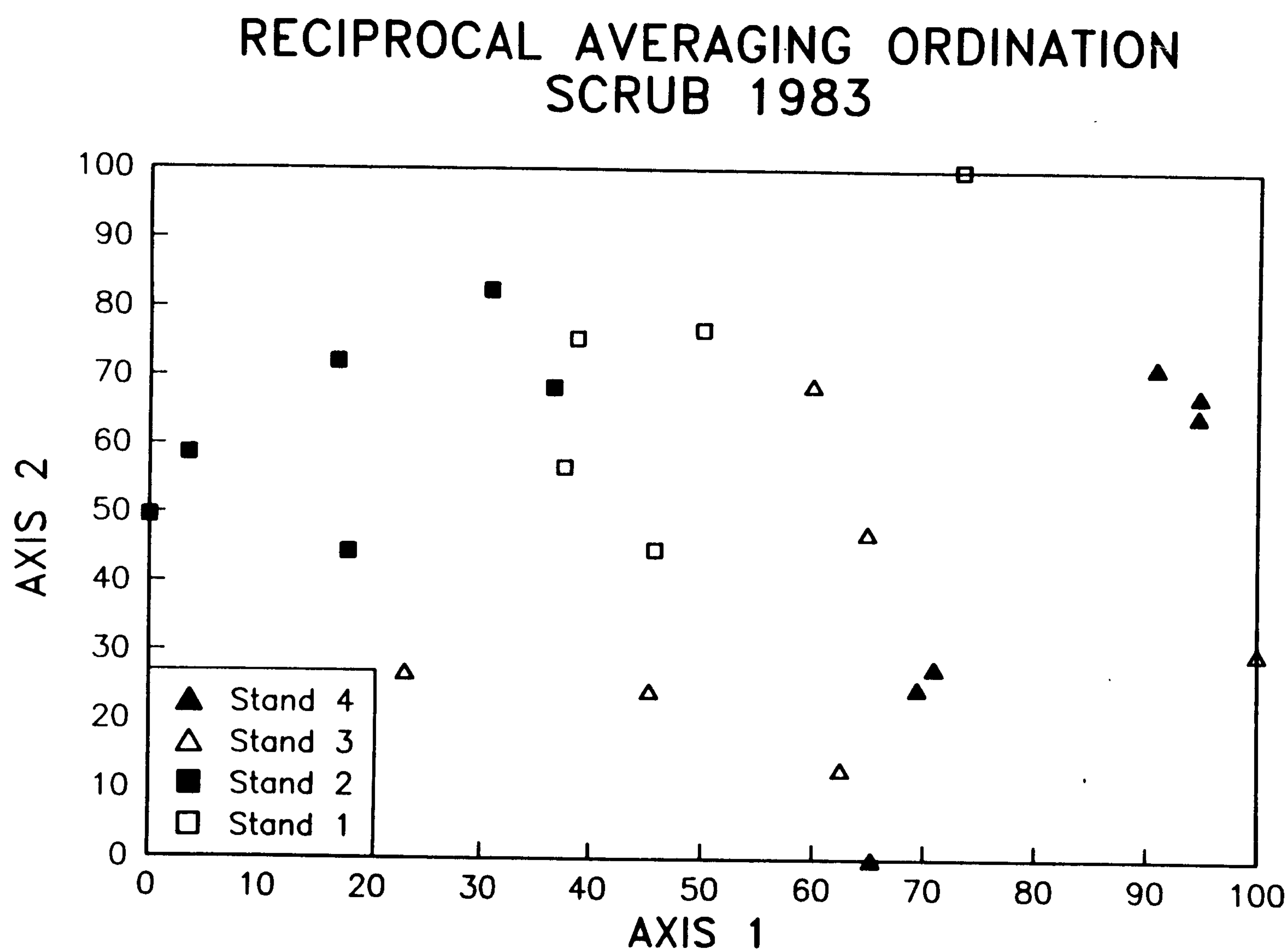


Figure 3. Reciprocal averaging stand ordination of scrub vegetation sampled in 1983.

Table 5. Spearman rank order correlations between reciprocal averaging scores and selected environmental variables for the 1983 scrub data[1].

Environmental Variable	Reciprocal Averaging Ordination Scores AXIS 1	AXIS 2	AXIS 3
Elevation	0.489	---	---
O Horizon Thickness	0.479	---	---
Water Depth Spring	-0.738	0.503	---
Water Depth Summer	-0.501	0.450	---
Water Depth Fall	-0.479	---	---
Water Depth Winter	-0.485	0.569	---
Years Since Fire	0.435	---	---

[1]Correlations significant at $p<0.05$.

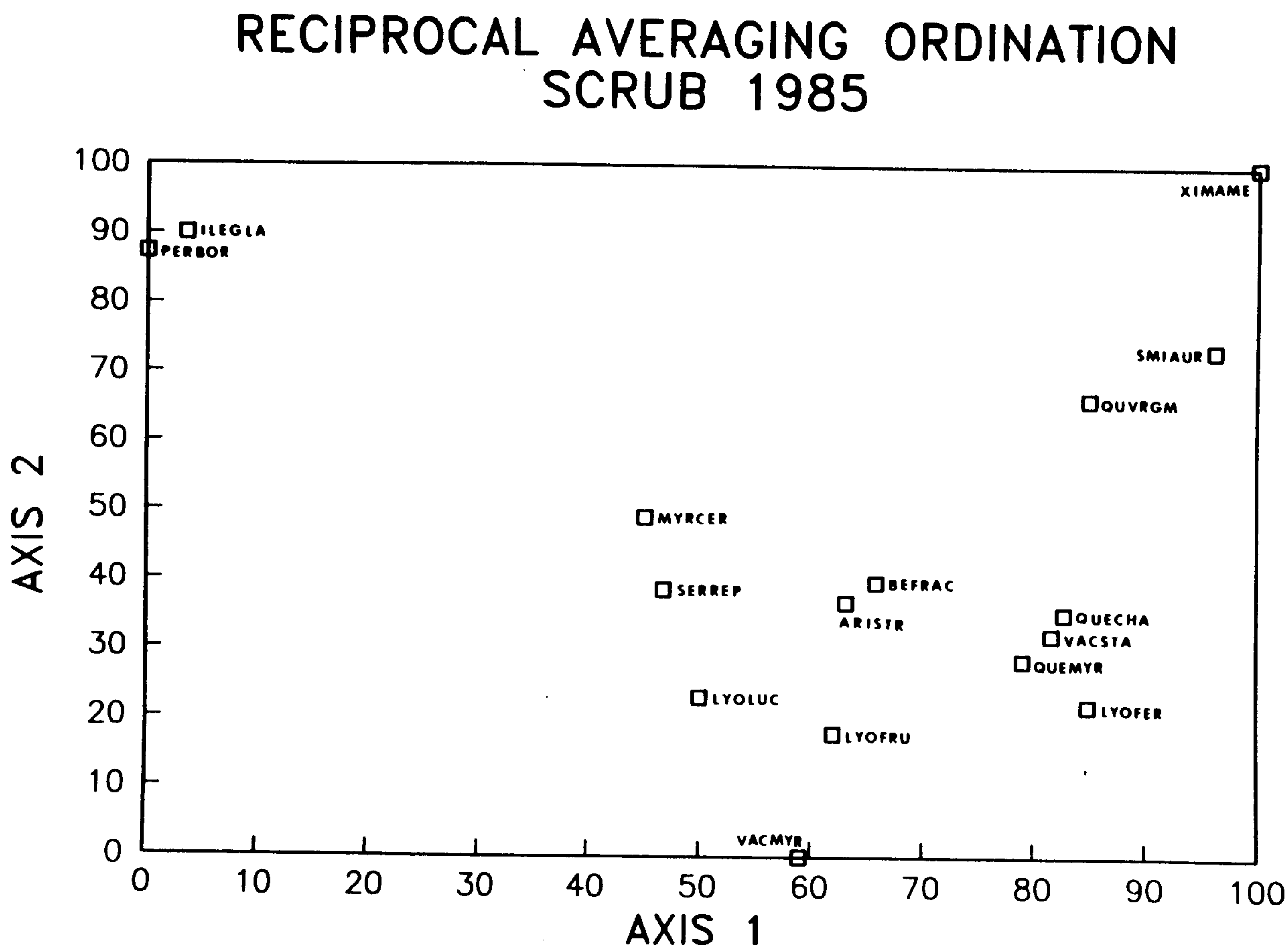


Figure 4. Reciprocal averaging species ordination of scrub vegetation sampled in 1985. Species are as in Figure 1 with the addition of VACSTA Vaccinium stamineum and XIMAME Ximenia americana.

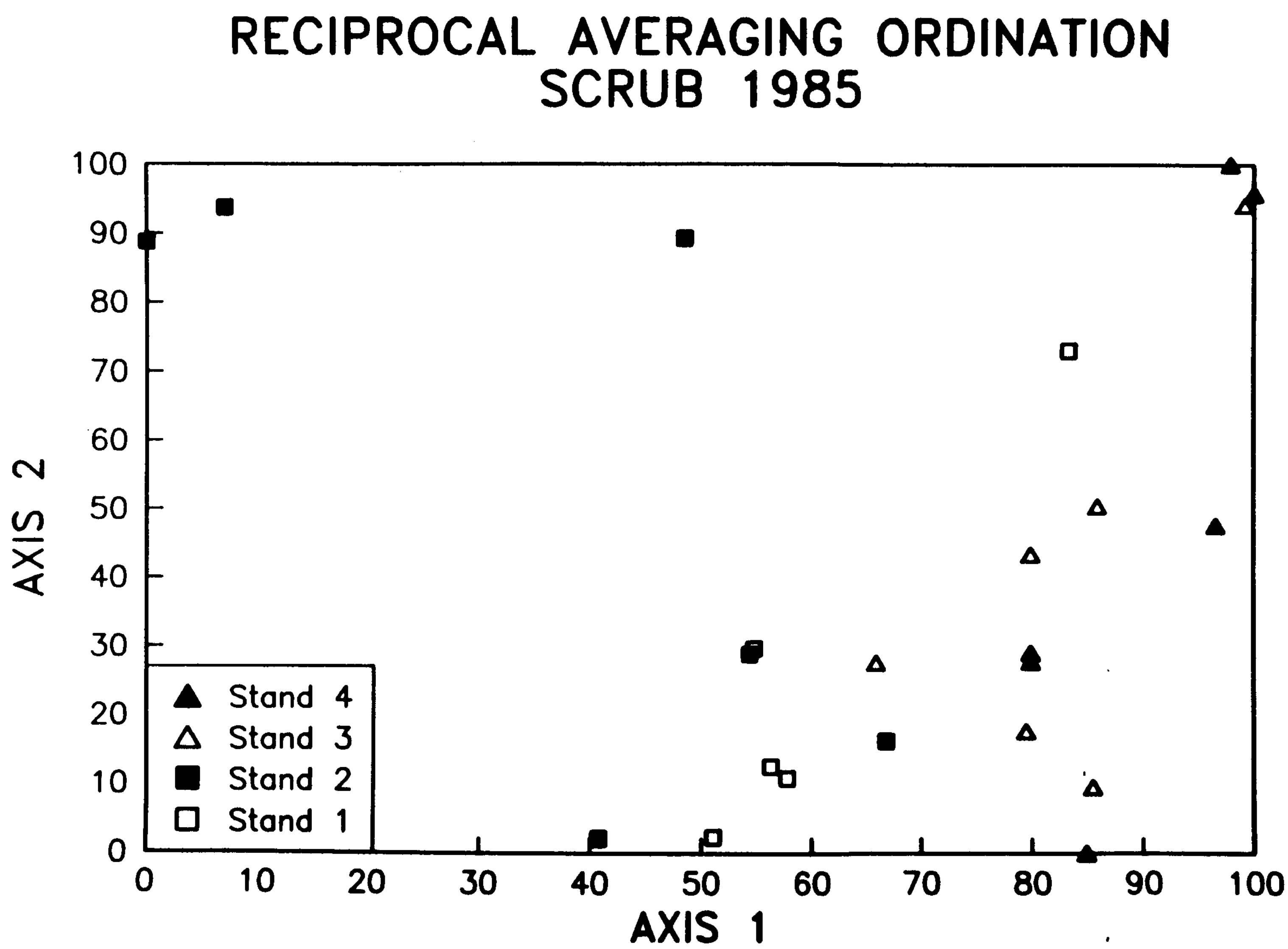


Figure 5. Reciprocal averaging stand ordination of scrub vegetation sampled in 1985.

Table 6. Spearman rank order correlations between reciprocal averaging ordination scores and selected environmental variables for the 1985 scrub data[1].

Environmental Variable	Reciprocal Averaging Ordination Scores AXIS 1	AXIS 2	AXIS 3
Elevation	0.489	---	-0.442
0 Horizon Thickness	---	---	---
Water Depth Spring	-0.807	---	---
Water Depth Summer	-0.609	---	---
Water Depth Fall	---	---	---
Water Depth Winter	-0.639	---	---
Years Since Fire	---	---	---

[1]Correlations significant at $p<0.05$.

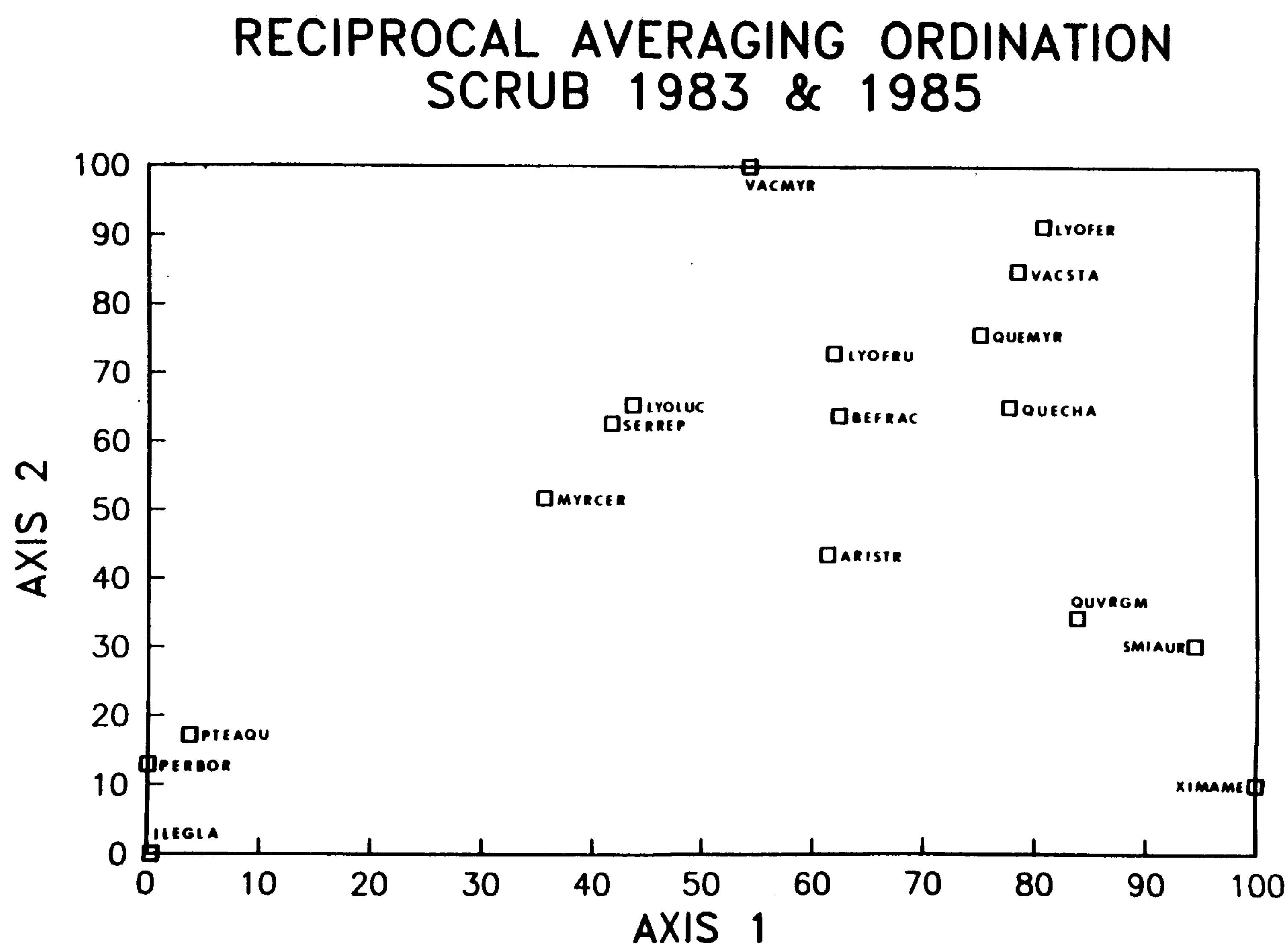


Figure 6. Reciprocal averaging species ordination of scrub vegetation sampled in 1983 and 1985. Species are as in Figures 1 and 2.

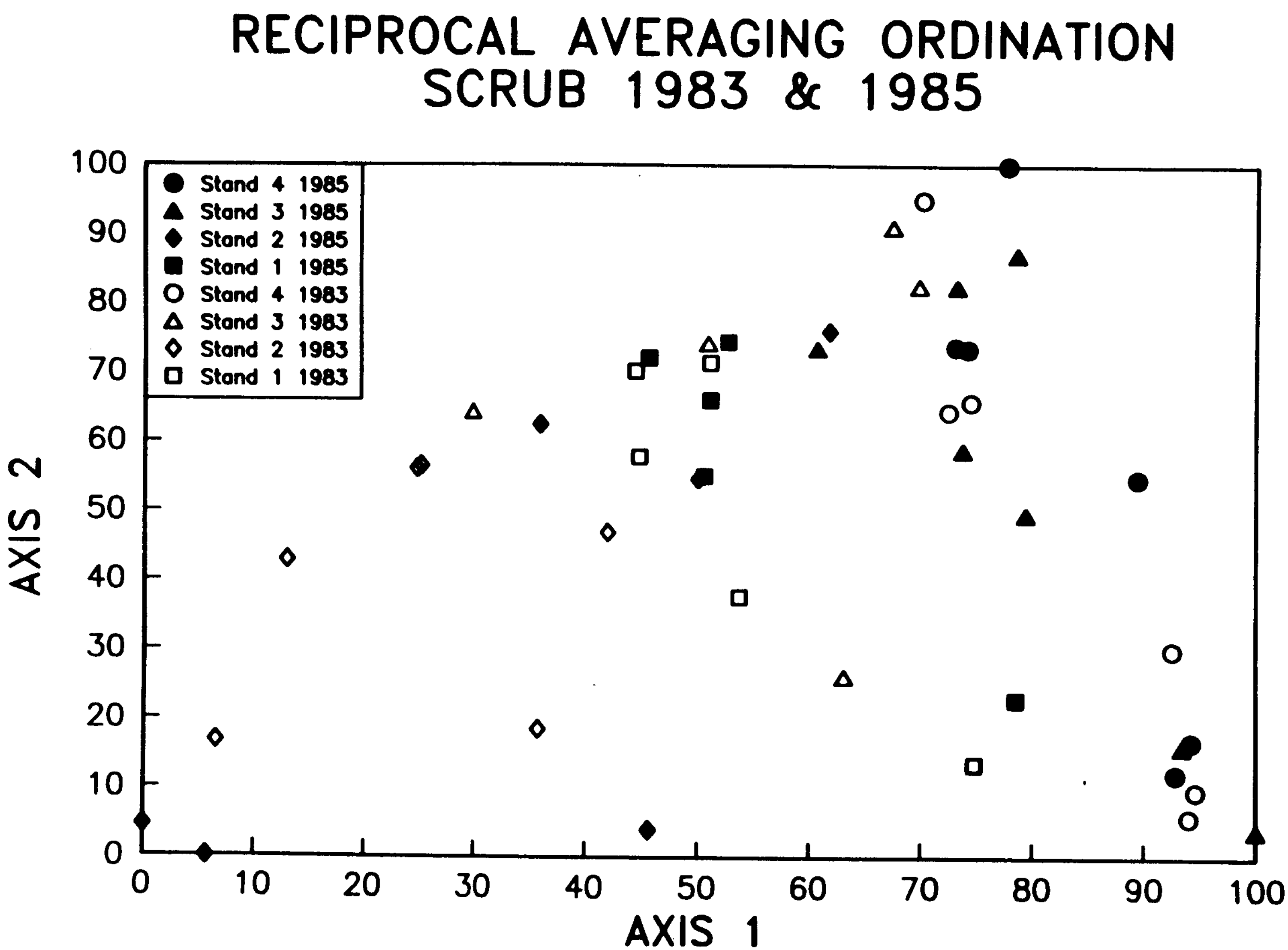


Figure 7. Reciprocal averaging stand ordination of scrub vegetation sampled in 1983 and 1985.

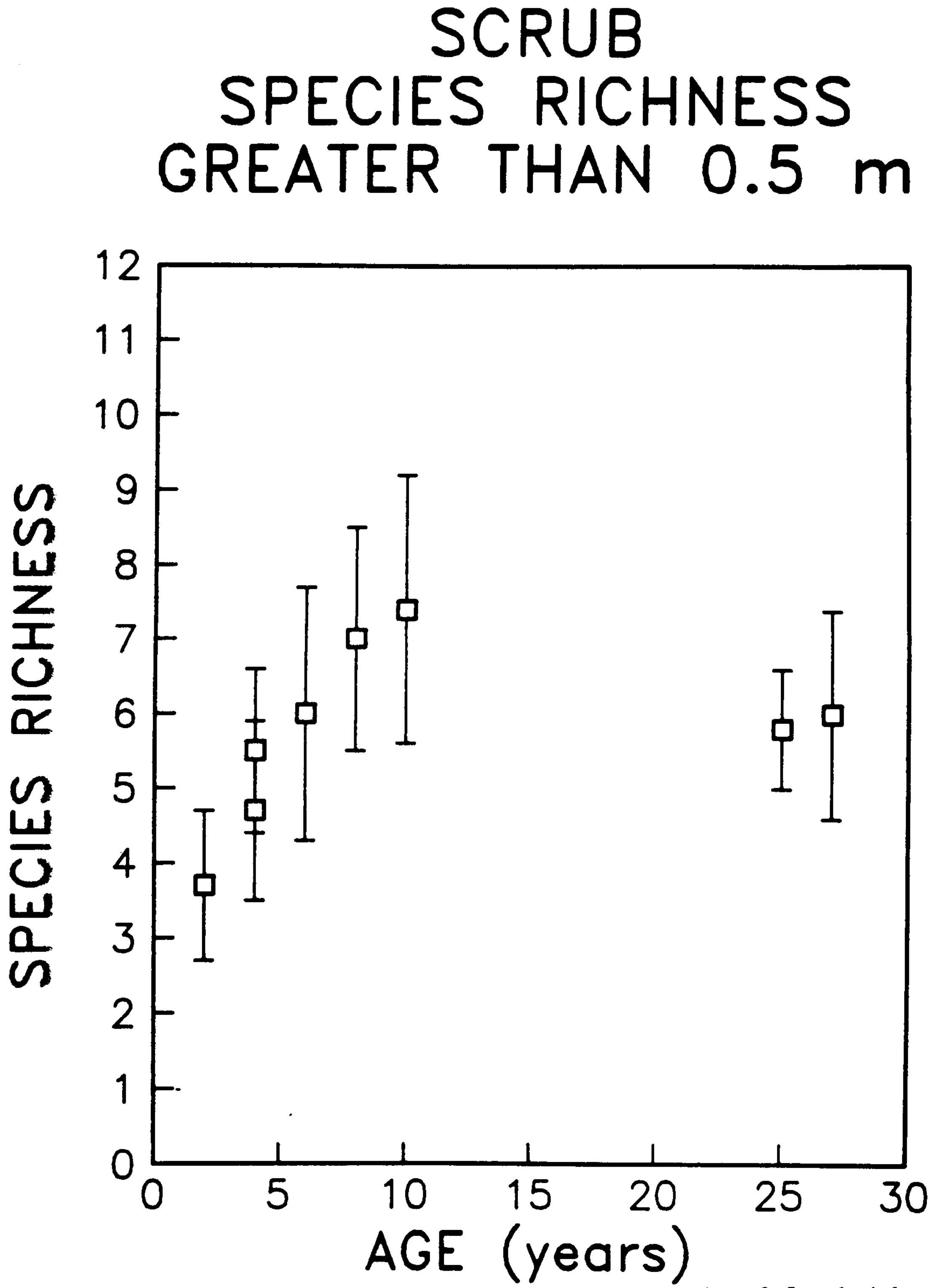


Figure 8. Species richness in the greater than 0.5 m height stratum in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

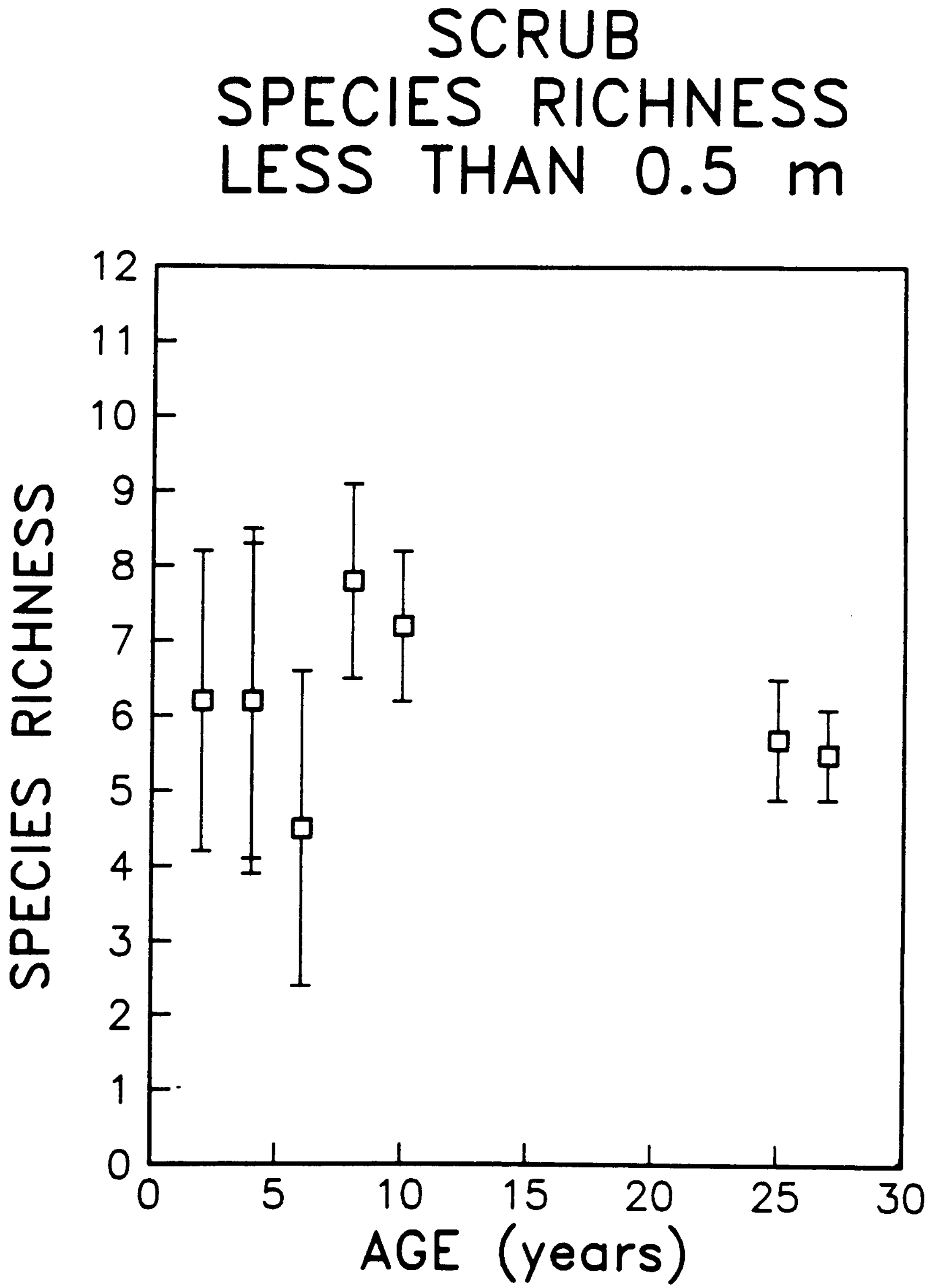


Figure 9. Species richness in the less than 0.5 m height stratum in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

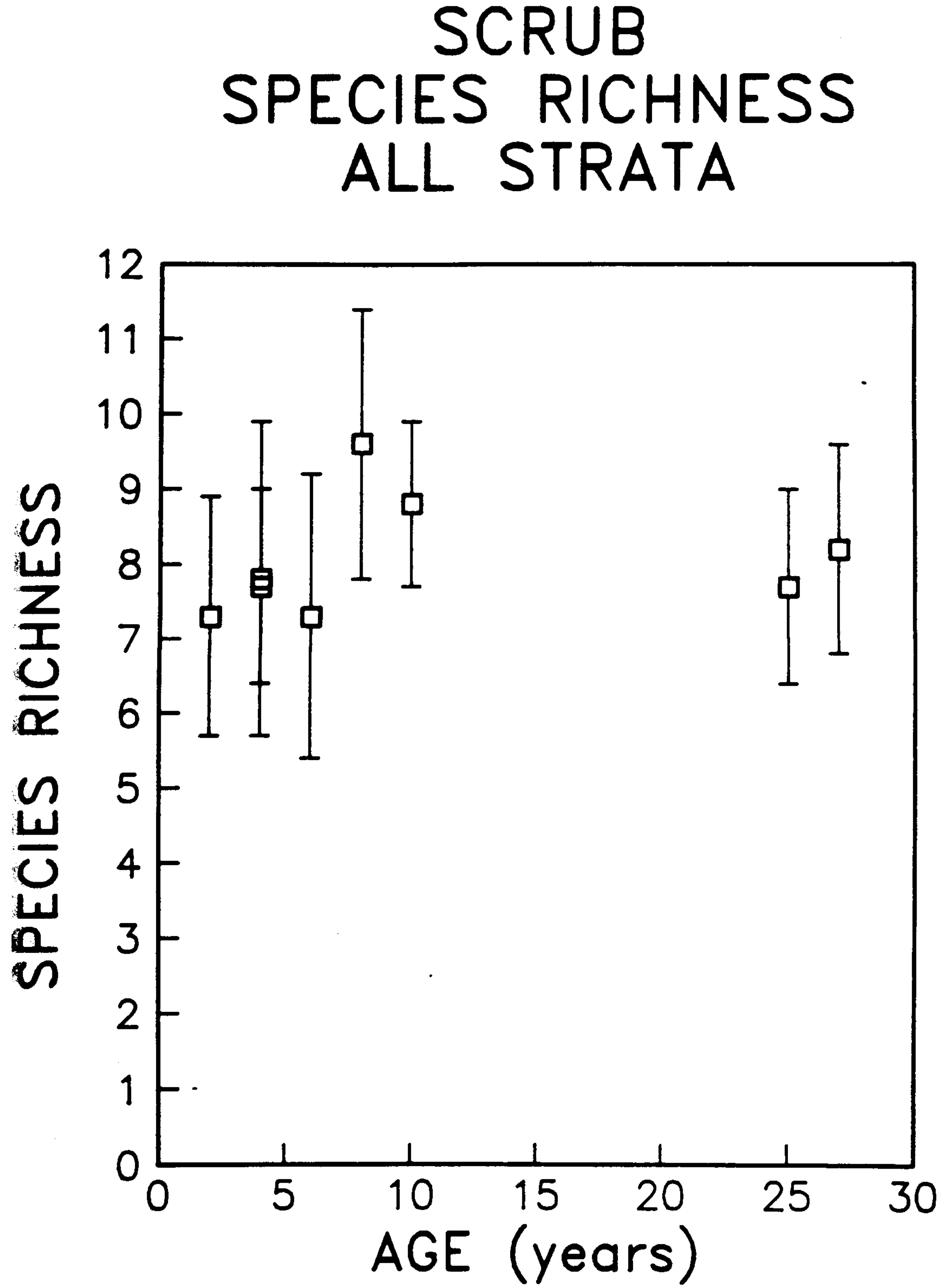


Figure 10. Species richness in both height strata in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

Community beta diversity for the 1983 scrub data was 2.3 half-changes (EV=.444), for 1985 data it was 2.2 half-changes (EV=.425), and for the 1983 and 1985 data combined the beta diversity was 2.2 half-changes (EV=.433). Thus, there was essentially no change in beta diversity with time nor did combining the two data sets produce greater community diversity.

Community Structure

Structural changes in the plant communities occurred with time since fire. Mean total cover in the greater than 0.5 m layer increased rapidly until about 8 years post-fire and then leveled off (Figure 11). In the less than 0.5 m layer, cover decreased from years 2 through 6 and then fluctuated (Figure 12). Scrub mean height (Figure 13) increased rapidly at first and then at a slower rate. Mean maximum height (Figure 14) followed the same pattern.

Multivariate analysis of variance (MANOVA) based on the structural parameters of percent cover for the greater than 0.5 m class, percent cover for the less than 0.5 m class, mean height, and mean maximum height indicated that there were significant overall differences between stands ($p \leq .001$) and between times ($p \leq .001$); the stand-by-time interaction was also significant ($p \leq .01$).

Univariate analysis of variance (ANOVA) for individual structural parameters gave the following results: percent cover for the greater than 0.5 m class was significantly different between stands ($p \leq .001$) and between times ($p \leq .001$); the stand by time interaction was also significant ($p \leq .001$). Percent cover for the less than 0.5 m class was significantly different between stands ($p \leq .001$) and between times ($p \leq .001$); the stand-by-time interaction was not significant. Mean height was significantly different between stands ($p \leq .001$); the time effects and stand-by-time interactions were not significant. Mean maximum height was significantly different between stands ($p \leq .001$) and between times ($p \leq .05$); the stand-by-time interactions were not significant.

Biomass

Biomass changes occurred with time since fire (Table 7). The trunks of saw palmetto are fire resistant and form a refractory part of the oak scrub community. Live biomass (excluding saw palmetto trunks) increased with time since fire, rapidly at first and then at a slower rate (Figure 15). Litter biomass (Figure 16) was highly variable in the most recently burned stand due to the patchy intensity of the fire which removed most litter in some places but not others. Litter increased with age to about year 8 and then leveled off. As with litter, standing dead biomass was highly variable in the recently

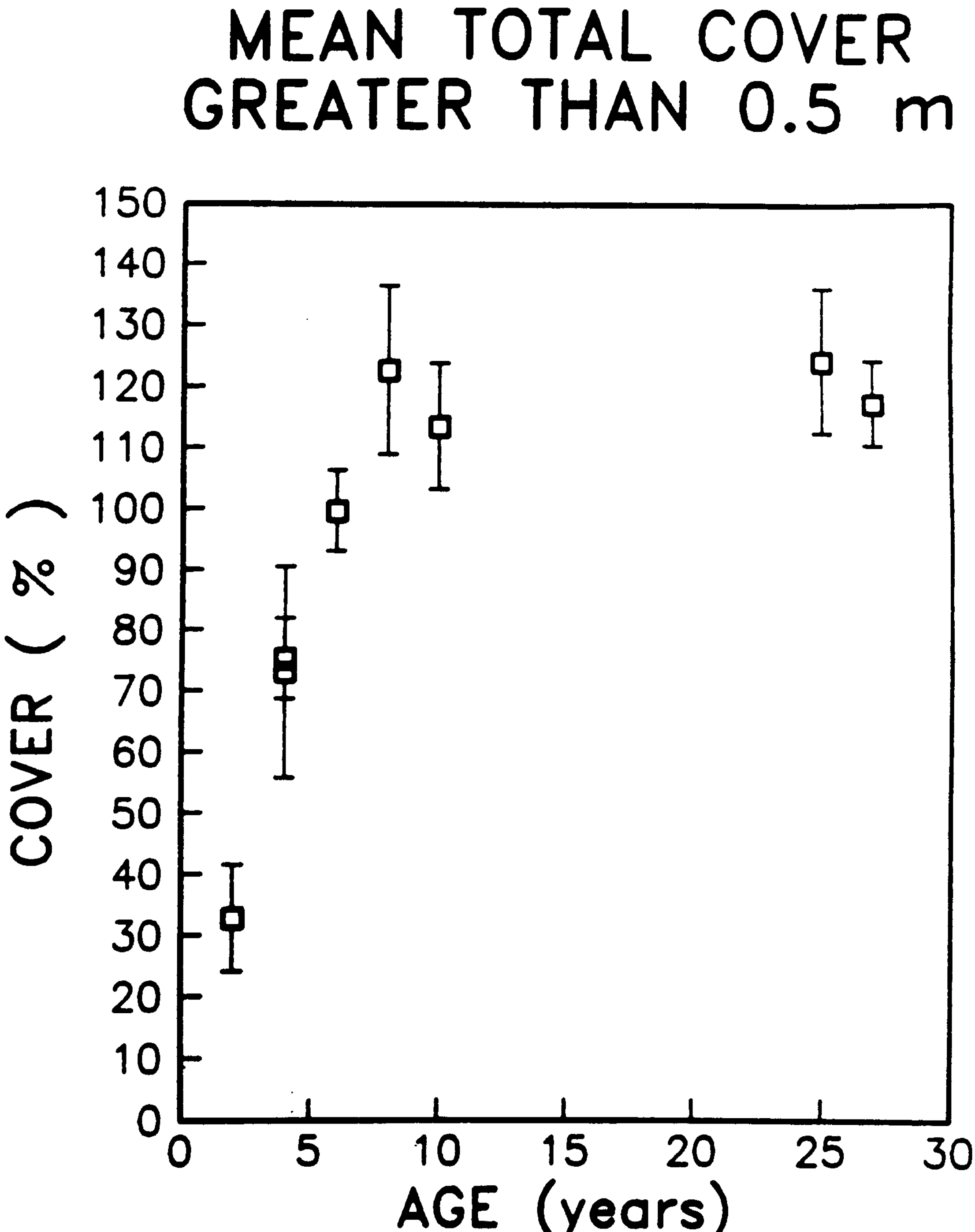


Figure 11. Mean total cover in the greater than 0.5 m height stratum in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

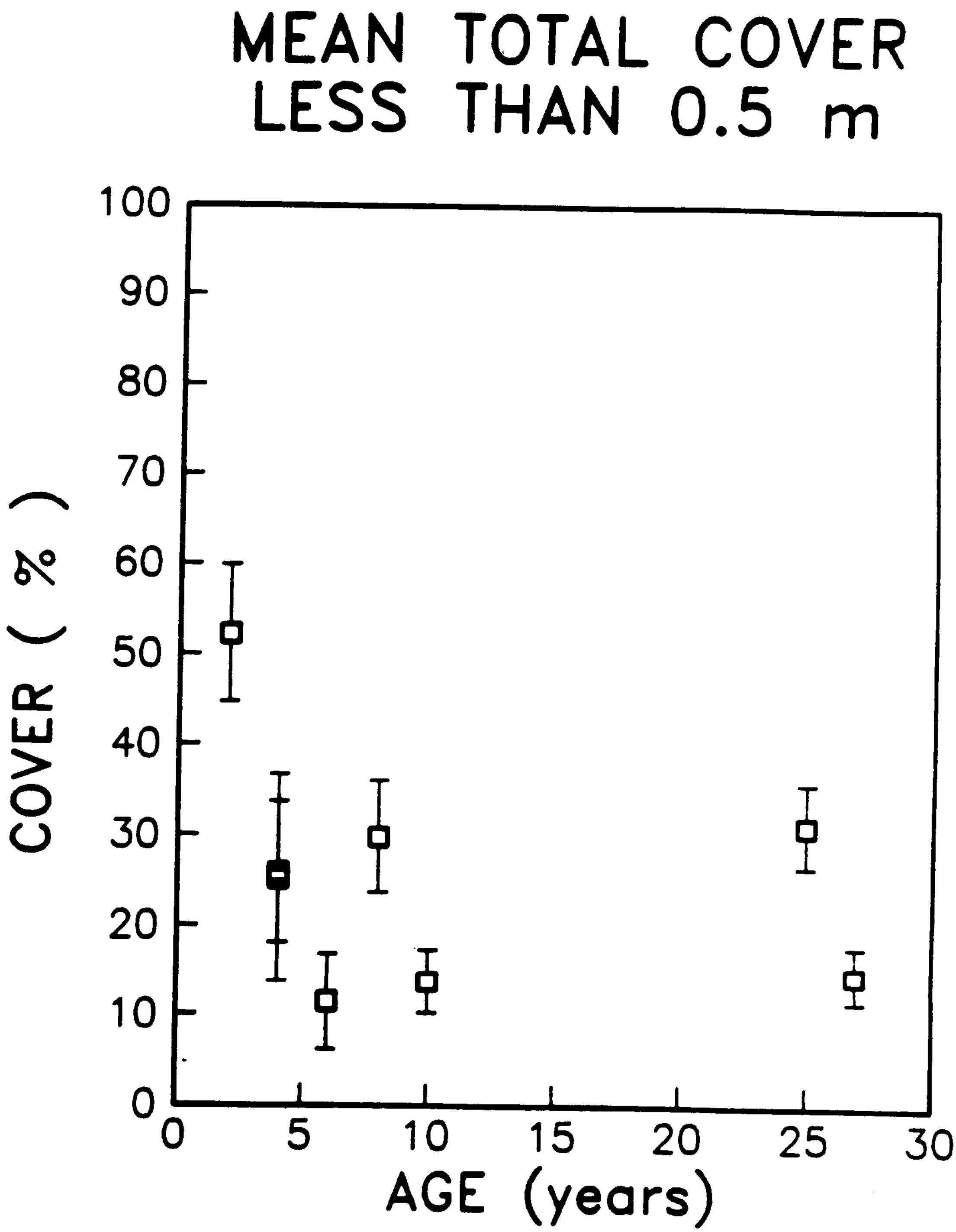


Figure 12. Mean total cover in the less than 0.5 m height stratum in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

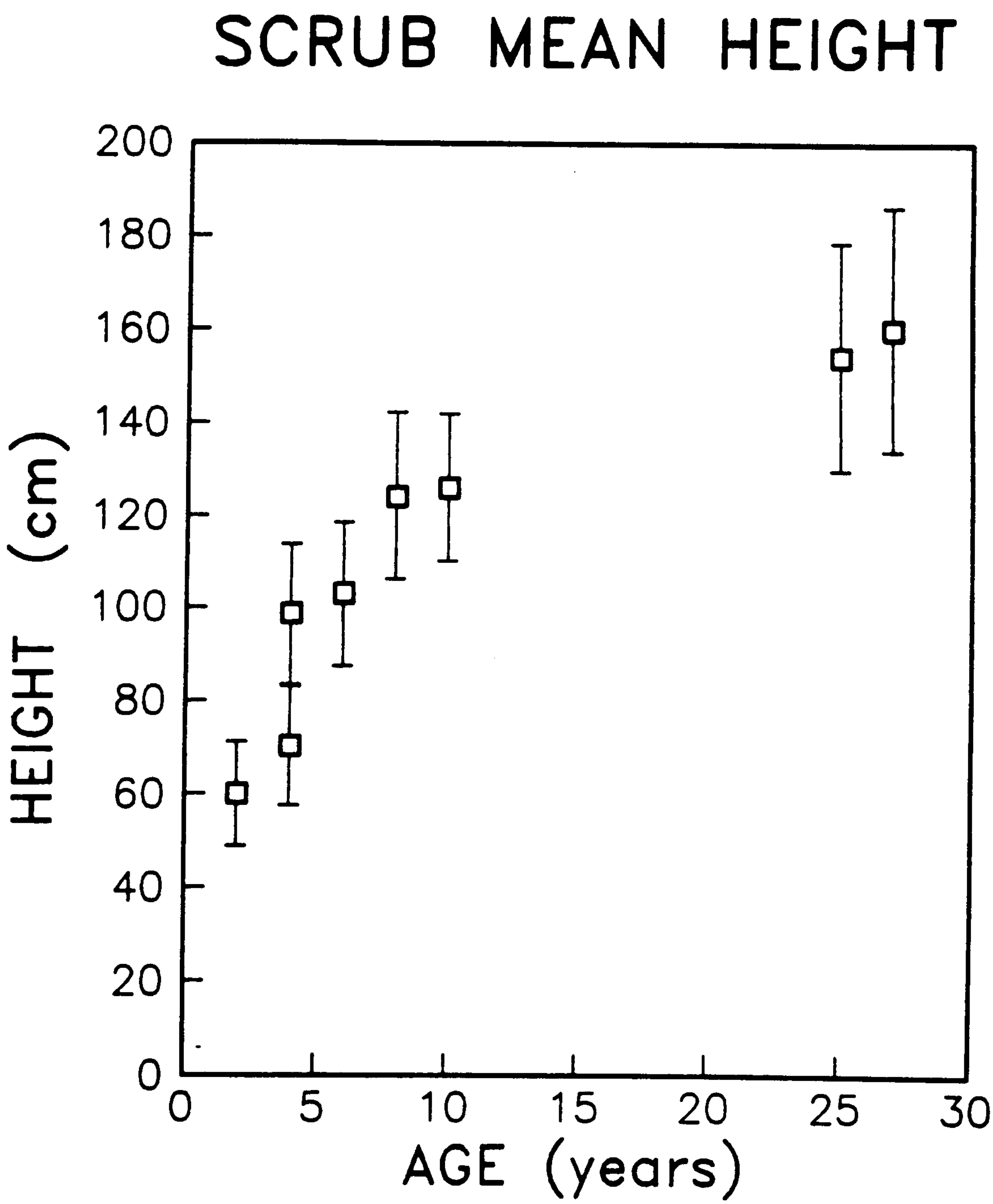


Figure 13. Mean height of vegetation in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

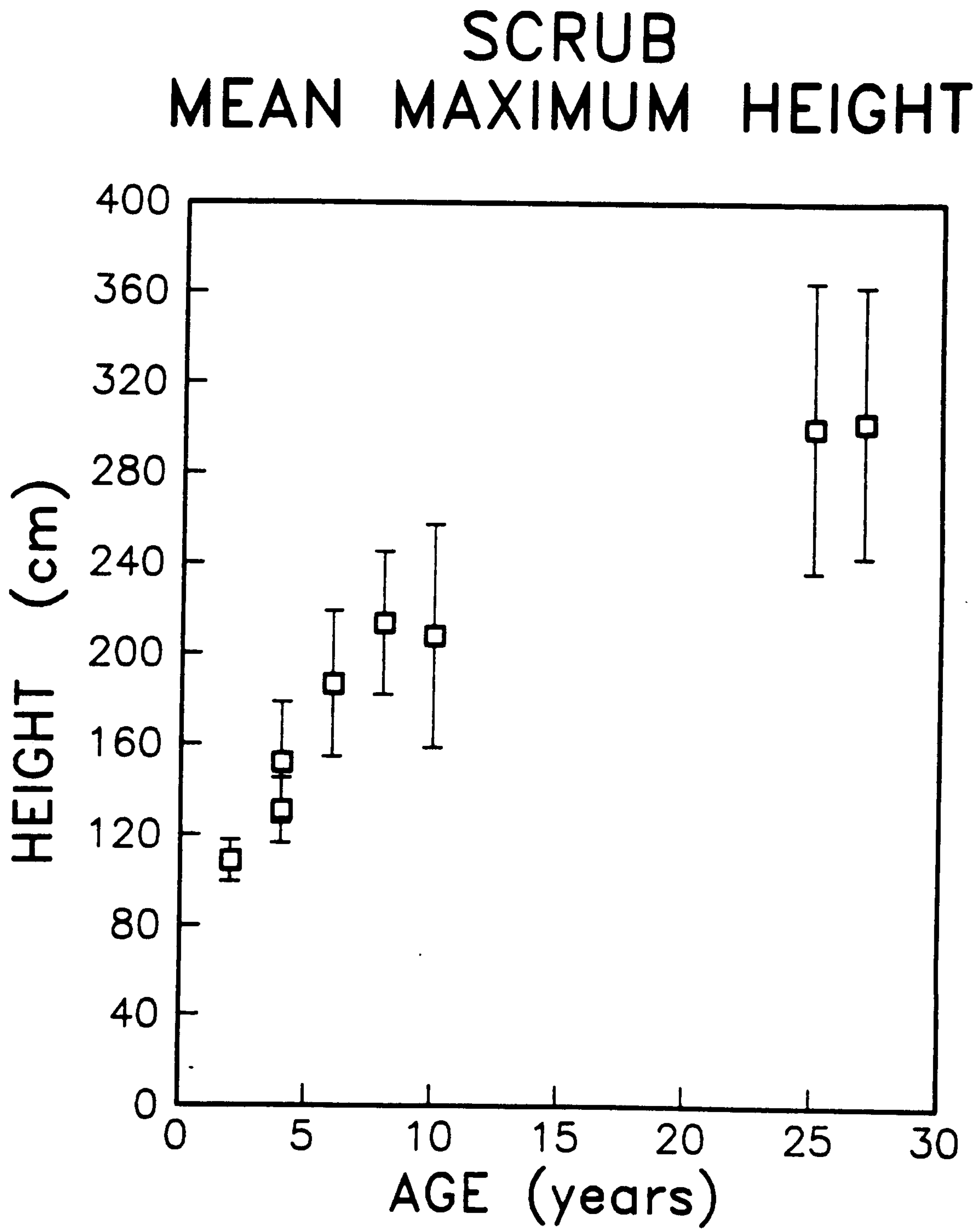


Figure 14. Mean maximum height of vegetation in scrub stands sampled in 1983 and 1985. Bars indicate 95% confidence interval about the mean.

Table 7. Biomass (g/m^2) in the scrub stands in 1983[1].

		Stand 3		Stand 2		Stand 1		Stand 4	
Age		2		4		8		25	
Number of Plots		6		6		7		6	
Taxa		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Aristida stricta		3.3	8.2	6.7	7.4	27.4	53.8	---	---
Befaria racemosa	leaves	18.3	44.9	0.5	1.2	---	---	---	---
	stems	19.7	48.2	0.3	0.8	---	---	---	---
Cyperaceae		0.2	0.4	---	---	---	---	0.7	1.6
Hypericum cistifolium		---	---	0.3	0.8				
H. reductum		---	---	1.7	4.1	---	---	---	---
Ilex glabra	leaves	---	---	3.2	7.8	---	---	---	---
	stems	---	---	3.5	8.6	---	---	---	---
Lyonia spp.[2]	leaves	40.7	77.4	33.0	34.5	51.9	66.6	47.0	75.2
(evergreen)	stems	20.7	41.3	24.3	25.7	52.4	65.6	130.3	197.6
Lyonia ligustrina (deciduous)	stems	---	---	---	---	---	---	60.3	147.8
Myrica cerifera	leaves	---	---	1.0	1.5	1.7	4.5	---	---
	stems	---	---	1.5	2.3	1.7	4.5	---	---
Quercus chapmanii	leaves	21.5	34.2	---	---	45.0	64.7	18.2	26.4
	stems	15.5	29.9	---	---	91.7	166.2	36.3	68.1
Q. myrtifolia	leaves	156.2	127.4	70.8	114.2	148.0	148.0	153.0	39.8
	stems	391.0	720.6	173.7	276.9	364.1	397.6	847.2	409.0
	trunks	---	---	---	---	---	---	567.5	1390.1
Q. virginiana var.	leaves	57.3	76.5	80.8	186.8	57.0	90.9	78.5	70.8
geminata	stems	64.3	106.6	117.2	271.9	143.0	226.0	264.5	247.2
Serenoa repens	leaves	99.3	112.9	393.5	295.2	328.6	370.0	66.3	111.6
	stems	15.7	19.3	96.7	81.0	57.7	64.0	19.3	32.5
	rhizomes	1696.7	3289.8	2939.7	2642.0	3239.6	3921.8	223.2	546.6
Vaccinium myrsinites		2.0	2.5	0.8	1.3	4.7	7.7	3.5	8.1
Ximenia americana	leaves	5.2	12.7	---	---	---	---	---	---
	stems	41.3	101.2	---	---	---	---	---	---
Miscellaneous herbs		---	---	0.8	2.0	26.0	52.6	---	---

Table 7. (continued).

	Stand 3		Stand 2		Stand 1		Stand 4	
Age	2		4		8		25	
Number of Plots	6		6		7		6	
Taxa	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Total-Live-Leaves	404.0	200.0	593.1	196.7	690.3	230.1	367.2	116.3
Total-Live-Stems	568.2	676.9	417.2	253.7	710.6	607.6	1925.4	1306.7
Standing Dead-Saw Palmetto	53.3	49.5	348.8	149.8	575.6	559.1	49.5	95.3
Standing Dead-Woody	809.5	1032.1	219.2	309.5	132.3	162.7	519.7	308.4
Total-Standing Dead	862.8	1028.6	568.0	291.6	707.9	452.9	569.2	334.0
Litter	439.3	669.1	513.0	187.5	1171.1	322.1	1091.3	250.5
Total-Standing Dead and Litter	1302.2	1171.2	1081.0	417.9	1879.0	373.9	1660.5	354.3
Total-Live-Excluding Saw palmetto rhizomes	972.2	766.7	1010.3	292.8	1401.0	675.8	2292.7	1296.2
Standing Dead and Litter/Total Live (%)	48.8		27.4		40.5		66.0	
Standing Dead and Litter/Total Live - Excluding Saw palmetto rhizomes (%)	133.9		107.0		134.1		72.4	

[1]Oven-dry weight.

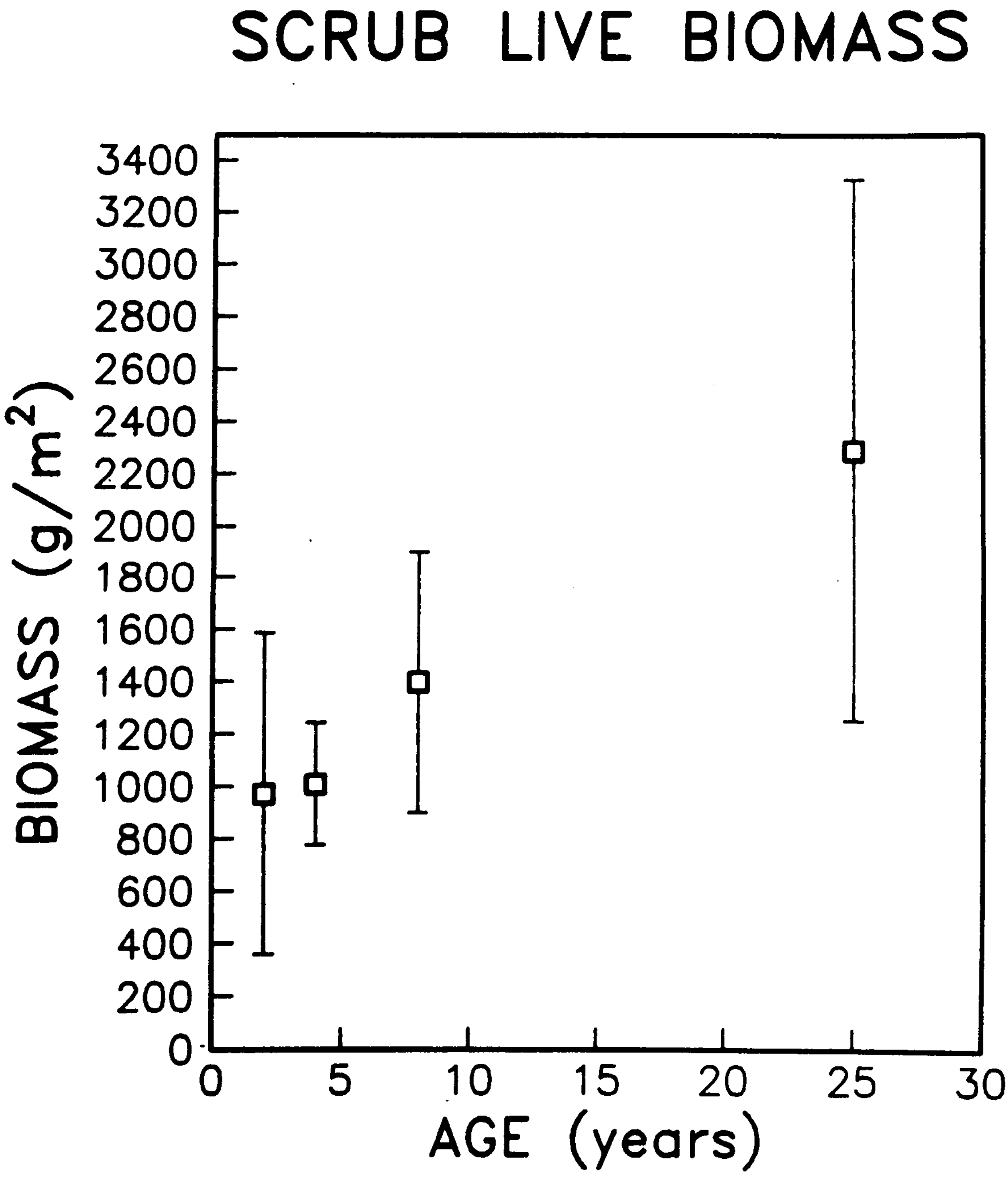


Figure 15. Live biomass (oven-dry weight, excluding palmetto rhizomes) of vegetation in scrub stands sampled in 1983. Bars indicate 95% confidence interval about the mean.

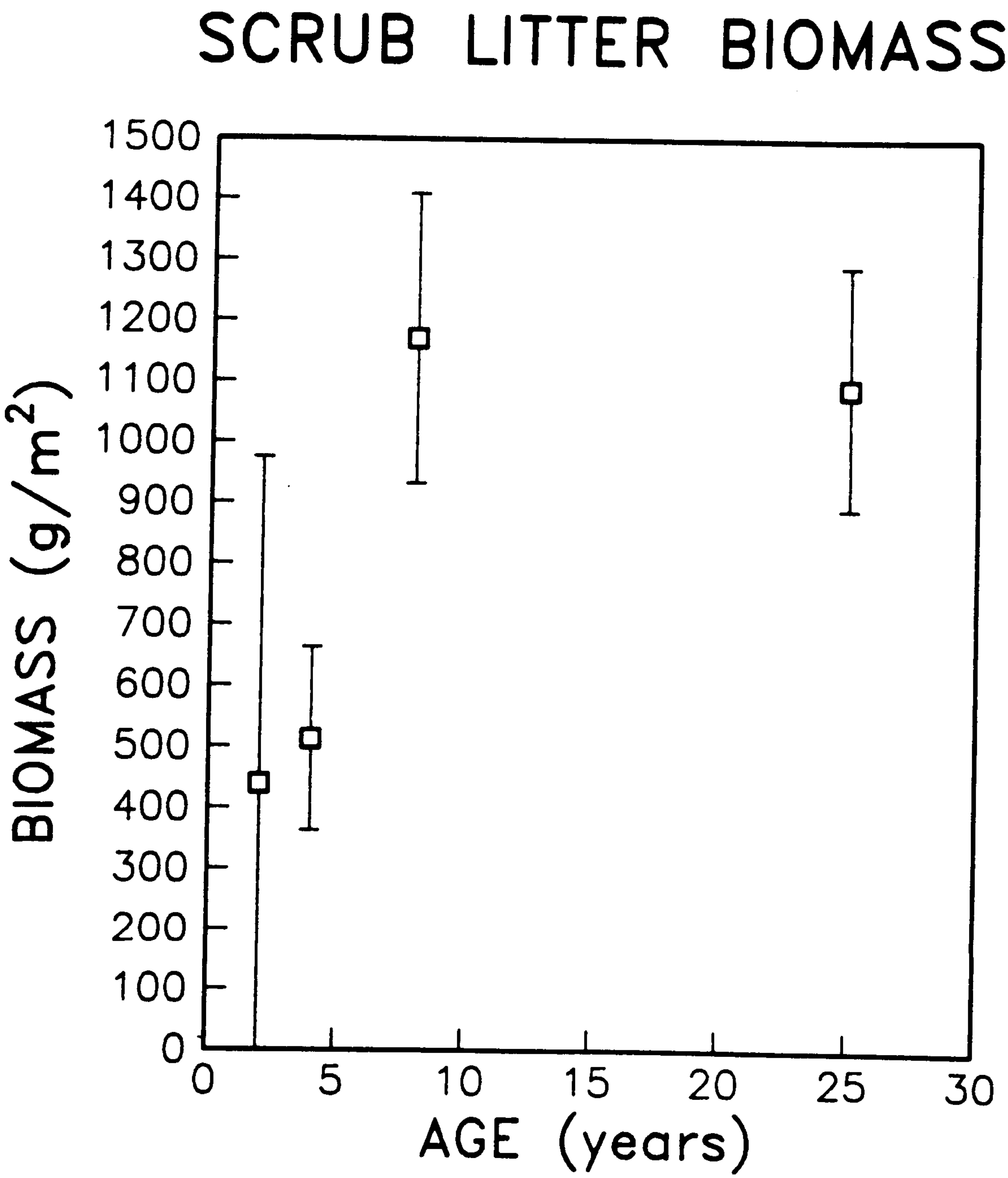


Figure 16. Litter biomass (oven-dry weight) in scrub stands sampled in 1983. Bars indicate 95% confidence interval about the mean.

burned stand (Figure 17). However, it did not show any trend of increase with time. The composition of the standing dead biomass did change with time. In the most recently burned stands, it was comprised of stems of shrubs and saw palmetto which were killed by the fire but were not consumed by it. After some years, these stems decay and fall to the ground. Observations suggest about 5 to 6 years were required for this decay; fire-killed standing dead was still prevalent in the 4 year old stand but not in the 6 or 8 year old one. Replacing the fire-killed stems in the standing dead category for 6 to 8 year old stands were dead stems and branches of shrubs and dead leaves of saw palmetto which had grown since the last fire. Biomass data are summarized in Figure 18.

Biomass Chemistry

Leaf tissue from certain scrub species from Merritt Island was analyzed by Vickers et al. (1975) for potassium, sodium, calcium, magnesium, aluminum, iron, zinc, and copper. Data for elements in common between that and the current study are summarized in Table 8.

Total Kjeldahl nitrogen concentrations in scrub vegetation are given in Table 9. Concentrations of nitrogen in live biomass showed no trend with time since fire. Standing crops of nitrogen are summarized in Table 10. Saw palmetto rhizomes contained considerable quantities of nitrogen. Standing dead and litter were also significant pools (Figure 19). Standing dead was particularly important in the youngest stand. Increases in live biomass with time also increased nitrogen standing crop but this was clear only when saw palmetto rhizomes were not considered. Accumulation occurred primarily in stem biomass in the oldest stand. Leaf standing crops changed little.

Total phosphorus concentrations in scrub vegetation are given in Table 11. Concentrations showed no consistent trends with time for species present in all stands. Standing crops of phosphorus are summarized in Table 12. Saw palmetto rhizomes, litter, and standing dead material contained major pools of phosphorus (Figure 20). Litter concentrations and standing crops were elevated in the 2 year old stand. Phosphorus also accumulated in live biomass with time since fire, primarily in stem tissue.

Calcium concentrations in scrub vegetation are given in Table 13. Time since fire did not have a consistent effect on these concentrations in live biomass. Standing crops of calcium are summarized in Table 14 and Figure 21. Litter concentration and hence standing crop were somewhat higher in the youngest stand. Calcium accumulated in stem biomass in the oldest stand.

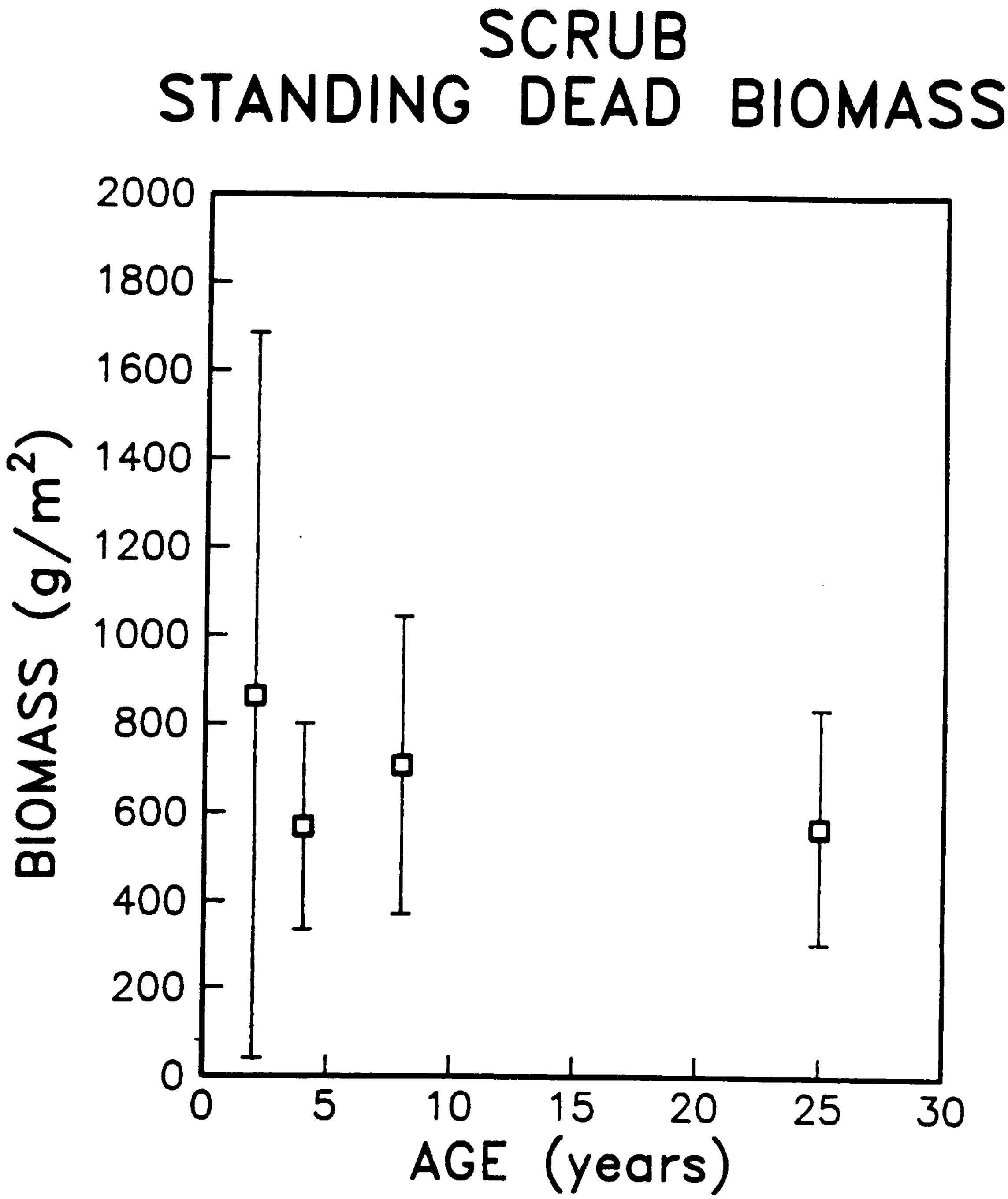


Figure 17. Biomass (oven-dry weight) of standing dead material in scrub stands sampled in 1983. Bars indicate 95% confidence interval about the mean.

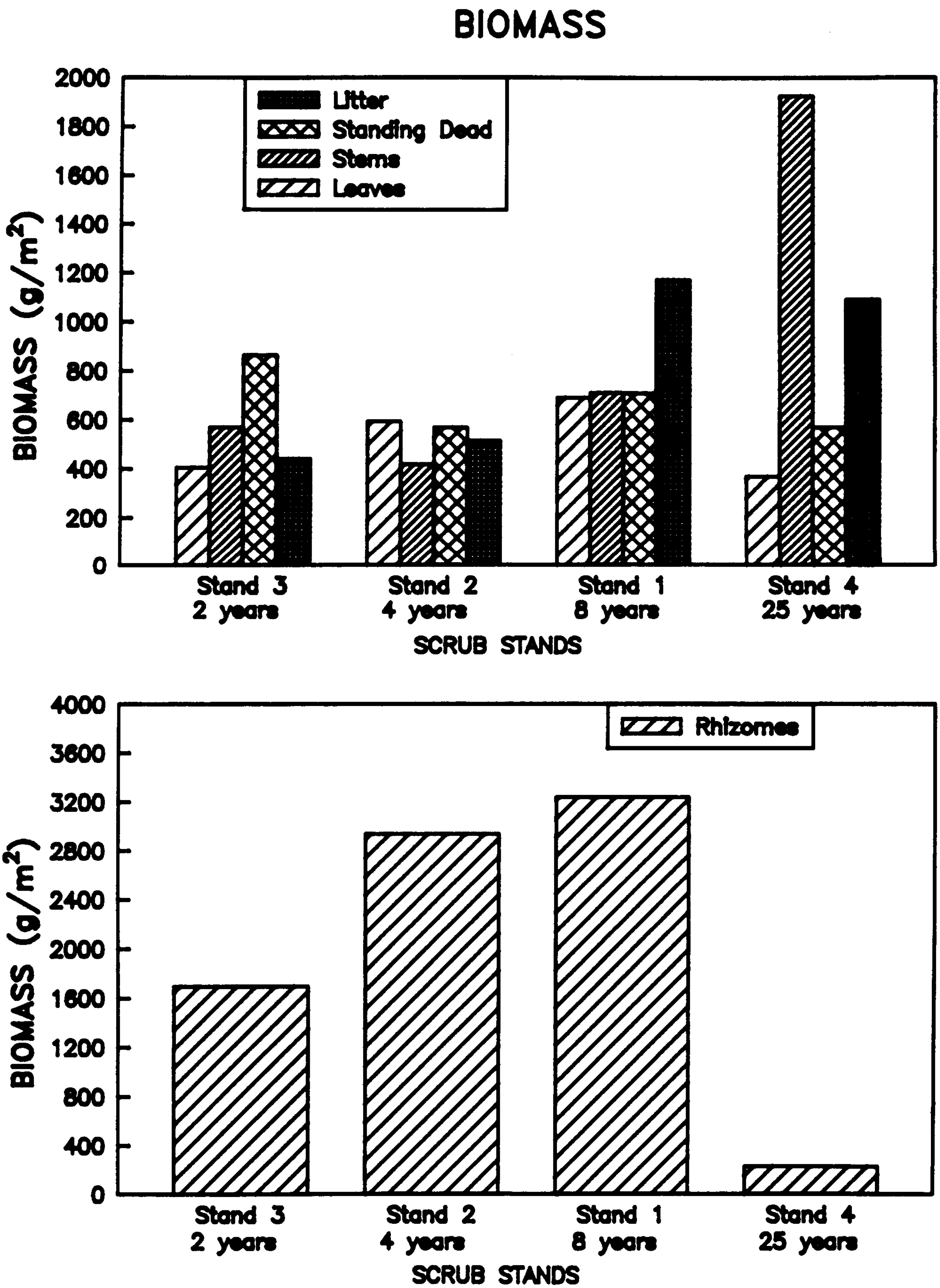


Figure 18. Biomass standing crops in the scrub stands.

Table 8. Elemental concentration (%) of leaf tissue from selected plants species collected on north Merritt Island in 1973 and 1974 (modified from Vickers et al. 1975).

Species	Potassium Aug.[1]	Potassium Apr.	Sodium Aug.	Sodium Apr.	Calcium Aug.	Calcium Apr.	Magnesium Aug.	Magnesium Apr.	Aluminum Aug.	Aluminum Apr.
Serenoa repens	0.510	0.910	0.380	0.240	0.083	0.110	0.150	0.144	0.0005	0.0008
std. dev.	0.120	0.190	0.170	0.084	0.023	0.023	0.041	0.031	0.0001	0.0003
Ilex glabra	0.430	-----	0.240	-----	0.270	-----	0.097	-----	0.0100	------
Lyonia fruticosa	0.560	-----	0.087	-----	0.630	-----	0.150	-----	0.0061	------
std. dev.	0.350	-----	0.033	-----	0.270	-----	0.027	-----	0.0034	------
Myrica cerifera	0.280	-----	0.340	-----	1.000	-----	0.700	-----	0.0087	------
std. dev.	0.061	-----	0.031	-----	0.160	-----	0.120	-----	0.0026	------
Quercus chapmanii	0.810	0.870	0.260	0.042	0.990	0.530	0.380	0.160	0.0047	0.0024
std. dev.	0.230	0.180	0.160	0.008	0.460	0.095	0.210	0.015	0.0018	0.0006
Quercus minima	0.570	-----	0.260	-----	0.800	-----	0.230	-----	0.0120	------
std. dev.	0.240	-----	0.430	-----	0.340	-----	0.130	-----	0.0190	------
Quercus myrtifolia	0.510	0.620	0.090	0.053	0.720	0.430	0.260	0.160	0.0051	0.0035
std. dev.	0.110	0.110	0.040	0.018	0.350	0.079	0.056	0.007	0.0008	0.0014
Quercus pumila	0.520	-----	0.080	-----	1.800	-----	0.240	-----	0.0081	------
std. dev.	0.250	-----	0.027	-----	0.700	-----	0.007	-----	0.0003	------
Quercus virginiana	-----	0.830	-----	0.076	-----	0.220	-----	0.170	------	0.0041
std. dev.	-----	0.045	-----	0.023	-----	0.039	-----	0.010	------	0.0015

[1]Samples from August 1973 and April 1974.

Table 9. Concentration of total Kjeldahl nitrogen (TKN) (%) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	1.4	1.3	1.4	-
Befaria racemosa	leaves	1.2	a	-	-
	stems	1.5	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	1.5	-	-
Ilex glabra	leaves	-	2.1	-	-
	stems	-	2.7	-	-
Lyonia spp.	leaves	5.4	1.8	1.5	2.1
	stems	2.7	2.9	2.0	3.8
Lyonia ligustrina	stems	-	-	-	(2.9)[b]
Myrica cerifera	leaves	-	2.8	3.4	
	stems	-	b	2.7	
Quercus chapmanii	leaves	1.6	-	2.7	2.0
	stems	1.7	-	2.2	2.0
Q. myrtifolia	leaves	2.4	3.0	2.2	3.5
	stems	2.3	1.5	2.0	2.3
	trunks	-	-	-	2.5
Q. virginiana var. geminata	leaves	1.9	1.9	2.1	1.7
	stems	1.5	4.3	1.8	1.8
Serenoa repens	leaves	1.7	2.0	2.2	1.8
	stems	1.7	1.8	2.2	1.1
	rhizomes	(1.4)[c]	(1.4)[c]	1.4	(1.4)[c]
Vaccinium myrsinites	-	2.1	1.9	2.2	(2.1)[c]
Ximenia americana	leaves	3.1	-	-	-
	stems	2.1	-	-	-
Misc. Herbs	-	-	a	2.0	-
Standing Dead-Saw Palmetto	-	1.8	2.4	2.0	3.5
Standing Dead-Woody	-	6.1	2.4	3.8	1.1
Litter	-	2.8	1.6	2.6	1.4

[a]insufficient sample for analysis
[b]estimated from other data
[c]estimated from other data

Table 10. Standing crop of total Kjeldahl nitrogen (TKN) (g/m^2) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.0462	0.0871	0.3836	-
Befaria racemosa	leaves	0.2196	(0.0060)[c]	-	-
	stems	0.2955	(0.0045)[c]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.0300	-	-
Ilex glabra	leaves	-	0.0672	-	-
	stems	-	0.0945	-	-
Lyonia spp.	leaves	2.1978	0.5940	0.7785	0.9870
	stems	0.5589	0.7047	1.0480	4.9514
Lyonia ligustrina	stems	-	-	-	(1.7186)[c]
Myrica cerifera	leaves	-	0.0280	0.0578	-
	stems	-	(0.0405)[b,c]	0.0459	-
Quercus chapmanii	leaves	0.3440	-	1.2150	0.3640
	stems	0.2635	-	2.0174	0.7260
Q. myrtifolia	leaves	3.7488	2.1240	3.2560	5.3550
	stems	8.9930	2.6055	7.2820	19.4856
	trunks	-	-	-	14.1875
Q. virginiana var. geminata	leaves	1.0887	1.5352	1.1970	1.3345
	stems	0.9645	5.0396	2.5740	4.7610
Serenoa repens	leaves	1.6881	7.8700	7.2292	1.1934
	stems	0.2669	1.7406	1.2694	0.2123
	rhizomes	(23.7538)[c]	(41.1558)[c]	45.3544	(3.1248)[c]
Vaccinium myrsinites	-	0.0420	0.0152	0.1034	(0.0735)[c]
Ximenia americana	leaves	0.1612	-	-	-
	stems	0.8673	-	-	-
Misc. Herbs	-	-	(0.0160)[c]	0.5200	-
Standing Dead-Saw Palmetto	-	0.9594	8.3712	11.5120	1.7325
Standing Dead-Woody	-	49.3795	5.2608	5.0274	5.7167
Litter	-	12.3004	8.2080	30.4486	15.2782
Total-live-leaves		9.5364	12.3727	14.7405	9.3074
Total-live-stems		12.2096	10.2299	14.2367	46.0424
Total live excluding saw palmetto rhizomes		21.7460	22.6026	28.9772	55.3498
Total live		45.4998	63.7584	74.3316	58.4746
Total standing dead		50.3389	13.6320	16.5394	7.4492
Total standing dead and litter		62.6393	21.8400	46.9880	22.7274
Total above ground		108.1391	85.5984	121.3196	81.2020
Total above ground exluding saw palmetto rhizomes		84.3853	44.4426	75.9652	78.1072

[a]insufficient sample for analysis
[b]estimated from other data
[c]estimated from other data

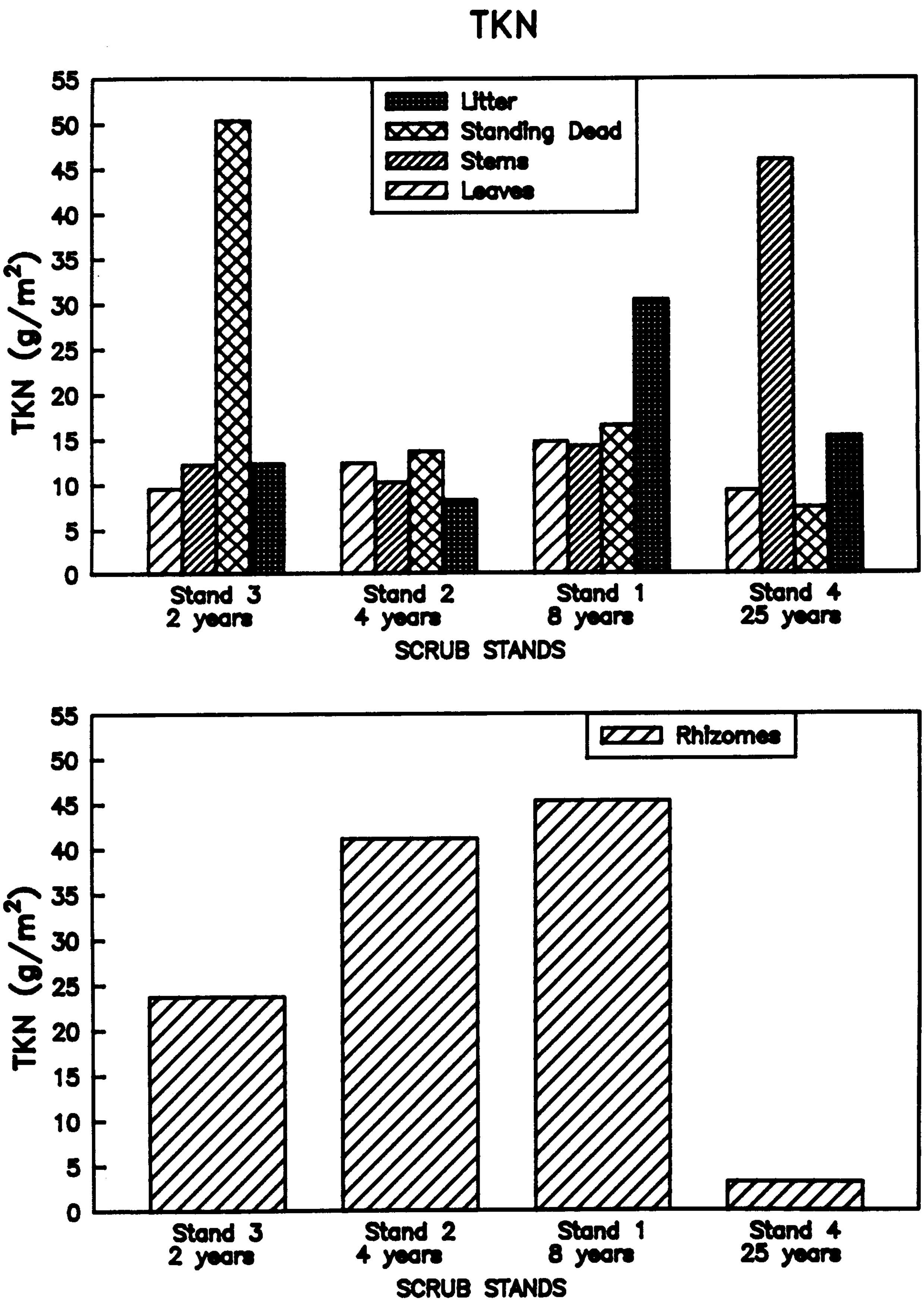


Figure 12. Total Kjeldahl nitrogen (TKN) standing crops in the scrub stands.

Table 11. Concentration of total phosphorus (P) (%) in scrub vegetation.

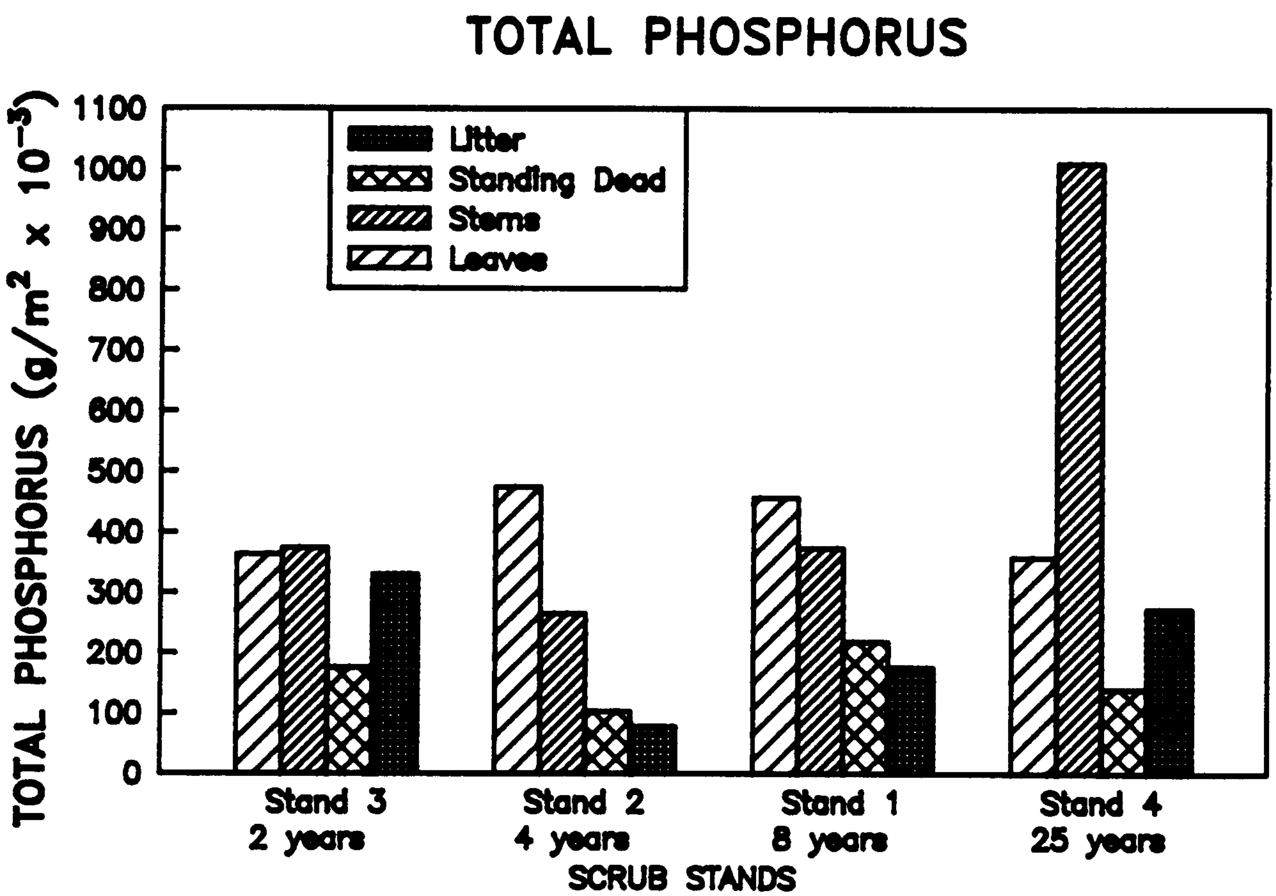
TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.065	0.025	0.030	-
Befaria racemosa	leaves	0.155	a	-	-
	stems	0.040	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.065	-	-
Ilex glabra	leaves	-	0.050	-	-
	stems	-	0.065	-	-
Lyonia spp.	leaves	0.070	0.070	0.035	0.075
	stems	0.035	0.030	0.025	0.045
Lyonia ligustrina	stems	-	-	-	(0.038)[b]
Myrica cerifera	leaves	-	0.040	0.030	-
	stems	-	0.030	0.010	-
Quercus chapmanii	leaves	0.150	-	0.095	0.195
	stems	0.100	-	0.060	0.065
Q. myrtifolia	leaves	0.080	0.080	0.058	0.115
	stems	0.060	0.060	0.050	0.060
	trunks	-	-	-	0.040
Q. virginiana var. geminata	leaves	0.095	0.095	0.075	0.085
	stems	0.080	0.070	0.055	0.060
Serenoa repens	leaves	0.070	0.079	0.075	0.065
	stems	0.068	0.070	0.078	0.072
	rhizomes	(0.080)[b]	(0.080)[b]	0.080	(0.080)[b]
Vaccinium myrsinites	-	0.070	0.060	0.045	(0.058)[b]
Ximenia americana	leaves	0.410	-	-	-
	stems	0.110	-	-	-
Misc. Herbs	-	-	a	0.040	-
Standing Dead Saw Palmetto	-	0.025	0.020	0.015	0.020
Standing Dead Woody	-	0.020	0.015	0.100	0.025
Litter	-	0.075	0.015	0.015	0.025

[a]insufficient sample for analysis
[b]estimated from other data

Table 12. Standing crop of total phosphorus (P) ($g/m^2 \times 10^{-3}$) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	2.15	1.68	8.22	-
Befaria racemosa	leaves	28.37	(0.78)[b]	-	-
	stems	7.88	(0.12)[b]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	1.30	-	-
Ilex glabra	leaves	-	1.60	-	-
	stems	-	2.28	-	-
Lyonia spp.	leaves	28.49	23.10	18.17	35.25
	stems	7.25	7.29	13.10	58.64
Lyonia ligustrina	stems	-	-	-	(20.50)[b]
Myrica cerifera	leaves	-	0.40	0.51	-
	stems	-	0.45	0.17	-
Quercus chapmanii	leaves	32.25	-	42.75	35.49
	stems	15.50	-	55.02	23.60
Q. myrtifolia	leaves	124.96	56.64	85.84	175.95
	stems	234.60	104.22	182.05	508.32
	trunks	-	-	-	227.00
Q. virginiana var.	leaves	54.44	76.76	42.75	66.73
geminata	stems	51.44	82.04	78.65	158.70
Serenoa repens	leaves	69.51	310.87	246.45	43.10
	stems	10.68	67.69	45.01	13.90
	rhizomes	(1357.36)[b]	(2351.76)[b]	2591.68	(178.56)[b]
Vaccinium myrsinites	-	1.40	0.48	2.12	(2.03)[b]
Ximenia americana	leaves	21.32	-	-	-
	stems	45.43	-	-	-
Misc. Herbs	-	-	(0.32)[b]	10.40	-
Standing Dead-Saw Palmetto	-	13.33	69.76	86.34	9.90
Standing Dead-Woody	-	161.90	32.88	132.30	129.93
Litter	-	329.48	76.95	175.67	272.83
Total-live-leaves		362.89	473.93	457.21	358.55
Total-live-stems		372.78	264.09	374.00	1010.66
Total live excluding saw palmetto rhizomes		735.67	738.02	832.21	1369.21
Total live		2093.03	3089.78	3422.89	1547.77
Total standing dead		175.23	102.64	218.64	139.83
Total standing dead and litter		504.71	179.59	394.31	412.66
Total above ground		2597.74	3269.37	3817.20	1960.43
Total above ground exluding saw palmetto rhizomes		1240.38	917.61	1225.52	1781.87

[a]insufficient sample for analysis
[b]estimated from other data



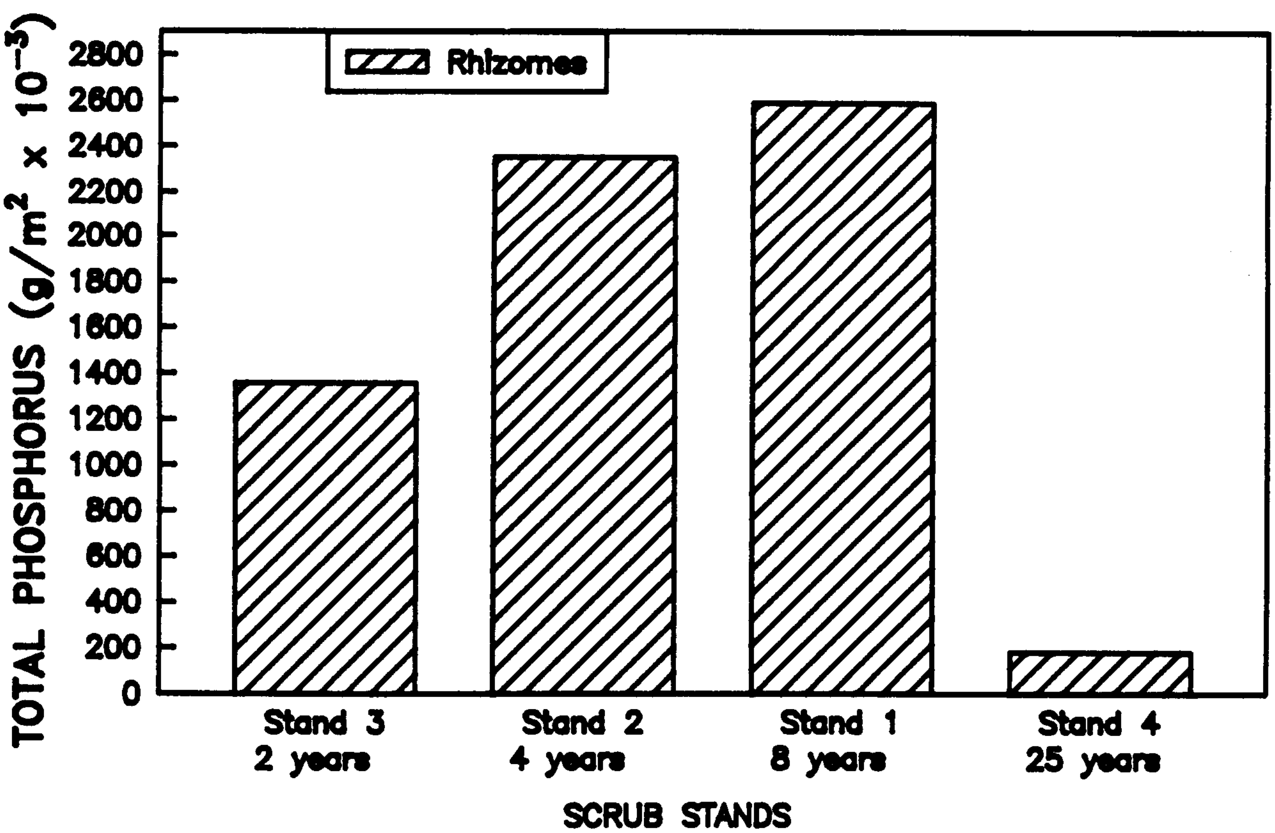


Figure 20. Total phosphorus standing crops in the scrub stands.

Table 13. Concentration of calcium (Ca) (%) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.122	0.083	0.070	-
Befaria racemosa	leaves	0.426	a	-	-
	stems	0.208	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.742	-	-
Ilex glabra	leaves	-	0.785	-	-
	stems	-	0.677	-	-
Lyonia spp.	leaves	1.046	0.995	0.584	0.548
	stems	0.489	0.518	0.340	0.464
Lyonia ligustrina	stems	-	-	-	(0.453)[b]
Myrica cerifera	leaves	-	1.058	0.559	-
	stems	-	0.846	0.512	-
Quercus chapmanii	leaves	0.481	-	0.835	0.658
	stems	0.608	-	0.850	1.243
Q. myrtifolia	leaves	0.587	0.669	0.650	0.604
	stems	0.771	0.708	0.700	0.837
	trunks	-	-	-	0.877
Q. virginiana var. geminata	leaves	0.503	0.525	0.603	0.547
	stems	0.887	0.536	0.844	0.926
Serenoa repens	leaves	0.090	0.172	0.237	0.116
	stems	0.222	0.200	0.230	0.220
	rhizomes	(0.194)[b]	(0.194)[b]	0.194	(0.194)[b]
Vaccinium myrsinites	-	0.485	0.660	0.739	(0.628)[b]
Ximenia americana	leaves	1.381	-	-	-
	stems	0.584	-	-	-
Misc. Herbs	-	-	a	0.591	-
Standing Dead Saw Palmetto	-	0.083	0.146	0.120	0.104
Standing Dead Woody	-	0.633	0.694	0.646	0.629
Litter	-	0.871	0.280	0.400	0.763

[a]insufficient sample for analysis
[b]estimated from other data

Table 14. Standing crop of calcium (Ca) ($g/m^2 \times 10^{-2}$) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.40	0.56	1.92	-
Befaria racemosa	leaves	7.80	(0.21)[b]	-	-
	stems	4.10	(0.06)[b]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	1.48	-	-
Ilex glabra	leaves	-	2.51	-	-
	stems	-	2.37	-	-
Lyonia spp.	leaves	42.57	32.83	30.31	25.76
	stems	10.12	12.59	17.82	60.46
Lyonia ligustrina	stems	-	-	-	(27.32)[b]
Myrica cerifera	leaves	-	1.06	0.95	-
	stems	-	1.27	0.87	-
Quercus chapmanii	leaves	10.34	-	37.58	11.98
	stems	9.42	-	77.95	45.12
Q. myrtifolia	leaves	91.69	47.37	96.20	92.41
	stems	301.46	122.98	254.87	709.11
	trunks	-	-	-	497.70
Q. virginiana var. geminata	leaves	28.82	42.42	34.37	42.94
	stems	57.03	62.82	120.69	244.93
Serenoa repens	leaves	8.94	67.68	77.88	7.69
	stems	3.49	19.34	13.27	4.25
	rhizomes	(3291.60)[b]	(5703.02)[b]	6284.82	(433.01)[b]
Vaccinium myrsinites	-	0.97	0.53	3.47	(2.20)[b]
Ximenia americana	leaves	7.18	-	-	-
	stems	24.12	-	-	-
Misc. Herbs	-	-	(0.47)[b]	15.37	-
Standing Dead-Saw Palmetto	-	4.42	50.92	69.07	5.15
Standing Dead-Woody	-	512.41	152.12	85.47	326.89
Litter	-	382.63	143.64	468.44	832.66
Total-live-leaves		198.71	197.12	298.05	182.98
Total-live-stems		409.74	221.43	485.47	1588.89
Total live excluding saw palmetto rhizomes		608.45	418.55	783.52	1771.87
Total live		3900.05	6121.57	7068.34	2204.88
Total standing dead		516.83	203.04	154.54	332.04
Total standing dead and litter		899.46	346.68	622.98	1164.70
Total above ground		4799.51	6468.25	7691.32	3369.58
Total above ground exluding saw palmetto rhizomes		1507.91	765.23	1406.50	2936.57

[a]insufficient sample for analysis
[b]estimated from other data

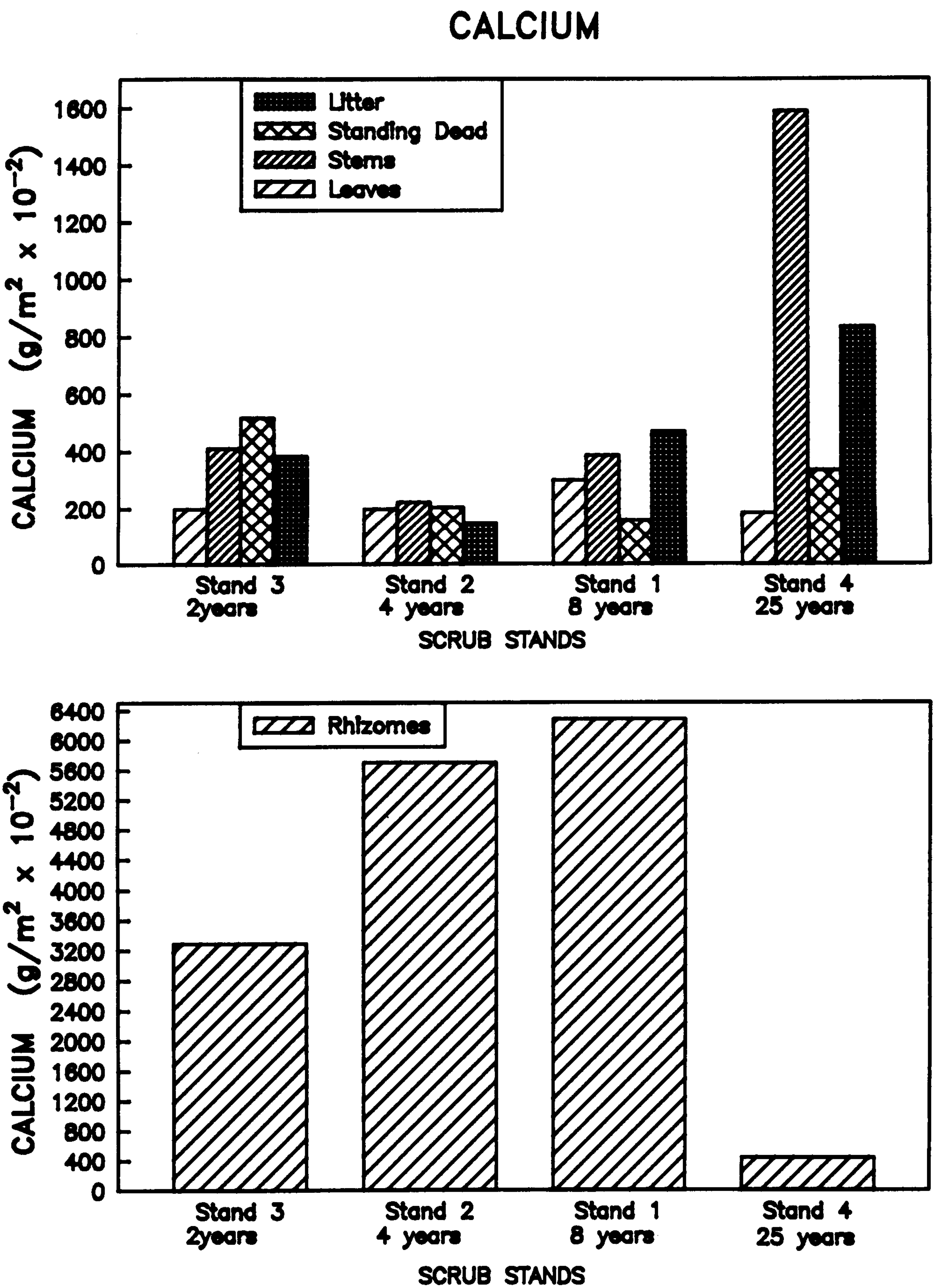


Figure 21. Calcium (Ca) standing crops in the scrub stands.

Magnesium concentrations in scrub vegetation are given in Table 15. No trends with time since fire in magnesium concentrations in live biomass were apparent. Magnesium standing crops are summarized in Table 16. Saw palmetto rhizomes, litter, and standing dead material were substantial pools of magnesium in this system (Figure 22). Stem biomass in the oldest stand contained substantial magnesium.

Sodium concentrations in scrub vegetation are given in Table 17. Concentrations in live biomass, litter, and standing dead showed no trend with time since fire. Standing crops of sodium are summarized in Table 18. Saw palmetto rhizomes represented a significant pool (Figure 23). Stem biomass accumulated some sodium with time.

Potassium concentrations in scrub vegetation are given in Table 19. No trends with time since fire in concentrations in live biomass were apparent. Litter and standing dead concentrations were elevated in the 2 year old stand. Standing crops of potassium are summarized in Table 20. Saw palmetto rhizomes, litter, and standing dead material represented significant pools (Figure 24). The standing dead pool was elevated in the 2 year old stand.

Aluminum concentrations in scrub vegetation are given in Table 21. Aluminum concentrations showed no trend with time since fire. Standing crops of aluminum are summarized in Table 22. Saw palmetto rhizomes and litter were major pools; standing dead material contained relatively smaller amounts. Live biomass (excluding palmetto rhizomes) generally increased in importance as a pool with time since fire (Figure 25).

Soil Chemistry

Chemical characteristics of scrub soils in the four stands are summarized in Table 23. Data for all parameters are within the range of values reported for inland scrub soils on Merritt Island (Pomello series) by Madsen (1980) (Table 24).

Multivariate analysis of variance (MANOVA) indicated significant differences (Wilks' lambda, $p=.005$) between the four stands based on the set of soil parameters for the 0 to 15 cm layer. Significant differences (Wilks' lambda, $p\leq.001$) also existed between the four stands for the 15 to 30 cm layer.

One-way analysis of variance (ANOVA) of the 0 to 15 cm layer of the four stands indicated that all soil parameters except nitrate-nitrogen, aluminum and manganese differed between the four stands (Table 25). For the 15 to 30 cm layer, all soil parameters except cation exchange capacity, and aluminum, copper, iron, manganese, and zinc concentrations differed between the four stands (Table 26). Multiple range tests (Tables 25, 26)

Table 15. Concentration of magnesium (Mg) (%) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.056	0.059	0.063	-
Befaria racemosa	leaves	0.150	a	-	-
	stems	0.077	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.258	-	-
Ilex glabra	leaves	-	0.332	-	-
	stems	-	0.154	-	-
Lyonia spp.	leaves	0.263	0.219	0.189	0.218
	stems	0.136	0.110	0.107	0.094
Lyonia ligustrina	stems	-	-	-	(0.112)[b]
Myrica cerifera	leaves	-	0.332	0.259	-
	stems	-	0.206	0.114	-
Quercus chapmanii	leaves	0.164	-	0.188	0.191
	stems	0.149	-	0.133	0.162
Q. myrtifolia	leaves	0.170	0.140	0.156	0.178
	stems	0.142	0.122	0.138	0.145
	trunks	-	-	-	0.059
Q. virginiana var. geminata	leaves	0.155	0.149	0.165	0.158
	stems	0.152	0.124	0.139	0.117
Serenoa repens	leaves	0.123	0.180	0.304	0.148
	stems	0.124	0.111	0.140	0.070
	rhizomes	(0.126)[b]	(0.126)[b]	0.126	(0.126)[b]
Vaccinium myrsinites	-	0.172	0.148	0.165	(0.162)[b]
Ximenia americana	leaves	0.224	-	-	-
	stems	0.080	-	-	-
Misc. Herbs	-	-	a	0.122	-
Standing Dead Saw Palmetto	-	0.113	0.111	0.131	0.093
Standing Dead Woody	-	0.102	0.078	0.105	0.110
Litter	-	0.149	0.090	0.106	0.099

[a]insufficient sample for analysis
[b]estimated from other data

Table 16. Standing crop of magnesium (Mg) ($g/m^2 \times 10^{-3}$) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	1.85	3.95	17.26	-
Befaria racemosa	leaves	27.45	(0.75)[b]	-	-
	stems	15.17	(0.23)[b]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	5.16	-	-
Ilex glabra	leaves	-	10.62	-	-
	stems	-	5.39	-	-
Lyonia spp.	leaves	107.04	72.27	98.09	102.46
	stems	28.15	26.73	56.07	122.48
Lyonia ligustrina	stems	-	-	-	(67.54)[b]
Myrica cerifera	leaves	-	3.32	4.40	-
	stems	-	3.09	1.94	-
Quercus chapmanii	leaves	35.26	-	84.60	34.76
	stems	23.10	-	121.96	58.81
Q. myrtifolia	leaves	265.54	99.12	230.88	272.34
	stems	555.22	211.91	502.46	1228.44
	trunks	-	-	-	334.83
Q. virginiana var. geminata	leaves	88.82	120.39	94.05	124.03
	stems	97.74	145.33	198.77	309.47
Serenoa repens	leaves	122.14	708.30	998.94	98.12
	stems	19.47	107.34	80.78	13.15
	rhizomes	(2137.84)[b]	(3704.02)[b]	4081.90	(281.23)[b]
Vaccinium myrsinites	-	3.44	1.18	7.76	(5.67)[b]
Ximenia americana	leaves	11.65	-	-	-
	stems	33.04	-	-	-
Misc. Herbs	-	-	(0.98)[b]	31.72	-
Standing Dead-Saw Palmetto	-	60.23	387.17	754.04	46.04
Standing Dead-Woody	-	825.69	170.98	138.92	571.67
Litter	-	654.56	461.70	1241.37	1080.39
Total-live-leaves		663.19	1026.04	1567.70	637.38
Total-live-stems		771.89	500.02	961.98	2135.08
Total live excluding saw palmetto rhizomes		1435.08	1526.06	2529.68	2772.46
Total live		3572.92	5230.28	6611.58	3053.69
Total standing dead		885.92	558.15	892.96	617.71
Total standing dead and litter		1540.48	1019.85	2134.33	1698.10
Total above ground		5113.40	6250.13	8745.91	4751.79
Total above ground exluding saw palmetto rhizomes		2975.56	2545.91	4664.01	4470.56

[a]insufficient sample for analysis
[b]estimated from other data

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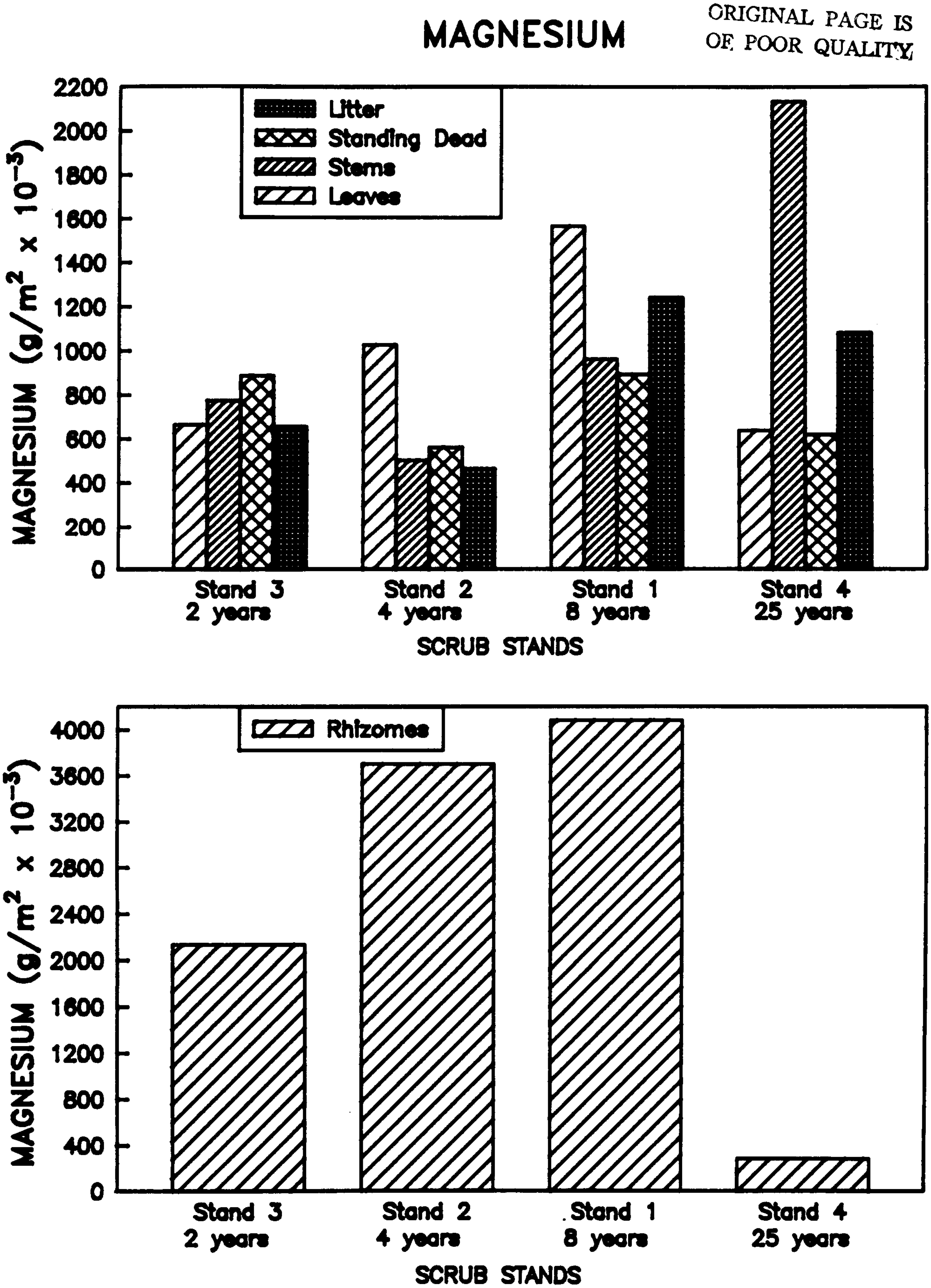


Figure 22. Magnesium (Mg) standing crops in the scrub stands.

Table 17. Concentration of sodium (Na) (%) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.069	0.051	0.053	-
Befaria racemosa	leaves	0.043	a	-	-
	stems	0.026	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.249	-	-
Ilex glabra	leaves	-	0.185	-	-
	stems	-	0.055	-	-
Lyonia spp.	leaves	0.075	0.074	0.073	0.113
	stems	0.059	0.059	0.051	0.068
Lyonia ligustrina	stems	-	-	-	(0.059)[b]
Myrica cerifera	leaves	-	0.176	0.209	-
	stems	-	0.063	0.041	-
Quercus chapmanii	leaves	0.046	-	0.049	0.044
	stems	0.042	-	0.049	0.042
Q. myrtifolia	leaves	0.045	0.034	0.053	0.037
	stems	0.042	0.047	0.048	0.041
	trunks	-	-	-	0.033
Q. virginiana var. geminata	leaves	0.037	0.055	0.037	0.039
	stems	0.058	0.053	0.077	0.046
Serenoa repens	leaves	0.061	0.116	0.086	0.068
	stems	0.228	0.507	0.313	0.238
	rhizomes	(0.528)[b]	(0.528)[b]	0.528	(0.528)[b]
Vaccinium myrsinites	-	0.068	0.081	0.058	(0.069)[b]
Ximenia americana	leaves	0.135	-	-	-
	stems	0.091	-	-	-
Misc. Herbs	-	-	a	0.045	-
Standing Dead Saw Palmetto	-	0.049	0.047	0.054	0.047
Standing Dead Woody	-	0.048	0.039	0.027	0.045
Litter	-	0.043	0.032	0.026	0.028

[a]insufficient sample for analysis
[b]estimated from other data

Table 18. Standing crop of sodium (Na) ($g/m^2 \times 10^{-3}$) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	2.28	3.42	14.52	-
Befaria racemosa	leaves	7.87	(0.22)[b]	-	-
	stems	5.12	(0.08)[b]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	4.98	-	-
Ilex glabra	leaves	-	5.92	-	-
	stems	-	1.93	-	-
Lyonia spp.	leaves	30.53	24.42	37.89	53.11
	stems	12.21	14.34	26.72	88.60
Lyonia ligustrina	stems	-	-	-	(35.58)[b]
Myrica cerifera	leaves	-	1.76	3.55	-
	stems	-	0.95	0.70	-
Quercus chapmanii	leaves	9.89	-	22.05	8.01
	stems	6.51	-	44.93	15.25
Q. myrtifolia	leaves	70.29	24.07	78.44	56.61
	stems	164.22	81.64	174.77	347.35
	trunks	-	-	-	186.29
Q. virginiana var. geminata	leaves	21.20	44.44	21.09	30.62
	stems	37.29	62.12	110.11	121.67
Serenoa repens	leaves	60.57	456.46	282.60	45.08
	stems	35.80	490.27	180.60	45.93
	rhizomes	(8958.58)[b]	(15521.62)[b]	17105.09	(1178.50)[b]
Vaccinium myrsinites	-	1.36	0.65	2.73	(2.42)[b]
Ximenia americana	leaves	7.02	-	-	-
	stems	37.58	-	-	-
Misc. Herbs	-	-	(0.36)[b]	11.70	-
Standing Dead-Saw Palmetto	-	26.12	163.94	310.82	23.27
Standing Dead-Woody	-	388.56	85.49	35.72	233.87
Litter	-	188.90	164.16	304.49	305.56
Total-live-leaves		211.01	566.70	474.57	195.85
Total-live-stems		298.73	651.33	537.83	840.67
Total live excluding saw palmetto rhizomes		509.74	1218.03	1012.40	1036.52
Total live		9468.32	16739.65	18117.49	2215.02
Total standing dead		414.68	249.43	346.54	257.14
Total standing dead and litter		603.58	413.59	651.03	562.70
Total above ground		10071.90	17153.24	18768.52	2777.72
Total above ground exluding saw palmetto rhizomes		1113.32	1631.62	1663.43	1599.22

[a]insufficient sample for analysis
[b]estimated from other data

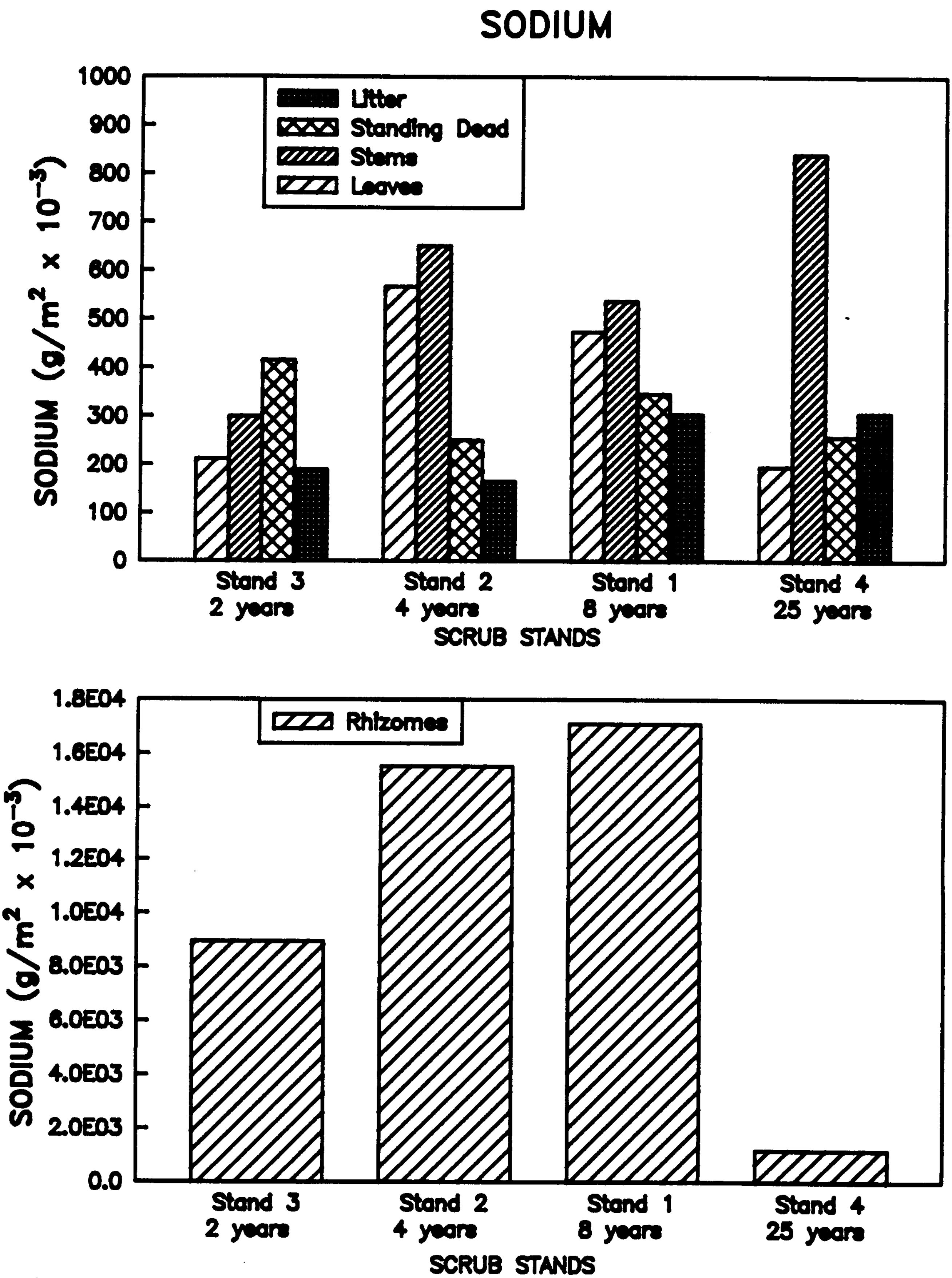


Figure 23. Sodium (Na) standing crops in the scrub stands.

Table 19. Concentration of potassium (K) (%) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.092	0.148	0.202	-
Befaria racemosa	leaves	0.805	a	-	-
	stems	0.137	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.575	-	-
Ilex glabra	leaves	-	0.296	-	-
	stems	-	0.182	-	-
Lyonia spp.	leaves	0.294	0.361	0.215	0.385
	stems	0.128	0.284	0.242	0.155
Lyonia ligustrina	stems	-	-	-	(0.202)[b]
Myrica cerifera	leaves	-	0.221	0.419	-
	stems	-	0.549	0.146	-
Quercus chapmanii	leaves	0.263	-	0.194	0.336
	stems	0.226	-	0.203	0.205
Q. myrtifolia	leaves	0.364	0.355	0.242	(0.320)[b]
	stems	0.195	0.167	0.212	0.145
	trunks	-	-	-	0.136
Q. virginiana var.	leaves	0.340	0.189	0.309	0.295
geminata	stems	0.298	0.308	0.154	0.158
Serenoa repens	leaves	0.368	0.403	0.379	0.672
	stems	1.045	0.442	0.748	0.727
	rhizomes	(0.976)[b]	(0.976)[b]	0.976	(0.976)[b]
Vaccinium myrsinites	-	0.264	0.259	0.258	(0.260)[b]
Ximenia americana	leaves	1.342	-	-	-
	stems	0.683	-	-	-
Misc. Herbs	-	-	a	0.170	-
Standing Dead Saw Palmetto	-	0.169	0.107	0.258	0.131
Standing Dead Woody	-	0.422	0.057	0.044	0.079
Litter	-	0.163	0.035	0.067	0.092

[a]insufficient sample for analysis
[b]estimated from other data

Table 20. Standing crop of potassium (K) ($g/m^2 \times 10^{-3}$) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	3.04	9.92	55.35	-
Befaria racemosa	leaves	147.32	(4.03)[b]	-	-
	stems	26.99	(0.41)[b]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	11.50	-	-
Ilex glabra	leaves	-	9.47	-	-
	stems	-	6.37	-	-
Lyonia spp.	leaves	119.66	119.13	111.59	180.95
	stems	26.50	69.01	126.81	201.97
Lyonia ligustrina	stems	-	-	-	(121.81)[b]
Myrica cerifera	leaves	-	2.21	7.12	-
	stems	-	8.24	2.48	-
Quercus chapmanii	leaves	56.55	-	87.30	61.15
	stems	35.03	-	186.15	74.42
Q. myrtifolia	leaves	568.57	251.34	358.16	489.60
	stems	762.45	290.08	771.89	1228.44
	trunks	-	-	-	771.80
Q. virginiana var. geminata	leaves	194.82	152.71	176.13	231.58
	stems	191.61	360.98	220.22	417.91
Serenoa repens	leaves	365.42	1585.81	1245.39	445.54
	stems	164.07	427.41	431.60	140.31
	rhizomes	(16559.79)[b]	(28691.47)[b]	31621.42	(2178.43)[b]
Vaccinium myrsinites	-	5.28	2.07	12.13	9.10
Ximenia americana	leaves	69.78	-	-	-
	stems	282.08	-	-	-
Misc. Herbs	-	-	(1.36)[b]	44.20	-
Standing Dead Saw Palmetto	-	90.08	373.22	1485.05	64.85
Standing Dead Woody	-	3416.09	124.94	58.21	410.56
Litter	-	716.06	179.55	784.64	1004.00
Total-live-leaves		1530.44	2149.55	2097.37	1417.92
Total-live-stems		1488.73	1162.50	1739.15	2956.66
Total live excluding saw palmetto rhizomes		3019.17	3312.05	3836.52	4374.58
Total live		19578.96	32003.52	35457.94	6553.01
Total standing dead		3506.17	498.16	1543.26	475.41
Total standing dead and litter		4222.23	677.71	2327.90	1479.41
Total above ground		23801.19	32681.23	37785.84	8032.42
Total above ground exluding saw palmetto rhizomes		7241.40	3989.76	6164.42	5853.99

[a]insufficient sample for analysis
[b]estimated from other data

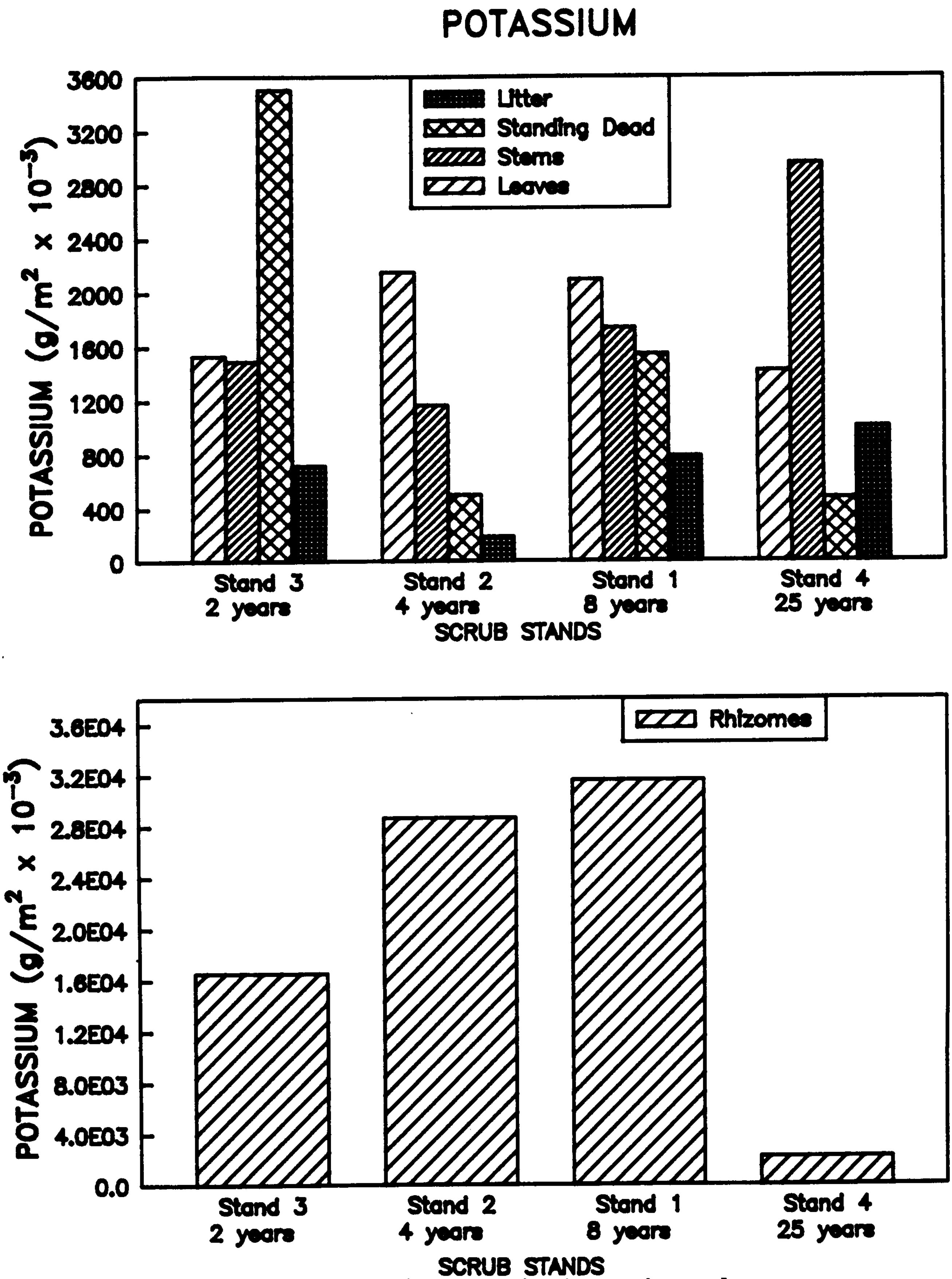


Figure 24. Potassium (K) standing crops in the scrub stands.

Table 21. Concentration of aluminum (Al) (%) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.0003	0.0019	0.0033	-
Befaria racemosa	leaves	0.0036	a	-	-
	stems	0.0002	a	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.0044	-	-
Ilex glabra	leaves	-	0.0034	-	-
	stems	-	0.0003	-	-
Lyonia spp.	leaves	0.0015	0.0013	0.0054	0.0022
	stems	0.0015	<0.0001	0.0015	0.0034
Lyonia ligustrina	stems	-	-	-	(0.0016)[b]
Myrica cerifera	leaves	-	0.0025	0.0034	-
	stems	-	0.0002	0.0020	-
Quercus chapmanii	leaves	0.0013	-	0.0064	0.0010
	stems	0.0012	-	0.0027	0.0022
Q. myrtifolia	leaves	0.0012	0.0006	0.0020	0.0016
	stems	0.0002	0.0001	0.0026	0.0012
	trunks	-	-	-	0.0008
Q. virginiana var. geminata	leaves	0.0030	0.0029	0.0026	0.0015
	stems	0.0005	0.0005	0.0039	0.0013
Serenoa repens	leaves	0.0013	<0.0001	0.0012	<0.0001
	stems	0.0001	0.0017	0.0078	0.0022
	rhizomes	(0.0026)[b]	(0.0026)[b]	0.0026	(0.0026)[b]
Vaccinium myrsinites	-	0.0027	0.0061	0.0046	(0.0045)[b]
Ximenia americana	leaves	0.0026	-	-	-
	stems	0.0053	-	-	-
Misc. Herbs	-	-	a	0.0037	-
Standing Dead Saw Palmetto	-	0.0003	0.0005	0.0020	0.0012
Standing Dead Woody	-	0.0006	0.0003	0.0012	0.0010
Litter	-	0.0040	0.0067	0.0051	0.0015

[a]insufficient sample for analysis
[b]estimated from other data

Table 22. Standing crop of aluminum (Al) ($g/m^2 \times 10^{-4}$) in scrub vegetation.

TAXA	AGE (yrs) PLANT PART	STAND 3 2	STAND 2 4	STAND 1 8	STAND 4 25
Aristida stricta	-	0.10	1.41	9.04	-
Befaria racemosa	leaves	6.59	(0.18)[b]	-	-
	stems	0.39	(0.01)[b]	-	-
Cyperaceae	-	a	-	-	a
Hypericum spp.	-	-	0.88	-	-
Ilex glabra	leaves	-	1.09	-	-
	stems	-	0.11	-	-
Lyonia spp.	leaves	6.11	4.29	28.03	10.34
	stems	3.11	0.24	7.86	44.30
Lyonia ligustrina	stems	-	-	-	(9.65)[b]
Myrica cerifera	leaves	-	0.25	0.58	-
	stems	-	0.03	0.34	-
Quercus chapmanii	leaves	2.80	-	28.80	1.82
	stems	1.86	-	24.76	7.99
Q. myrtifolia	leaves	18.74	4.25	29.60	24.48
	stems	7.82	1.74	94.67	101.66
	trunks	-	-	-	45.16
Q. virginiana var. geminata	leaves	17.19	23.43	14.82	11.78
	stems	3.22	5.86	55.77	34.39
Serenoa repens	leaves	12.91	3.94	39.43	0.66
	stems	0.16	16.44	45.01	4.25
	rhizomes	(441.14)[b]	(764.32)[b]	842.30	(58.03)[b]
Vaccinium myrsinites	-	0.54	0.49	2.16	(1.58)[b]
Ximenia americana	leaves	1.35	-	-	-
	stems	21.89	-	-	-
Misc. Herbs	-	-	(0.30)[b]	9.62	-
Standing Dead-Saw Palmetto	-	1.60	17.44	115.12	5.94
Standing Dead-Woody	-	48.57	6.58	15.88	51.97
Litter	-	175.72	343.71	597.26	163.70
Total-live-leaves		66.33	40.51	162.08	50.66
Total-live-stems		38.45	24.43	228.41	247.40
Total live excluding saw palmetto rhizomes		104.78	64.94	390.49	298.06
Total live		545.92	829.26	1232.79	356.09
Total standing dead		50.17	24.02	131.00	57.91
Total standing dead and litter		225.89	367.73	728.26	221.61
Total above ground		771.81	1196.99	1961.05	577.70
Total above ground exluding saw palmetto rhizomes		330.67	432.67	1118.75	519.67

[a]insufficient sample for analysis
[b]estimated from other data

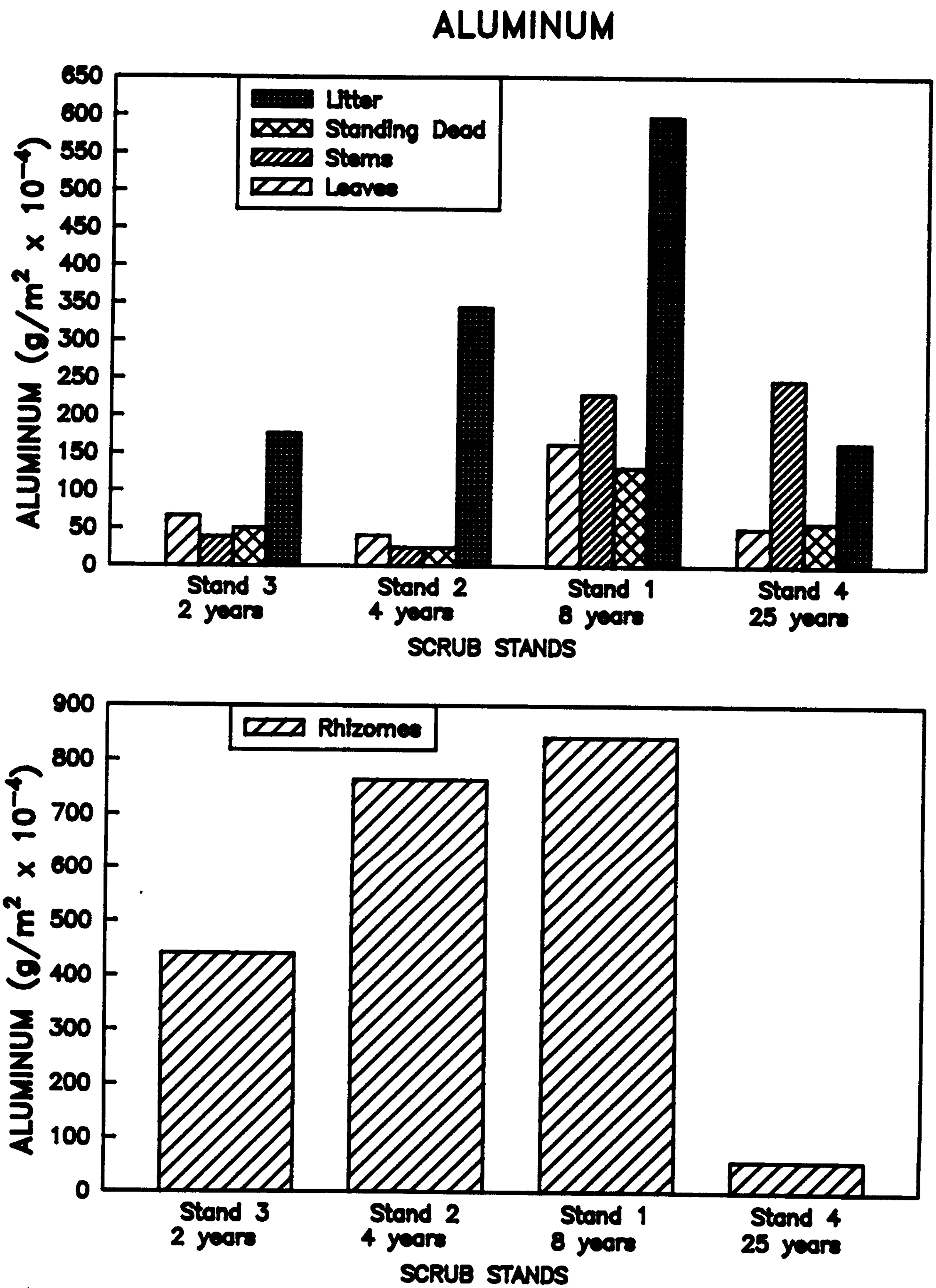


Figure 25. Aluminum (Al) standing crops in the scrub stands.

Table 23. Chemical characteristics of soils in the scrub stands.

PARAMETER	HORIZON	STAND 3 2 years 0–15cm N=12	STAND 3 2 years 15–30cm N=12	STAND 2 4 years 0–15cm N=12	STAND 2 4 years 15–30cm N=12	STAND 1 8 years 0–15cm N=12	STAND 1 8 years 15–30cm N=12	STAND 4 25 years 0–15cm N=12	STAND 4 25 years 15–30cm N=12
pH	$\bar{X}$	4.46	4.69	3.87	4.11	4.19	4.54	4.17	4.41
	SD	(0.36)	(0.29)	(0.19)	(0.16)	(0.74)	(0.20)	(0.33)	(0.27)
Conductivity	$\bar{X}$	36.8	22.8	95.1	42.7	67.9	23.5	54.9	24.6
(umhos/cm)	SD	(10.3)	(5.0)	(36.5)	(17.7)	(15.6)	(8.2)	(13.6)	(5.5)
Organic matter	$\bar{X}$	1.8	1.3	8.8	3.2	3.6	0.6	3.3	1.2
(%)	SD	(0.7)	(1.5)	(5.5)	(3.5)	(1.8)	(0.5)	(1.3)	(0.7)
Available phosphorus	$\bar{X}$	0.90	0.20	10.01	2.55	3.17	0.90	1.77	0.30
(mg/kg)	SD	(0.90)	(0.24)	(7.30)	(1.68)	(2.11)	(1.12)	(1.22)	(0.32)
Total Kjeldahl	$\bar{X}$	201.16	83.67	1271.42	260.58	449.28	65.26	290.51	92.04
nitrogen (mg/kg)	SD	(86.51)	(45.78)	(796.98)	(165.55)	(212.80)	(19.61)	(92.88)	(36.27)
Exchangeable nitrate-	$\bar{X}$	0.64	0.45	0.70	0.53	0.71	0.75	0.52	0.49
nitrogen (mg/kg)	SD	(0.48)	(0.09)	(0.19)	(0.11)	(0.25)	(0.33)	(0.11)	(0.07)
Exchangeable ammonia	$\bar{X}$	6.31	1.56	24.26	5.11	10.23	2.50	10.13	2.18
nitrogen (mg/kg)	SD	(7.79)	(0.39)	(22.02)	(2.65)	(3.86)	(0.96)	(7.89)	(0.94)
Cation exchange	$\bar{X}$	0.27	0.19	4.30	0.49	0.45	0.21	0.31	0.21
capacity (meq/100 g)	SD	(0.30)	(0.13)	(5.85)	(0.54)	(0.34)	(0.25)	(0.16)	(0.09)
Exchangeable aluminum	$\bar{X}$	7.10	8.73	8.52	6.92	6.83	2.77	9.27	7.82
(mg/kg)	SD	(5.30)	(9.06)	(7.05)	(5.02)	(5.17)	(5.31)	(7.82)	(5.87)
Available copper	$\bar{X}$	0.07	0.06	0.13	0.09	0.12	0.10	0.09	0.07
(mg/kg)	SD	(0.03)	(0.02)	(0.04)	(0.04)	(0.02)	(0.05)	(0.03)	(0.05)
Available iron	$\bar{X}$	21.35	9.79	36.39	11.69	16.22	9.45	28.45	13.05
(mg/kg)	SD	(12.58)	(6.95)	(25.00)	(11.38)	(10.39)	(15.44)	(19.00)	(7.62)
Available manganese	$\bar{X}$	0.85	0.15	1.30	0.16	1.66	0.17	0.83	0.16
(mg/kg)	SD	(0.58)	(0.16)	(1.08)	(0.13)	(2.54)	(0.20)	(0.30)	(0.09)
Available zinc	$\bar{X}$	0.312	0.099	0.734	0.152	0.622	0.193	0.510	0.145
(mg/kg)	SD	(0.159)	(0.066)	(0.440)	(0.093)	(0.438)	(0.214)	(0.195)	(0.069)
Exchangeable calcium	$\bar{X}$	54.73	25.90	190.68	50.98	111.35	21.63	55.08	22.37
(mg/kg)	SD	(24.86)	(11.75)	(99.76)	(24.28)	(133.05)	(11.19)	(11.92)	(5.35)
Exchangeable magnesium	$\bar{X}$	12.21	3.86	88.00	24.41	31.55	4.39	12.97	3.52
(mg/kg)	SD	(7.77)	(2.04)	(70.70)	(17.60)	(23.51)	(2.73)	(4.39)	(1.30)
Exchangeable potassium	$\bar{X}$	18.55	10.13	61.62	19.63	31.82	10.05	29.78	8.20
(mg/kg)	SD	(7.12)	(4.12)	(43.44)	(11.18)	(13.70)	(7.20)	(12.81)	(2.72)
Exchangeable sodium	$\bar{X}$	16.57	12.51	39.28	21.21	20.16	13.00	20.46	12.48
(mg/kg)		(4.01)	(1.60)	(21.36)	(10.14)	(4.16)	(3.20)	(5.08)	(1.41)

Table 24. Chemical characteristics of inland scrub soils on Merritt Island sampled in 1976 and 1977 (modified from Madsen 1980)[1].

Parameter	$\bar{X}$	SD	N
pH	4.1	0.13	14
Sodium (mg/kg)	33	8.9	14
Potassium (mg/kg)	9.3	1.6	14
Calcium (mg/kg)	104	18.3	14
Magnesium (mg/kg)	16.8	4.6	14
Phosphorus (mg/kg)	0.86	1.00	14
Nitrate-nitrogen (mg/kg)	2.3	1.3	14
Ammonia-nitrogen (mg/kg)	0.75	1.07	14
Total Kjeldahl nitrogen (mg/kg)	190	60	14
Organic matter (%)	1.9	1.2	14
Aluminum (mg/kg)	20.3	20.7	14
Ion exchange capacity (meg/100g)	1.5	0.7	14

[1]Data are from two stands of oak scrub vegetation at inland sites on KSC on Pomello soil. Each site was sampled in July 1976, December 1976, and March 1977.

Table 25. Analysis of variance of the 0-15 cm layer of soil between the four scrub stands.

Parameter	Significance Level of ANOVA	Pairs of Stands Significantly Different (p<.05) in Duncan Multiple Range Tests
pH	.025	3&2
Conductivity	<.0001	3&4, 3&1, 3&2, 4&2, 1&2
Organic matter	<.0001	3&2, 4&2, 1&2
Cation exchange capacity	.003	3&2, 4&2, 1&2
Phosphorus	<.0001	3&2, 4&2, 1&2
Total Kjeldahl nitrogen	<.0001	3&2, 4&2, 1&2
Nitrate-nitrogen	N.S.	---
Ammonia-nitrogen	.006	3&2, 4&2, 1&2
Aluminum	N.S.	---
Copper	.001	3&1, 4&1, 3&2, 4&2
Iron	.039	1&2
Manganese	N.S.	---
Zinc	.024	3&1, 3&2
Calcium	.0006	3&2, 4&2, 1&2
Magnesium	<.0001	3&2, 4&2, 1&2
Potassium	.0005	3&2, 4&2, 1&2
Sodium	<.0001	3&2, 4&2, 1&2

Table 26. Analysis of variance of the 15-30 cm layer of soil between the four scrub stands.

Parameter	Significance Level of ANOVA	Pairs of Stands Significantly Different ($p<.05$) in Duncan Multiple Range Tests
pH	<.0001	2&4, 2&1, 2&3, 4&3
Conductivity	<.0001	3&2, 1&2, 4&2
Organic matter	.014	1&2, 4&2, 3&2
Cation exchange capacity	N.S.	---
Phosphorus	<.0001	3&2, 4&2, 1&2
Total Kjeldahl nitrogen	<.0001	1&2, 3&2, 4&2
Nitrate-nitrogen	.001	3&1, 4&1, 2&1
Ammonia-nitrogen	<.0001	3&2, 4&2, 1&2
Aluminum	N.S.	---
Copper	N.S.	---
Iron	N.S.	---
Manganese	N.S.	---
Zinc	N.S.	---
Calcium	<.0001	1&2, 4&2, 3&2
Magnesium	<.0001	4&2, 3&2, 1&2
Potassium	.001	4&2, 3&2, 1&2
Sodium	.0004	4&2, 3&2, 1&2

indicated that, in many cases, Stand 2 differed from the other stands. As shown earlier, Stand 2 had a water table closer to the surface than the other stands and contained some plots with differing soil types. Wetter soils are likely to accumulate more organic matter and therefore have greater cation exchange capacity and differ in other properties from better drained soils. In order to separate out effects that may be related to soil drainage from those associated with fire, the soil data were analyzed excluding Stand 2.

Multivariate analysis of variance was not significant for the three stands for the 0 to 15 cm layer or for the 15 to 30 cm layer based on soil characteristics. Since multivariate differences were not significant, univariate (one way analysis of variance) results must be viewed with caution. However, for the 0 to 15 cm layer conductivity, organic matter, phosphorus, total Kjeldahl nitrogen, copper, zinc, magnesium, and potassium differed between the three stands (Table 27). For the 15 to 30 cm layer, only pH, phosphorus, nitrate-nitrogen and ammonia-nitrogen differed between the three stands (Table 28). For both soil layers, range tests indicated that Stand 3 (the most recently burned) differed from one or both of the other stands (Table 27, 28) suggesting that some fire effects might be involved.

In order to examine these differences further, each soil parameter was examined. Correlations between soil variables were calculated and are given in Tables 29, 30, 31, and 32. In the 0 to 15 cm layer of the four stands, there were strong correlations between organic matter, cation exchange capacity, total Kjeldahl nitrogen, and phosphorus (Table 29). Magnesium, potassium, and sodium were also strongly correlated to each other. Similar, though in some cases weaker, correlations existed between these variables for the 15 to 30 cm layer for the four stands (Table 30). When Stand 2 was excluded from consideration, there were still significant relationships between organic matter, cation exchange capacity, total Kjeldahl nitrogen, ammonia-nitrogen, and phosphorus in the 0 to 15 cm layer (Table 31). In the 15 to 30 cm layer, however, the exclusion of Stand 2 eliminated that set of relationships (Table 32).

pH in the most recently burned stand was elevated in both the 0 to 15 and 15 to 30 cm layers (Figure 26) although these differences were not all significant (Tables 25 to 28). Stand 2 had lower pH, probably due to the greater amount of organic matter in the soil of Stand 2 and the negative correlation between pH and organic matter (Table 29).

Conductivity was lower in the 0 to 15 cm layer of the most recently burned stand (Figure 27) than in the other stands. Stand 2 had higher conductivity in both the 0 to 15 and 15 to 30

Table 27. Analysis of variance of the 0-15 cm layer of soil between the three scrub stands, stand 2 excluded.

Parameter	Significance Level of ANOVA	Pairs of Stands Significantly Different ($p<.05$) in Duncan Multiple Range Tests
pH	N.S.	---
Conductivity	.0008	1&3, 4&3
Organic matter	.0047	1&3, 4&3
Cation exchange capacity	N.S.	---
Phosphorus	.0029	1&3, 1&4
Total Kjeldahl nitrogen	.0006	1&3, 1&4
Nitrate-nitrogen	N.S.	---
Ammonia-nitrogen	N.S.	---
Aluminum	N.S.	---
Copper	.002	1&3, 1&4
Iron	N.S.	---
Manganese	N.S.	---
Zinc	.0423	1&3
Calcium	N.S.	---
Magnesium	.0034	1&3, 1&4
Potassium	.0177	1&3, 4&3
Sodium	N.S.	---

Table 28. Analysis of variance of the 15-30 cm layer of soil between the three scrub stands, stand 2 excluded.

Parameter	Significance Level of ANOVA	Pairs of Stands Significantly Different ($p<.05$) in Duncan Multiple Range Tests
pH	.0398	3&4
Conductivity	N.S.	---
Organic matter	N.S.	---
Cation exchange capacity	N.S.	---
Phosphorus	.0368	1&3, 1&4
Total Kjeldahl nitrogen	N.S.	---
Nitrate-nitrogen	.0016	1&3, 1&4
Ammonia-nitrogen	.0254	1&3
Aluminum	N.S.	---
Copper	N.S.	---
Iron	N.S.	---
Manganese	N.S.	---
Zinc	N.S.	---
Calcium	N.S.	---
Magnesium	N.S.	---
Potassium	N.S.	---
Sodium	N.S.	---

Table 29. Correlations between soil parameters in the 0-15 cm layer of the four scrub stands (N=48)[1].

	pH	Cond	OM	P	TKN	NO_3-N	NH_3-N	CEC	Al	Cu	Fe	Mn	Zn	Ca	Mg	K	Na
pH	1.0	-0.501	-0.437	-0.332	-0.355	---	-0.275	---	---	-0.321	---	0.591	---	0.241	-0.349	-0.387	-0.359
Conductivity		1.0	0.892	0.840	0.893	---	0.701	0.749	0.254	0.538	0.478	---	0.633	0.539	0.802	0.751	0.857
Organic matter			1.0	0.905	0.938	---	0.765	0.867	0.250	0.434	0.557	---	0.573	0.566	0.918	0.863	0.845
Phosphorus				1.0	0.939	---	0.871	0.807	---	0.376	0.477	---	0.525	0.554	0.930	0.851	0.881
Total Kjeldahl nitrogen					1.0	---	0.795	0.855	0.310	0.413	0.524	---	0.553	0.597	0.948	0.794	0.926
Nitrate-nitrogen						1.0	---	---	---	---	---	---	---	0.280	---	---	---
Ammonia-nitrogen							1.0	0.641	---	0.280	0.495	---	0.509	0.375	0.793	0.763	0.814
Cation exchange capacity								1.0	0.416	0.318	0.602	---	0.423	0.485	0.861	0.768	0.750
Aluminum									1.0	---	0.514	---	---	---	0.280	---	0.285
Copper										1.0	---	0.242	0.557	0.383	0.359	0.354	0.327
Iron											1.0	---	0.346	---	0.499	0.476	0.548
Manganese												1.0	---	0.746	---	---	---
Zinc													1.0	0.405	0.494	0.404	0.544
Calcium														1.0	0.496	0.379	0.462
Magnesium															1.0	0.888	0.860
Potassium																1.0	0.707
Sodium																	1.0

[1]Correlations significant at $p \leq .05$.

Table 30. Correlations between soil parameters in the 15-30 cm layer of the four scrub stands (N=48)[1].

	pH	Cond	OM	P	TKN	NO_3-N	NH_3-N	CEC	Al	Cu	Fe	Mn	Zn	Ca	Mg	K	Na
ph	1.0	-0.536	-0.422	-0.578	-0.550	---	0.526	0.272	---	0.279	---	---	---	-0.429	-0.572	-0.454	-0.461
Conductivity		1.0	0.529	0.834	0.878	---	0.850	0.643	---	---	0.341	---	---	0.717	0.866	0.766	0.800
Organic matter			1.0	0.561	0.619	---	0.527	0.469	---	0.348	---	---	---	0.529	0.733	0.540	0.560
Phosphorus				1.0	0.816	---	0.783	0.570	---	0.352	0.285	---	0.316	0.695	0.905	0.857	0.892
Total Kjeldahl nitrogen					1.0	---	0.878	0.750	0.202	---	0.338	---	0.267	0.839	0.932	0.794	0.838
Nitrate-nitrogen						1.0	---	---	-0.264	0.580	---	---	0.255	---	---	---	---
Ammonia-nitrogen							1.0	0.672	---	0.290	---	---	0.326	0.770	0.862	0.713	0.758
Cation exchange capacity								1.0	0.216	---	0.426	---	---	0.639	0.693	0.587	0.593
Aluminum									1.0	---	0.388	---	---	---	---	---	---
Copper										1.0	---	---	---	---	0.312	0.275	0.247
Iron											1.0	0.418	0.436	---	0.300	0.459	0.274
Manganese												1.0	0.608	---	---	---	---
Zinc													1.0	0.348	0.228	0.331	---
Calcium														1.0	0.813	0.824	0.879
Magnesium															1.0	0.807	0.892
Potassium																1.0	0.776
Sodium																	1.0

[1]Correlations significant at $p \leq .05$.

Table 31. Correlations between soil parameters in the 0-15 cm layer of three scrub stands, stand 2 excluded (N=36)[1].

	pH	Cond	OM	P	TKN	NO_3-N	NH_3-N	CEC	Al	Cu	Fe	Mn	Zn	Ca	Mg	K	Na
ph	1.0	-.472	-.487	---	-.300	---	---	---	---	---	---	.723	---	.659	-.288	-.395	-.456
Conductivity		1.0	.805	.598	.722	---	.559	---	---	.378	---	---	.564	---	.431	.726	.737
Organic matter			1.0	.546	.695	---	.421	.321	---	.303	---	---	.631	---	.586	.787	.778
Phosphorus				1.0	.697	.295	.470	---	-.363	.417	-.331	---	.415	.337	.542	.584	.462
Total Kjeldahl nitrogen					1.0	---	.536	.423	---	.462	---	---	.643	---	.751	.611	.627
Nitrate-nitrogen						1.0	---	---	---	---	-.335	.297	---	.349	---	---	---
Ammonia-nitrogen							1.0	---	---	.286	---	---	.325	---	---	.385	.588
Cation exchange capacity								1.0	.325	---	---	---	.338	---	.567	.430	---
Aluminum									1.0	---	.603	---	---	-.288	---	---	---
Copper										1.0	---	---	.444	---	.371	.302	.335
Iron											1.0	---	---	---	---	---	---
Manganese												1.0	---	.939	---	---	---
Zinc													1.0	---	.547	.381	.498
Calcium														1.0	---	---	---
Magnesium															1.0	.662	.489
Potassium																1.0	.706
Sodium																	1.0

[1]Correlations significant at $p \leq .05$.

Table 32. Correlations between soil parameters in the 15-30 cm layer of three scrub stands, stand 2 excluded (N=36)[1].

	pH	Cond	OM	P	TKN	NO_3-N	NH_3-N	CEC	Al	Cu	Fe	Mn	Zn	Ca	Mg	K	Na
ph	1.0	---	---	-.290	---	---	---	---	.370	---	---	---	---	---	-.311	---	---
Conductivity		1.0	---	.283	---	---	.380	---	---	---	.312	---	---	---	.259	.349	.572
Organic matter			1.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Phosphorus				1.0	---	.332	---	---	-.410	.353	---	---	.371	---	.639	.721	.575
Total Kjeldahl nitrogen					1.0	---	---	---	.282	---	---	---	---	---	.381	---	---
Nitrate-nitrogen						1.0	.315	---	-.325	.632	-.351	---	---	---	---	---	---
Ammonia-nitrogen							1.0	---	---	---	---	---	.374	.320	---	---	---
Cation exchange capacity								1.0	.334	---	---	---	---	---	-.346	---	---
Aluminum									1.0	---	.383	---	---	---	-.339	---	---
Copper										1.0	---	---	---	---	---	---	---
Iron											1.0	.440	.342	---	---	.364	---
Manganese												1.0	.683	.347	---	---	---
Zinc													1.0	.392	---	---	---
Calcium														1.0	.369	---	---
Magnesium															1.0	.533	.451
Potassium																1.0	.520
Sodium																	1.0

[1]Correlations significant at $p \leq .05$.

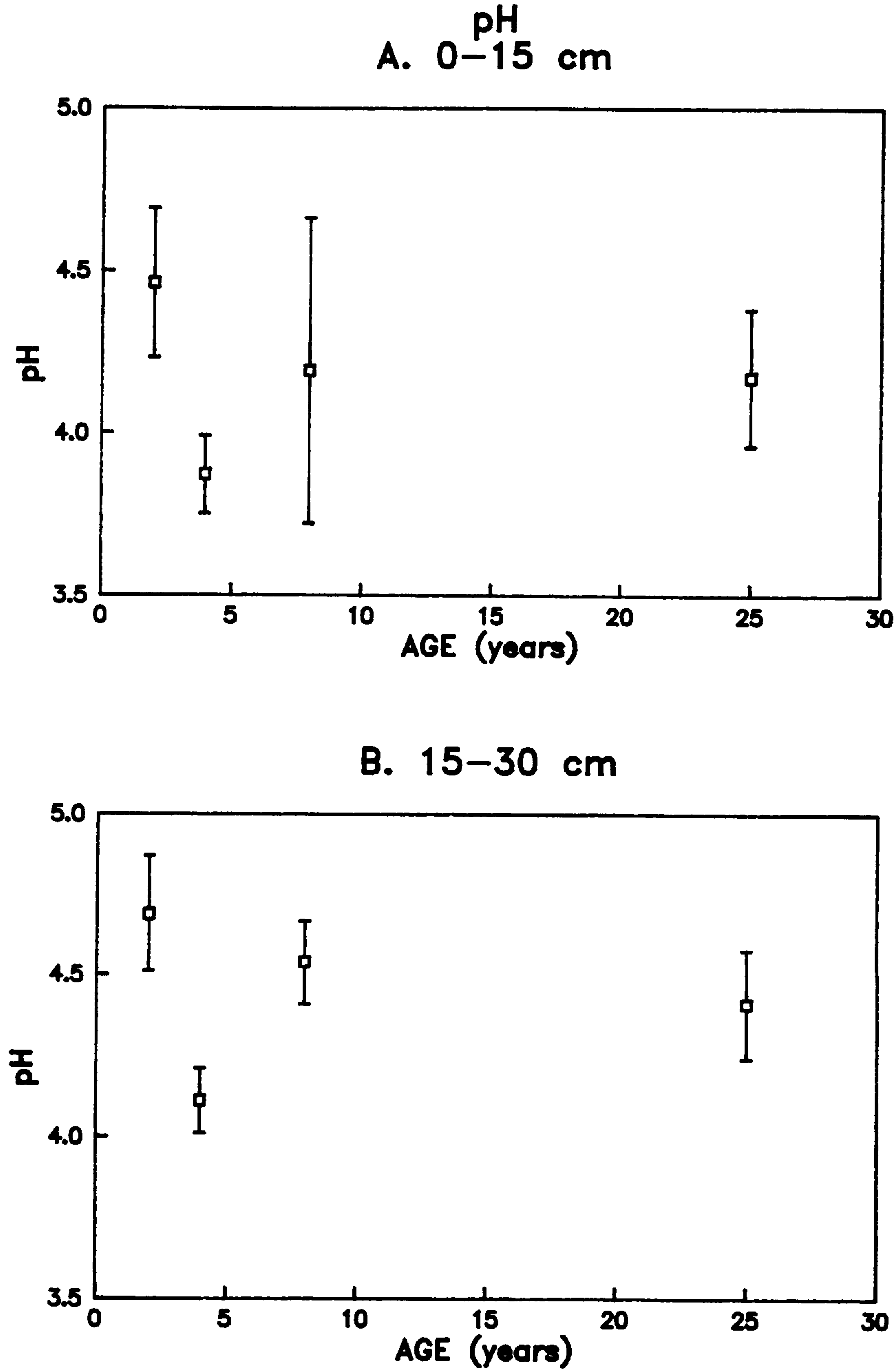


Figure 26. pH of soils in the scrub stands.

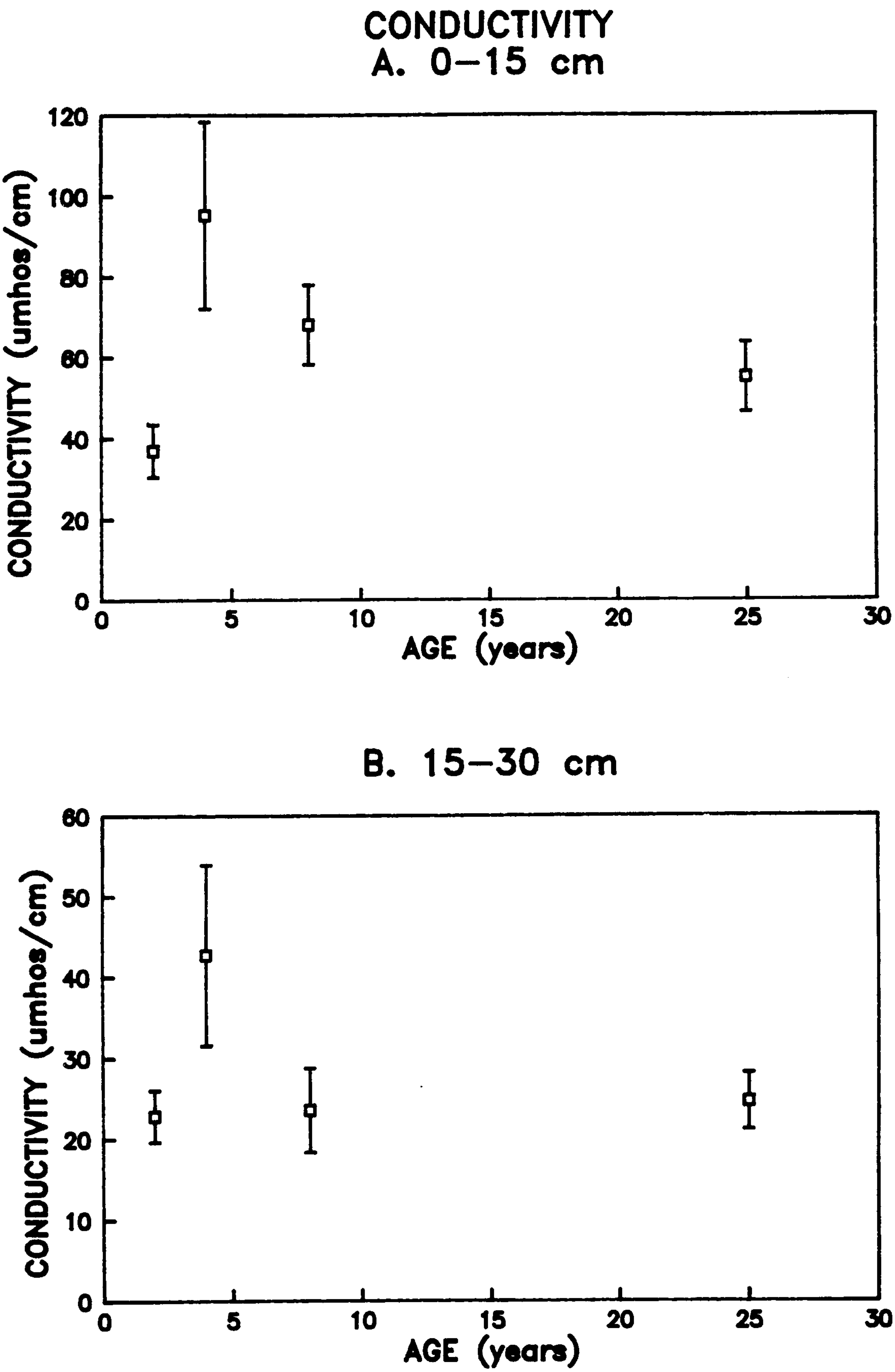


Figure 27. Conductivity of soils in the scrub stands.

cm layers. When Stand 2 was excluded, differences remained between Stand 3 (the most recently burned) and the others in the 0 to 15 cm layer but not in the 15 to 30 cm layer (Table 27, 28).

Stand 2 had higher levels of organic matter in both the 0 to 15 and 15 to 30 cm layers (Figure 28). When Stand 2 was eliminated, differences remained in the upper but not the lower soil layer (Tables 27, 28). The most recently burned stand was lower in organic matter in the 0 to 15 cm layer than the older stands.

Cation exchange capacity was higher in Stand 2 than in the other stands (Figure 29) probably due to the greater amount of organic matter; organic matter and cation exchange capacity were highly correlated in these soils (Table 29).

Phosphorus was elevated in Stand 2 relative to the others (Figure 30). Phosphorus was highly correlated to organic matter (Table 29). When Stand 2 was excluded, differences between some stands remained (Tables 27, 28) but these were not clearly related to fire.

Total Kjeldahl nitrogen was higher in Stand 2 than in the other stands (Figure 31). TKN was highly correlated to organic matter (Tables 29, 30). The most recently burned stand was lower in TKN in the 0 to 15 cm layer than the next older stand when Stand 2 was excluded (Table 27) which may be related to fire.

Ammonia-nitrogen was closely related to TKN and to organic matter (Table 29). It was elevated in Stand 2 relative to the other stands (Figure 32). The most recently burned stand was lower in ammonia-nitrogen in the 15 to 30 cm layer but not in the 0 to 15 cm layer than the next oldest stand when Stand 2 was excluded (Table 28).

Nitrate-nitrogen, in contrast, showed no differences between stands in the 0 to 15 cm layer (Figure 33, Table 25). There were some differences between stands in the 15 to 30 cm layer but they did not appear related to time since fire (Figure 33, Table 28).

Calcium was higher in Stand 2 than in the other stands (Figure 34). Differences between stands were not significant when Stand 2 was excluded (Tables 27, 28). Magnesium was similar, being elevated in Stand 2 (Figure 35). The surface layer of Stand 1 (8 years since fire) differed from the other two stands (Table 27) but this difference did not appear related to time since burning.

Potassium (Figure 36) and sodium (Figure 37) were also elevated in Stand 2 compared to the other stands. No significant differences remained between stands for sodium when Stand 2 was excluded (Tables 27, 28); however, the upper layer of the most recently burned stand was lower in potassium than the other stands (Table 27).

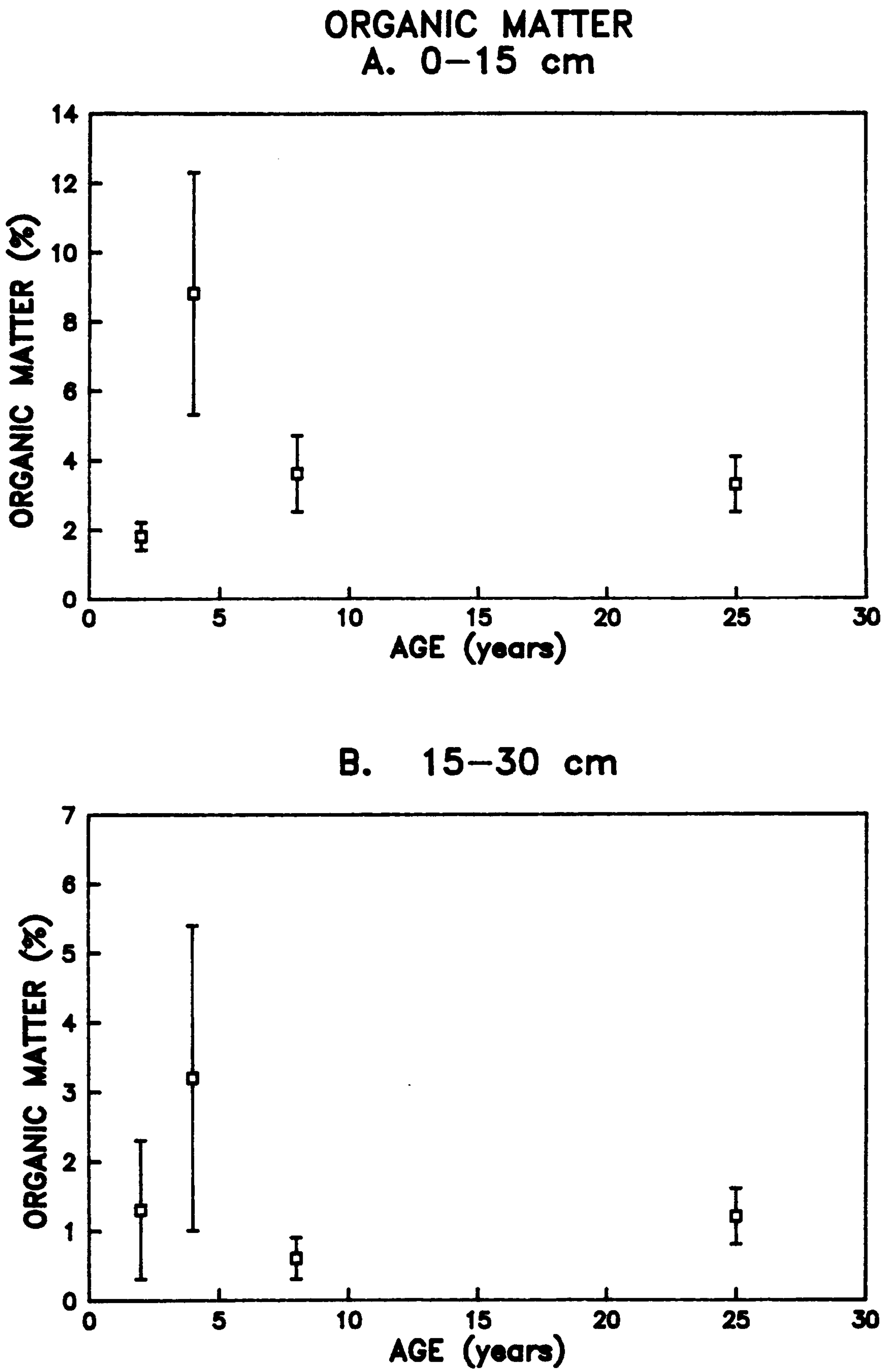


Figure 28. Organic matter of soils in the scrub stands.

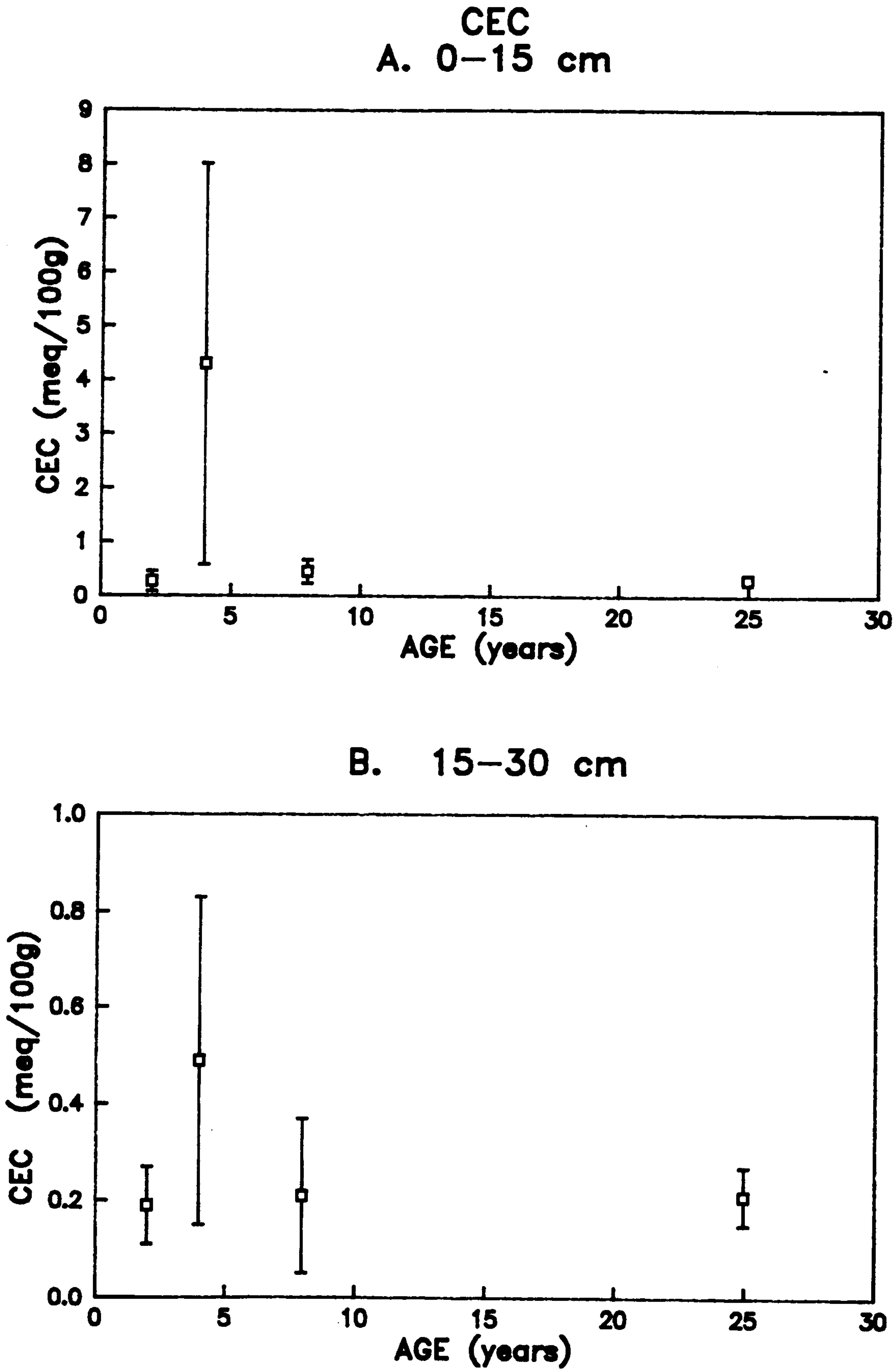


Figure 29. Cation exchange capacity (CEC) of soils in the scrub stands.

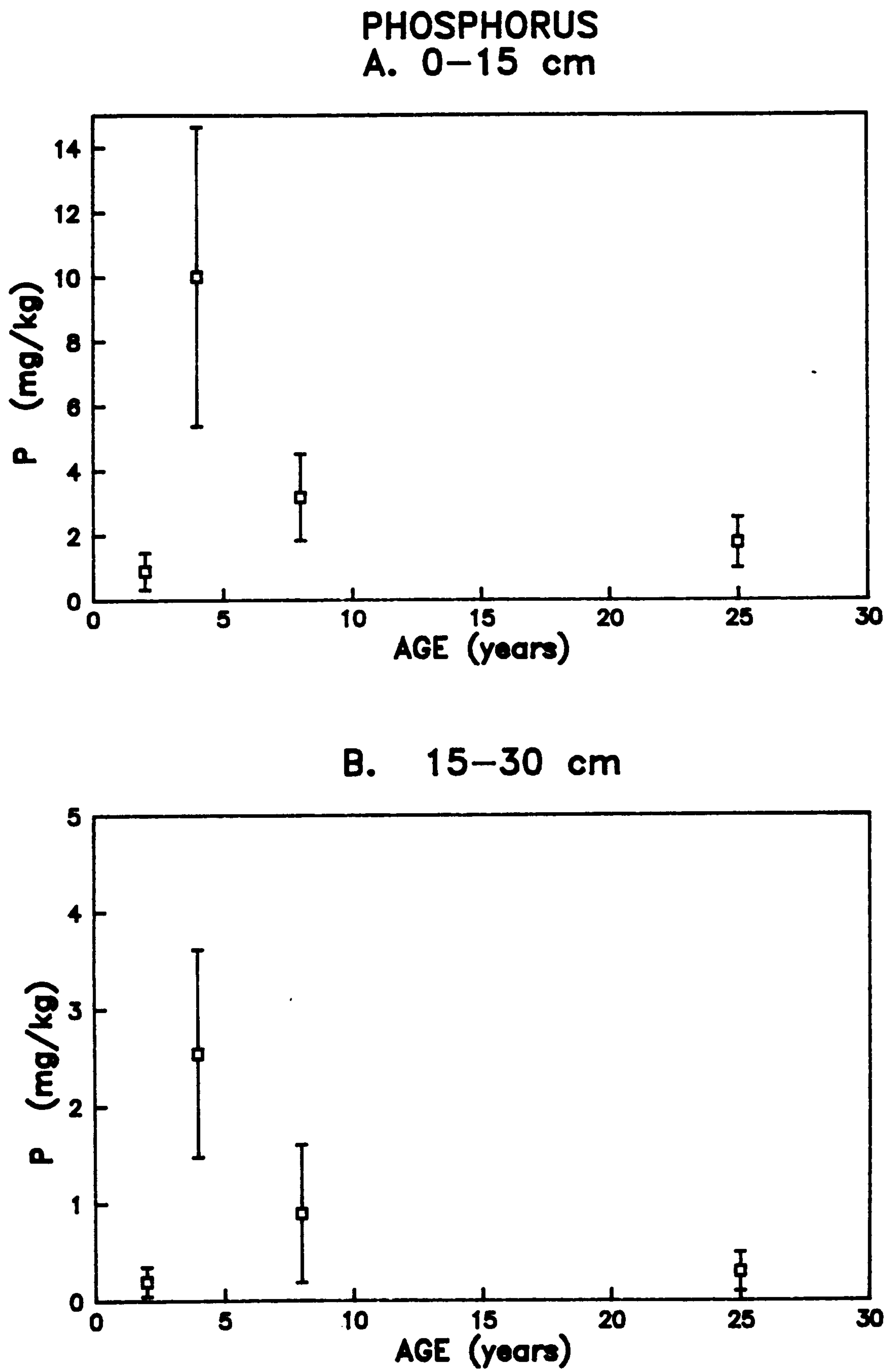


Figure 30. Available phosphorus (P) in soils of the scrub stands.

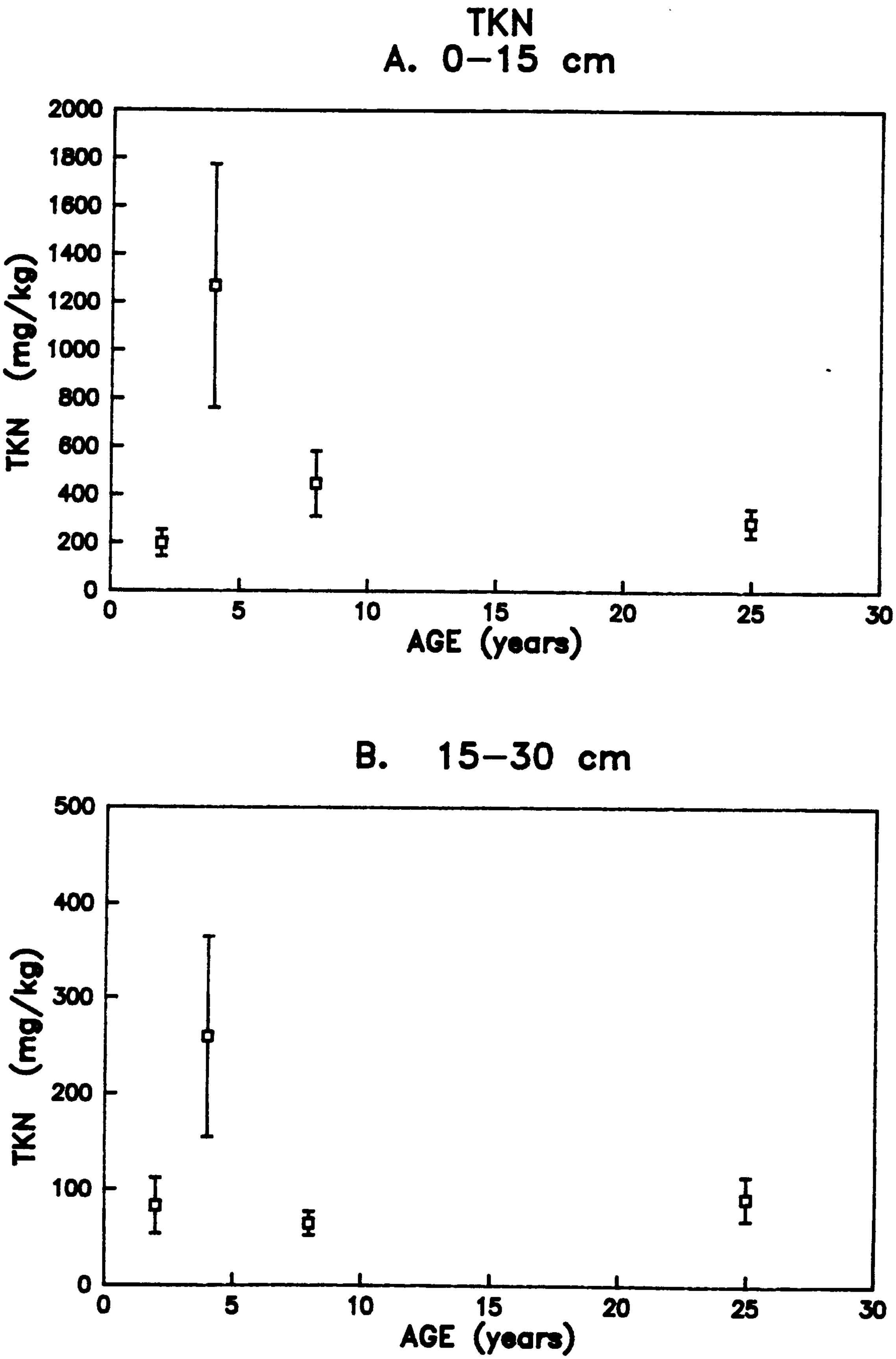


Figure 31. Total Kjeldahl nitrogen (TKN) of soils in the scrub stands.

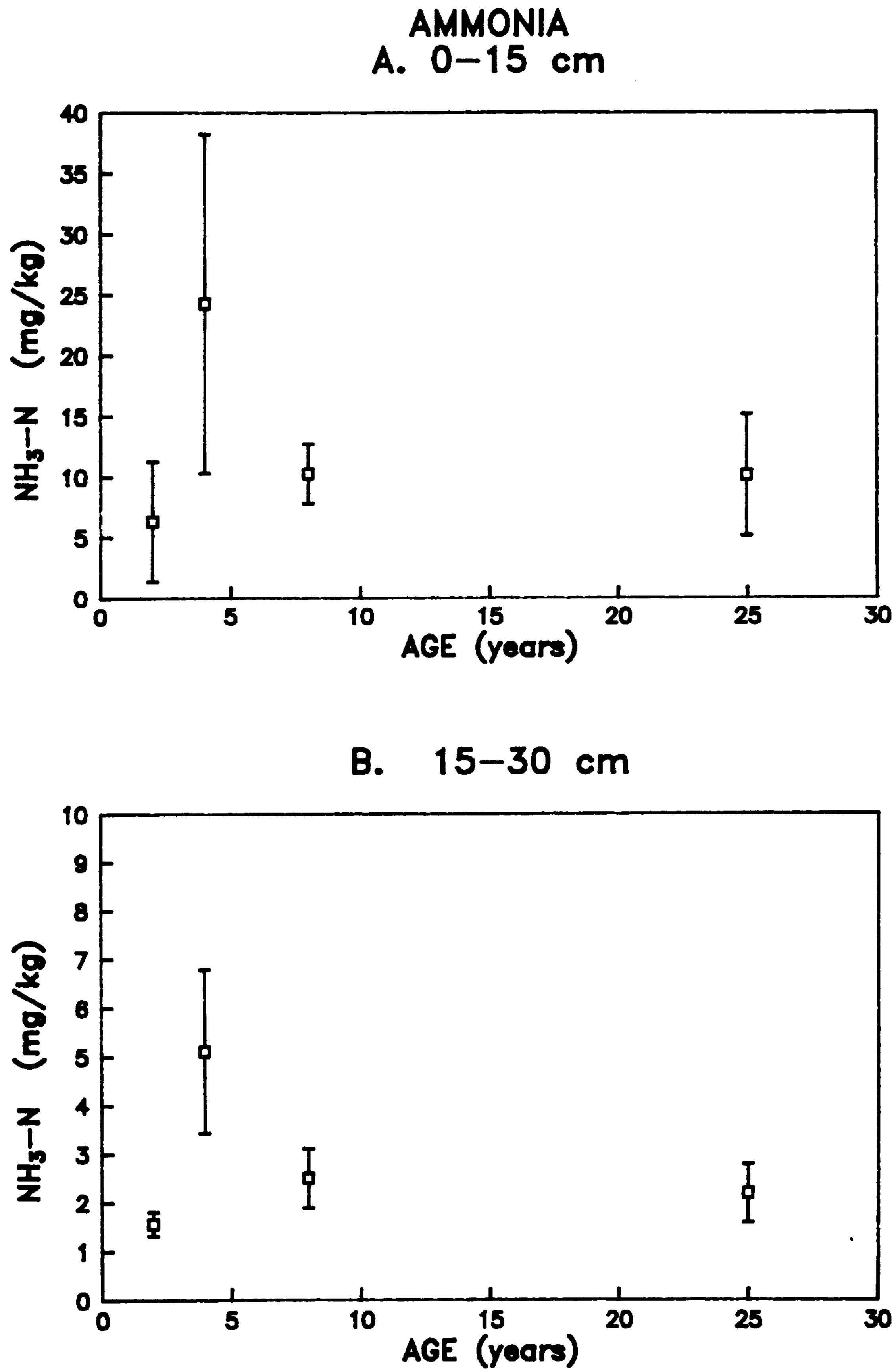


Figure 32. Exchangeable ammonia-nitrogen (NH_3-N) of soils in the scrub stands.

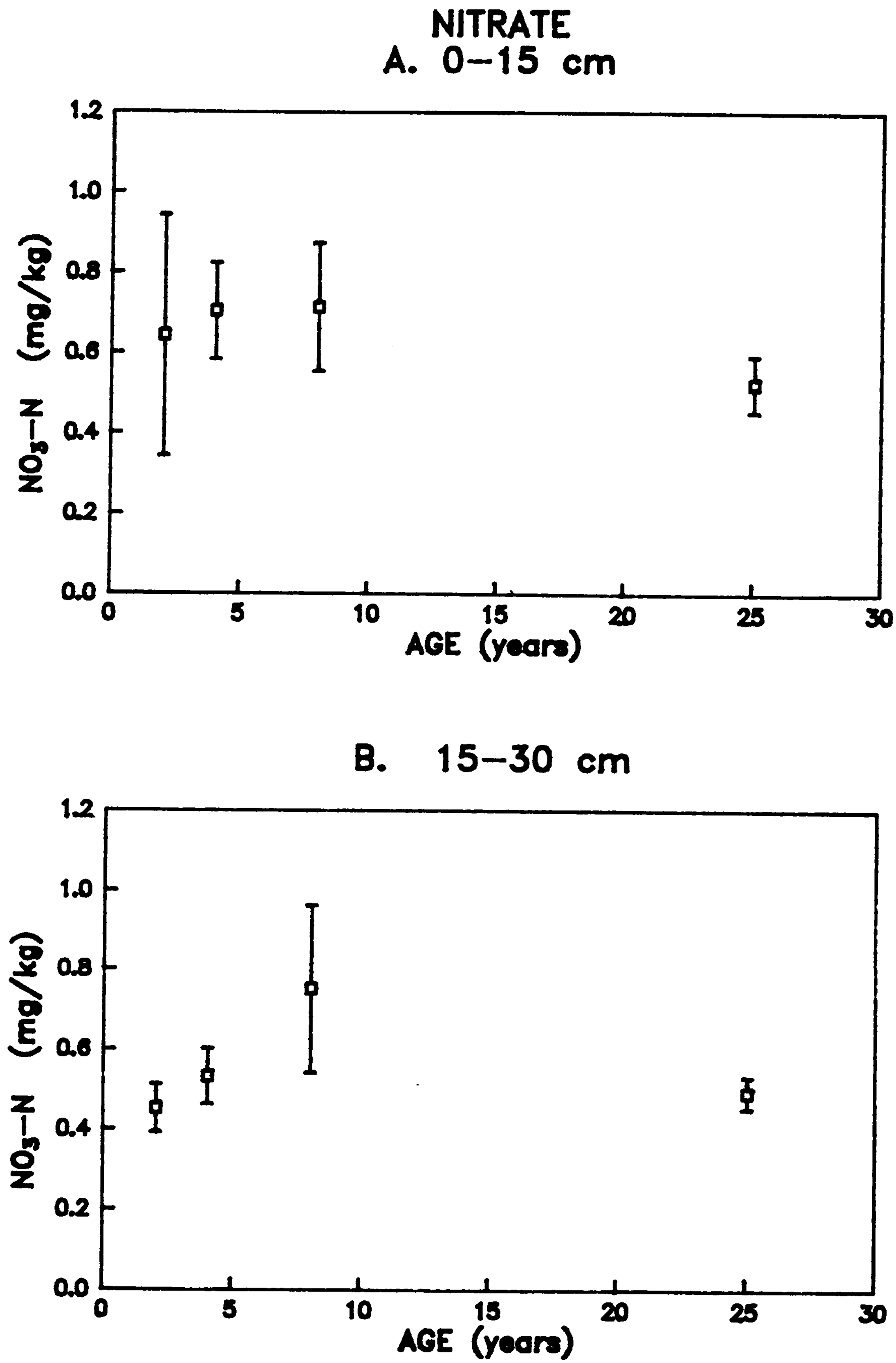


Figure 33. Exchangeable nitrate-nitrogen (NO_3-N) of soils in the scrub stands.

C-2

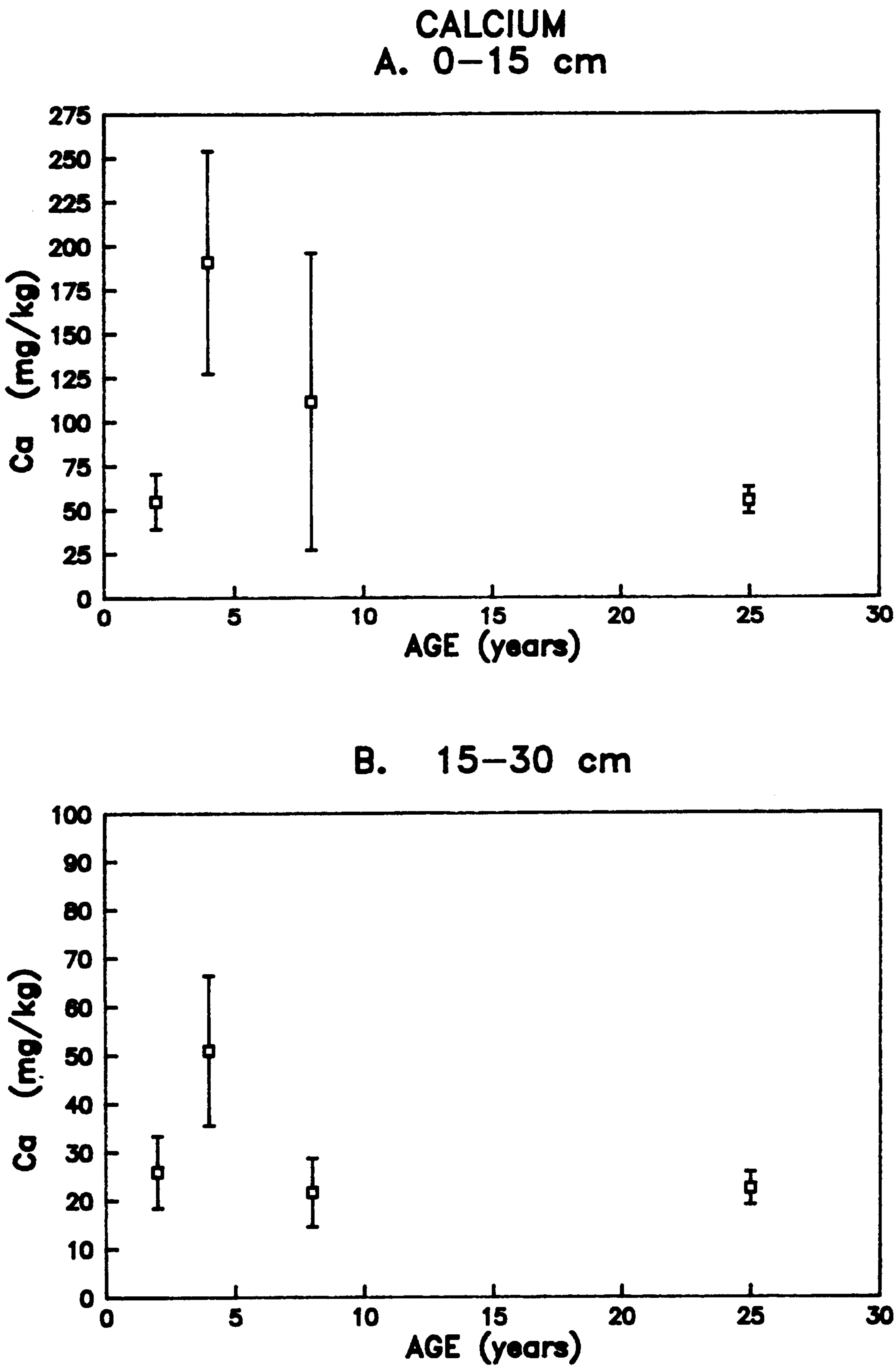


Figure 34. Exchangeable calcium (Ca) of soils in the scrub stands.

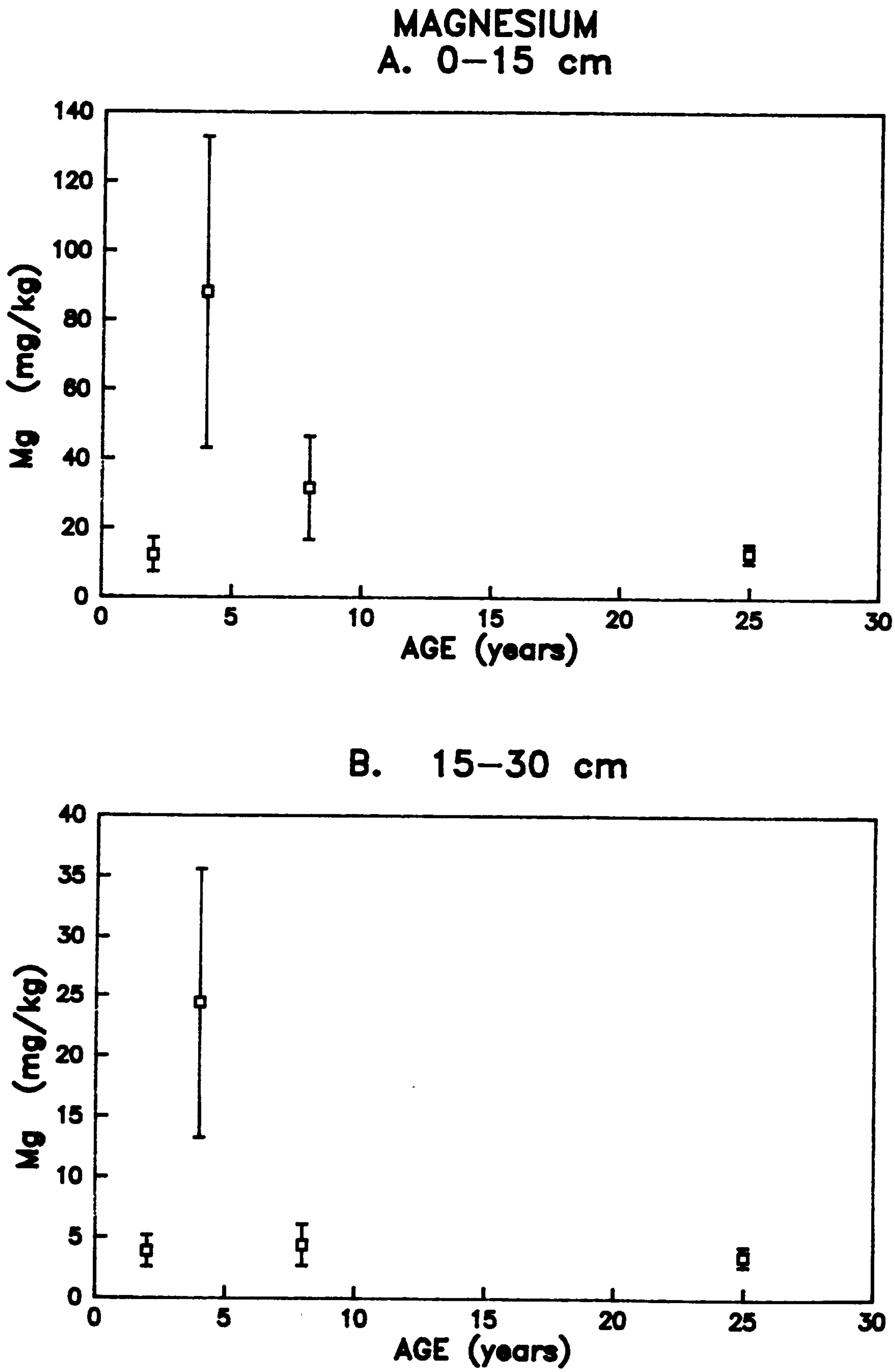


Figure 35. Exchangeable magnesium (Mg) of soils in the scrub stands.

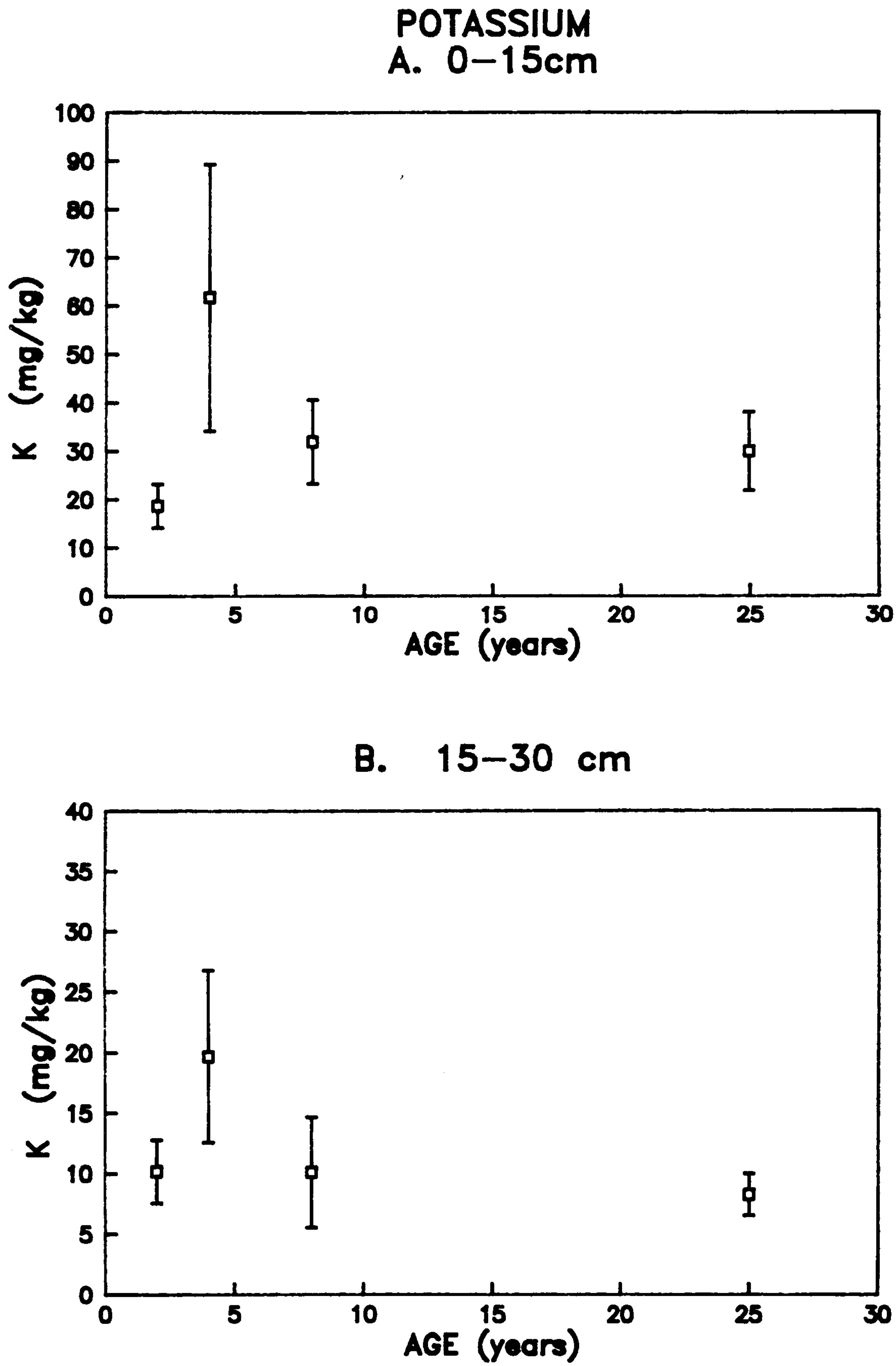


Figure 36. Exchangeable potassium (K) of soils in the scrub stands.

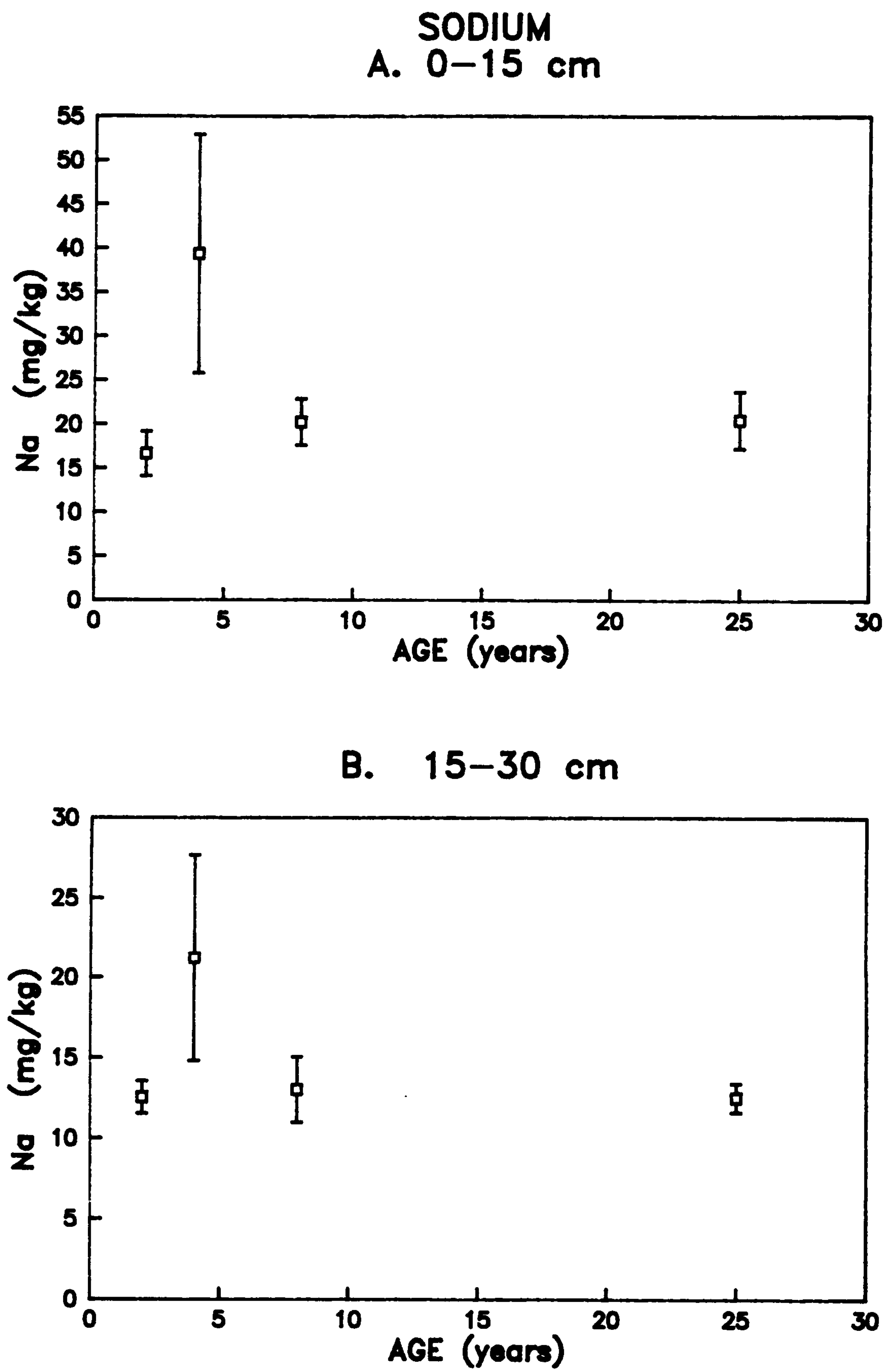


Figure 37. Exchangeable sodium (Na) of soils in the scrub stands.

Aluminum (Figure 38) and manganese (Figure 39) did not differ between stands (Tables 25, 26). Copper (Figure 40) and iron (Figure 41) showed some differences between stands in the 0-15 cm layer (Tables 25, 27) but these differences were not clearly related to time since fire. Zinc (Figure 42) was lower in the 0 to 15 cm layer in the most recently burned stand relative to two of the other stands (Tables 25, 27).

Nutrient Standing Crops in Biomass and Soils

Standing crops of nutrients and metals in soils of the scrub stands are summarized in Table 33. For all parameters except aluminum and copper, standing crops were greater in the 0 to 15 cm layer than in the 15 to 30 cm layer; aluminum and copper were in approximately equal amounts in both layers.

Total Kjeldahl nitrogen standing crops in living and dead biomass equalled or exceeded that in soil (0-30 cm) in three of four scrub stands (Table 34, Figure 43). Stand 2 with greater organic matter in the soil had a much greater standing crop of nitrogen in the soil than the other stands and more in the soil than in biomass.

Standing crops of phosphorus in living and dead biomass exceeded that in soil (0-30 cm) for all stands (Table 35, Figure 44). Stand 2 had much more soil phosphorus than the other stands probably due to greater soil organic matter. Saw palmetto rhizomes were a major pool in three of four stands where they had high biomass.

Calcium standing crops in living and dead biomass exceeded that in soil (0-30 cm) for all stands (Table 36, Figure 45). Stand 2 had greater amounts of calcium in the soil than the other stands. Palmetto rhizomes were a major pool in three of the four stands.

Magnesium standing crops in living and dead biomass exceeded that in soil (0-30 cm) for two stands while soil was the greater pool in the other two stands (Table 37, Figure 46). Stand 2 had a much greater soil magnesium standing crop than the other stands.

Potassium standing crops in living and dead biomass exceeded that in soil (0-30 cm) for all stands (Table 38, Figure 47). Saw palmetto rhizomes were a particularly important pool for potassium. In the oldest stand which had much less saw palmetto rhizome biomass, soil and biomass pools of potassium were nearly equal.

Standing crops of sodium in living and dead biomass exceeded that in soil (0-30 cm) for three of the four scrub stands (Table 39, Figure 48). Saw palmetto rhizomes were the major biomass

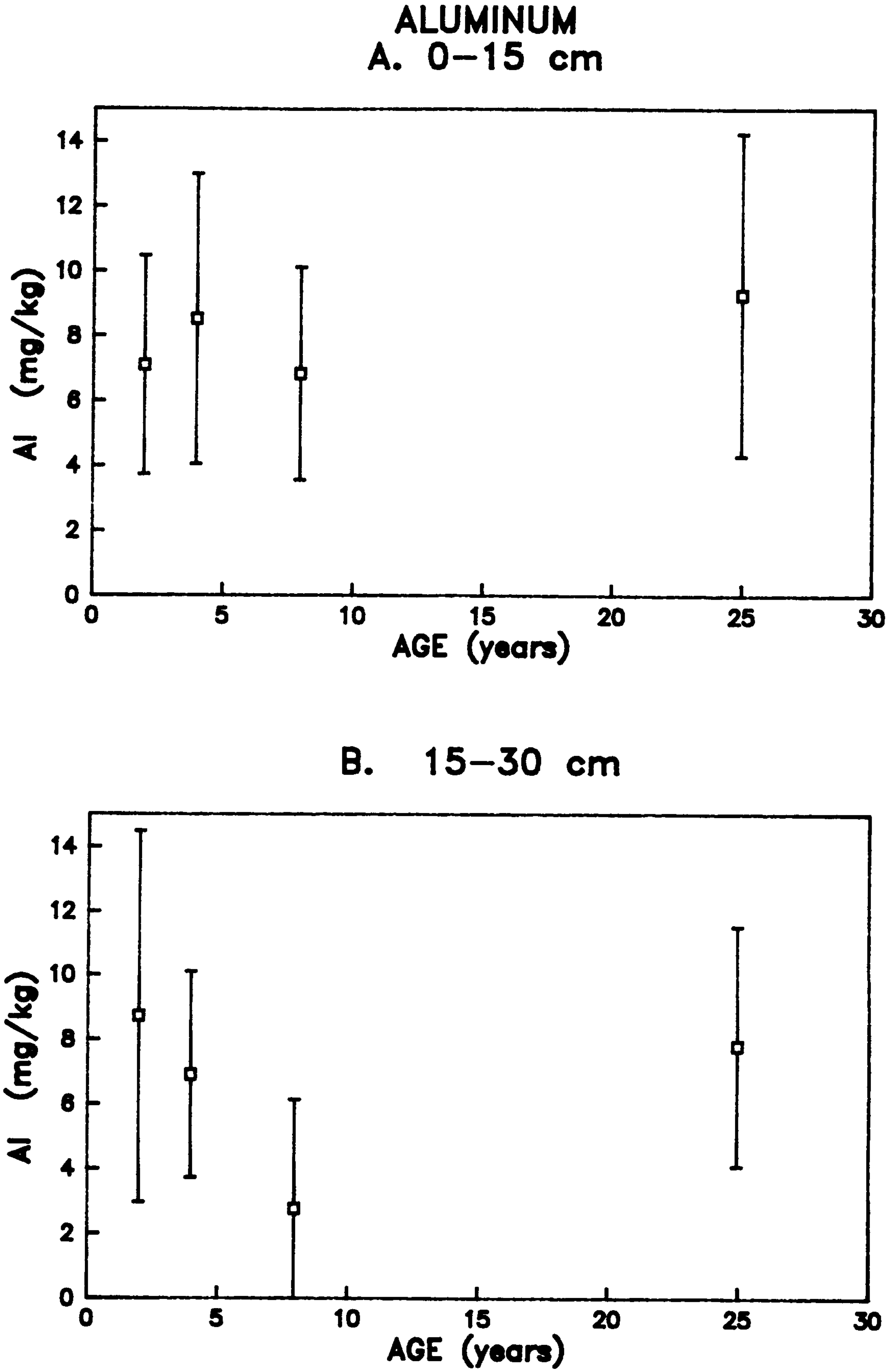
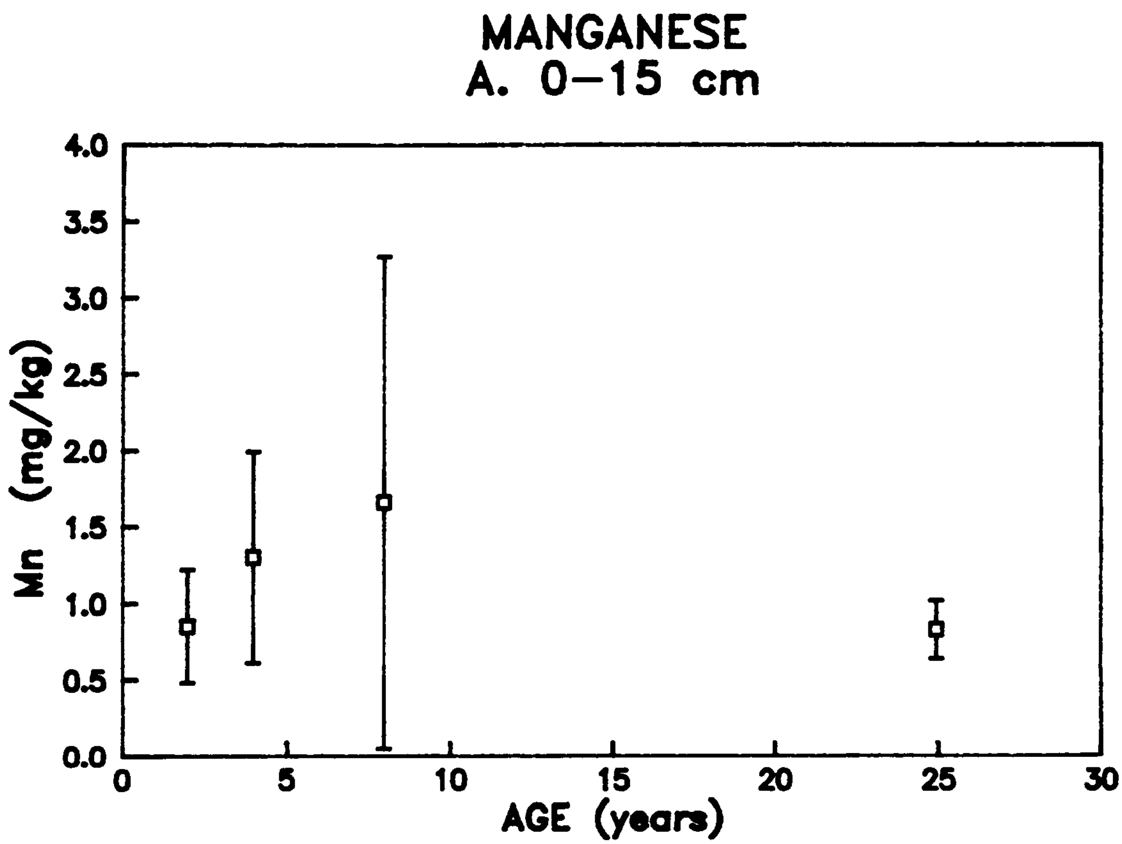


Figure 38. Exchangeable aluminum (Al) of soils in the scrub stands.



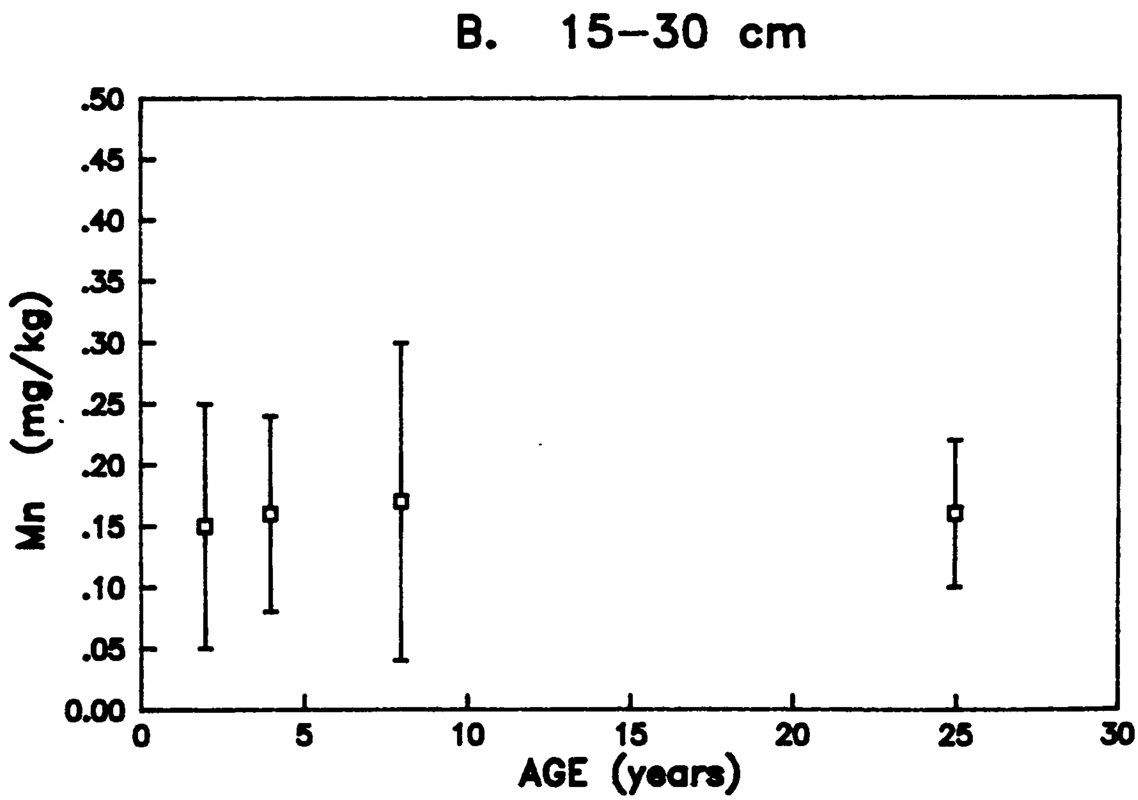


Figure 39. Available manganese (Mn) of soils in the scrub stands.

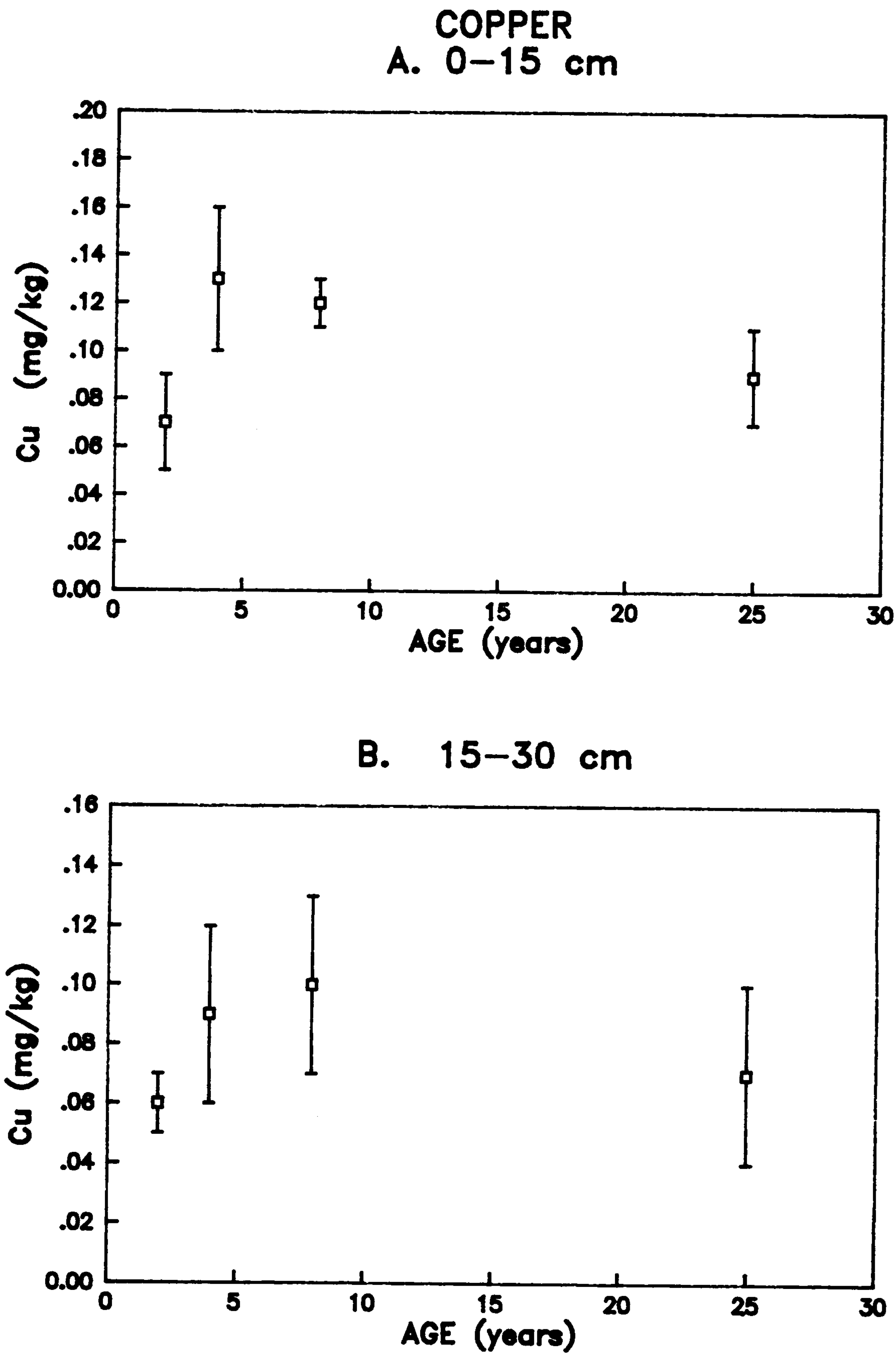


Figure 40. Available copper (Cu) of soils in the scrub stands.

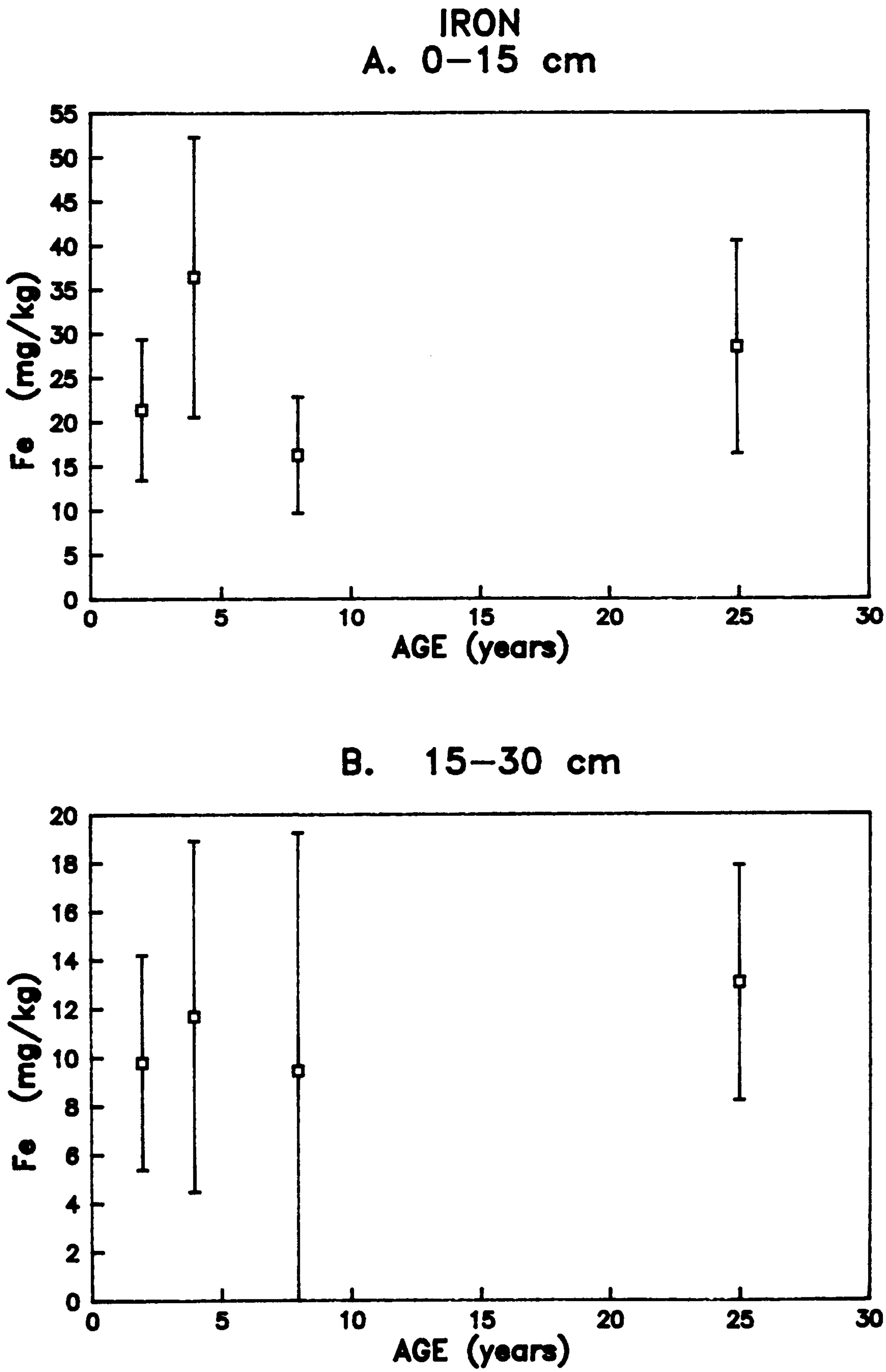


Figure 41. Available iron (Fe) of soils in the scrub stands.

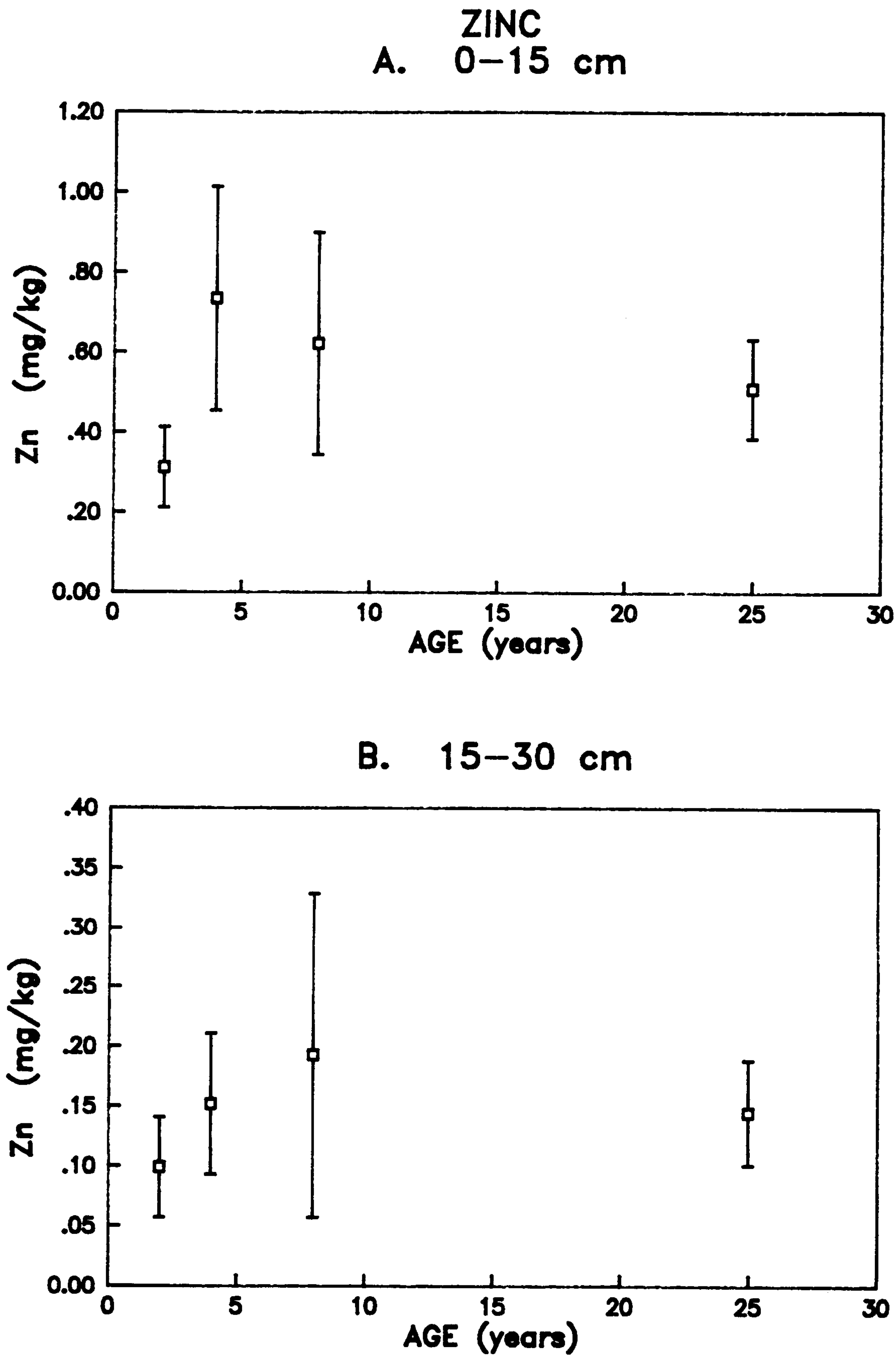


Figure 42. Available zinc (Zn) of soils in the scrub stands.

Table 33. Standing crops of nutrients and metals (g/m^2/horizon) in soils of the scrub stands.

Parameter	Horizon	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Phosphorus	0-15cm	0.162	1.802	0.571	0.319
	15-30cm	0.045	0.574	0.203	0.068
Total Kjeldahl nitrogen	0-15cm	36.209	228.886	80.870	52.292
	15-30cm	18.826	58.631	14.684	20.709
Nitrate-nitrogen	0-15cm	0.115	0.126	0.128	0.094
	15-30cm	0.081	0.119	0.169	0.113
Ammonia-nitrogen	0-15cm	1.136	4.367	1.841	1.823
	15-30cm	0.351	1.150	0.563	0.491
Calcium	0-15cm	9.851	34.322	20.043	9.914
	15-30cm	5.828	11.471	4.867	5.033
Magnesium	0-15cm	2.198	15.840	5.679	2.335
	15-30cm	0.869	5.492	0.988	0.792
Potassium	0-15cm	3.339	11.092	5.728	5.360
	15-30cm	2.279	4.417	2.261	1.845
Sodium	0-15cm	2.983	7.070	3.629	3.683
	15-30cm	2.815	4.772	2.925	2.808
Aluminum	0-15cm	1.278	1.534	1.229	1.669
	15-30cm	1.964	1.557	0.623	1.760
Copper	0-15cm	0.013	0.023	0.022	0.016
	15-30cm	0.014	0.020	0.023	0.016
Iron	0-15cm	3.843	6.550	2.920	5.121
	15-30cm	2.203	2.630	2.126	2.936
Manganese	0-15cm	0.153	0.234	0.299	0.149
	15-30cm	0.034	0.036	0.038	0.036
Zinc	0-15cm	0.056	0.132	0.112	0.092
	15-30cm	0.022	0.034	0.043	0.033
Organic matter	0-15cm	3240	15840	6480	5940
	15-30cm	2925	7200	1350	2700

Table 34. Summary of standing crops of total Kjeldahl nitrogen (TKN) (g/m^2) in biomass and soil of scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	21.746	23.603	28.977	55.350
Saw palmetto rhizomes	23.754	41.156	43.354	3.125
Total live	45.500	63.758	74.332	58.475
Litter and standing dead	62.639	21.840	46.988	22.727
Total above ground	108.139	85.598	121.320	78.107
Soil 0-15 cm	36.209	228.886	80.870	52.292
Soil 15-30 cm	18.826	58.631	14.684	20.709
Soil Total 0-30 cm	55.035	287.517	95.554	73.001

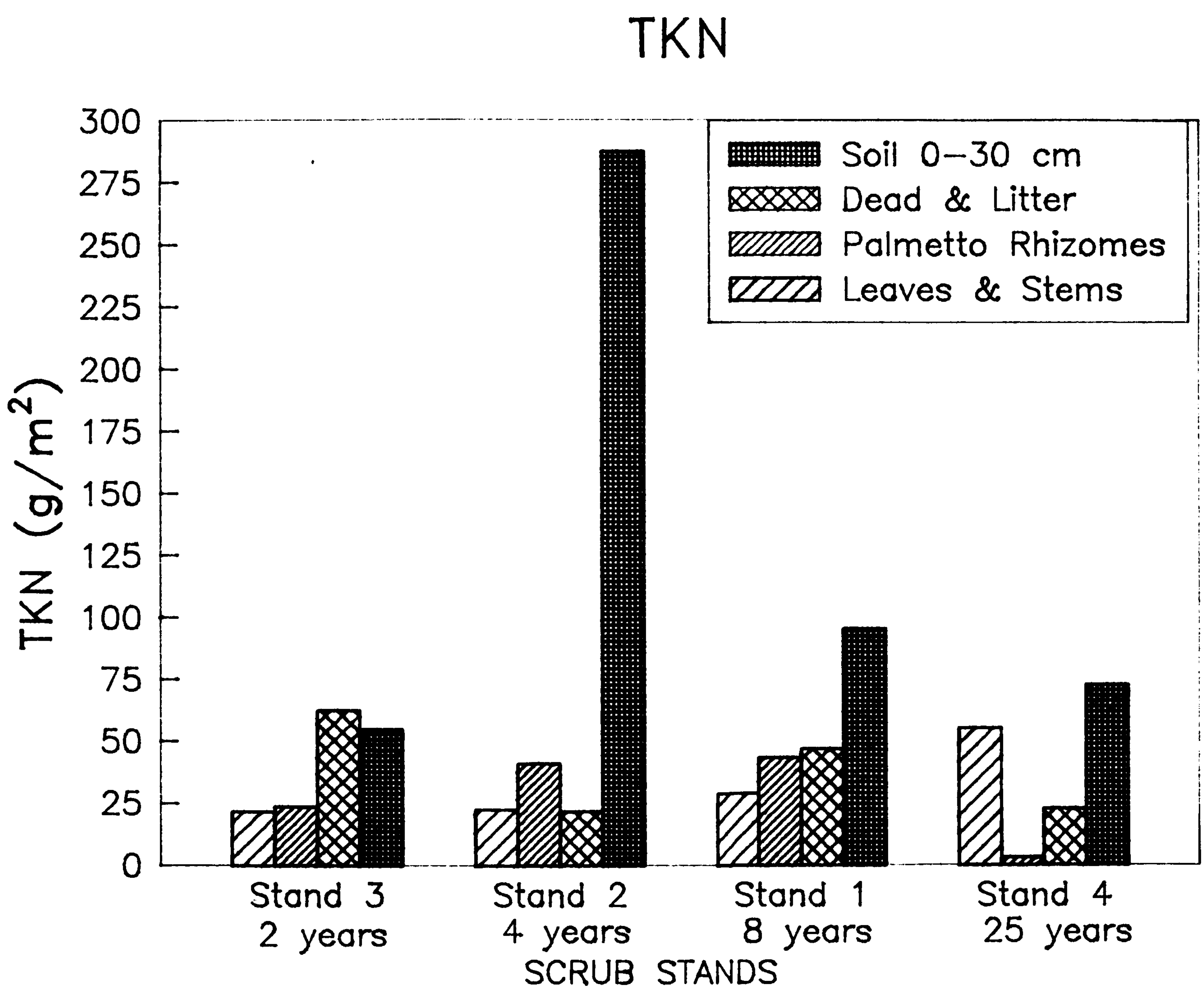


Figure 43. Standing crops of total Kjeldahl nitrogen (TKN) in biomass and soil of scrub stands.

Table 35. Summary of standing crops of phosphorus (P) (g/m^2) in biomass and soil of the scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	0.736	0.738	0.832	1.369
Saw palmetto rhizomes	1.357	2.352	2.592	0.179
Total live	2.093	3.090	3.423	1.548
Litter and standing dead	0.505	0.180	0.394	0.413
Total above ground	2.598	3.269	3.817	1.960
Soil 0-15 cm	0.162	1.802	0.571	0.319
Soil 15-30 cm	0.045	0.574	0.203	0.068
Soil Total 0-30 cm	0.207	2.376	0.774	0.387

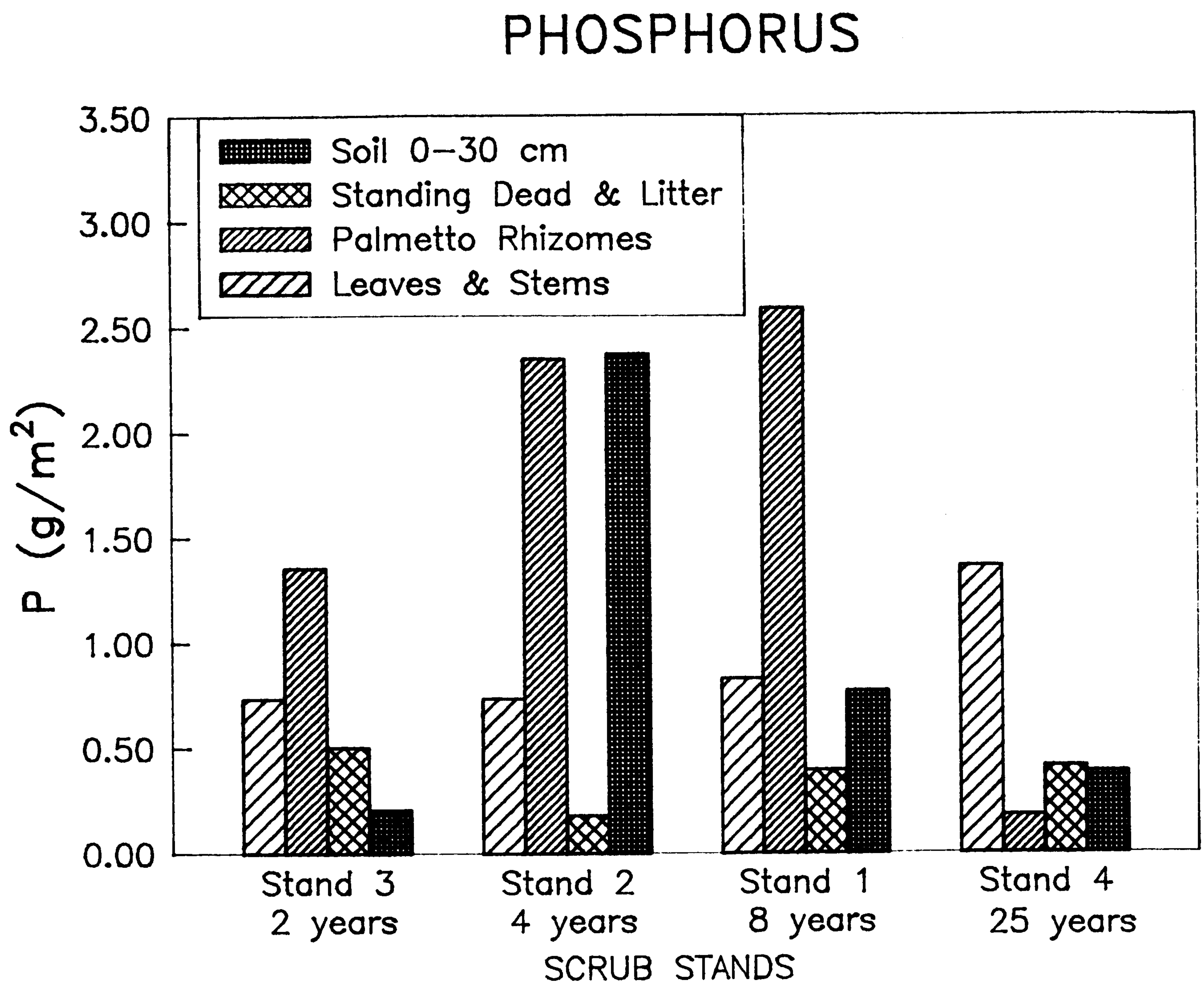


Figure 44. Standing crops of phosphorus (P) in biomass and soil of scrub stands.

Table 36. Summary of standing crops of calcium (Ca) (g/m^2) in biomass and soil of the scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	6.085	4.186	7.835	17.719
Saw palmetto rhizomes	32.916	57.030	62.848	4.330
Total live	39.001	61.216	70.683	22.049
Litter and standing dead	8.995	3.467	6.230	11.647
Total above ground	47.995	64.683	76.913	33.696
Soil 0-15 cm	9.851	34.322	20.043	9.914
Soil 15-30 cm	5.828	11.471	4.867	5.033
Soil Total 0-30 cm	15.679	45.793	24.910	14.947

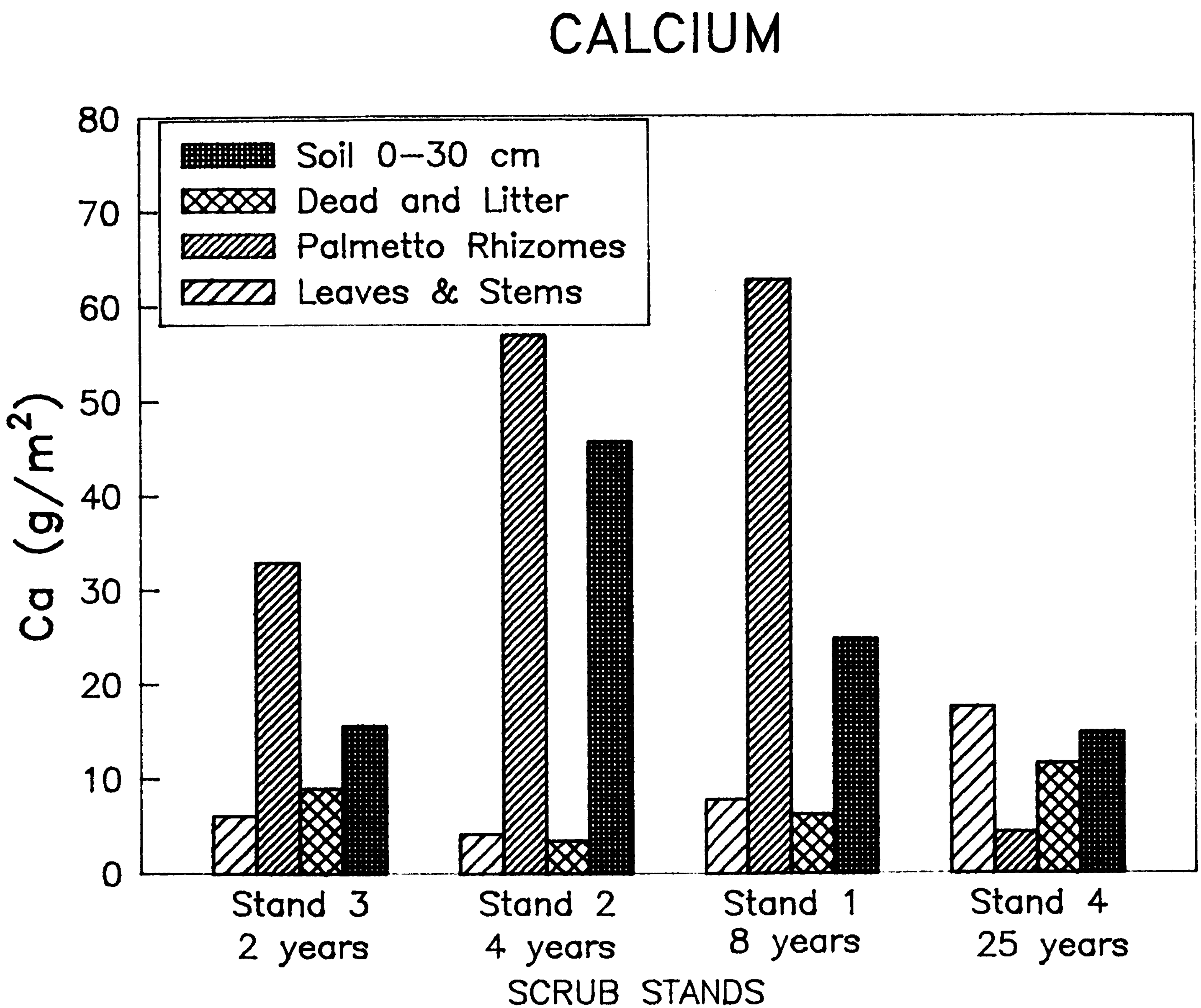


Figure 45. Standing crops of calcium (Ca) in biomass and soil of scrub stands.

Table 37. Summary of standing crops of magnesium (Mg) (g/m^2) in biomass and soil of the scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	1.435	1.526	2.530	2.772
Saw palmetto rhizomes	2.138	3.704	4.082	0.281
Total live	3.573	5.230	6.612	3.054
Litter and standing dead	1.540	1.020	2.134	1.698
Total above ground	5.113	6.250	8.746	4.752
Soil 0-15 cm	2.198	15.840	5.679	5.360
Soil 15-30 cm	0.869	5.492	0.988	1.845
Soil Total 0-30 cm	3.067	21.332	6.667	7.205

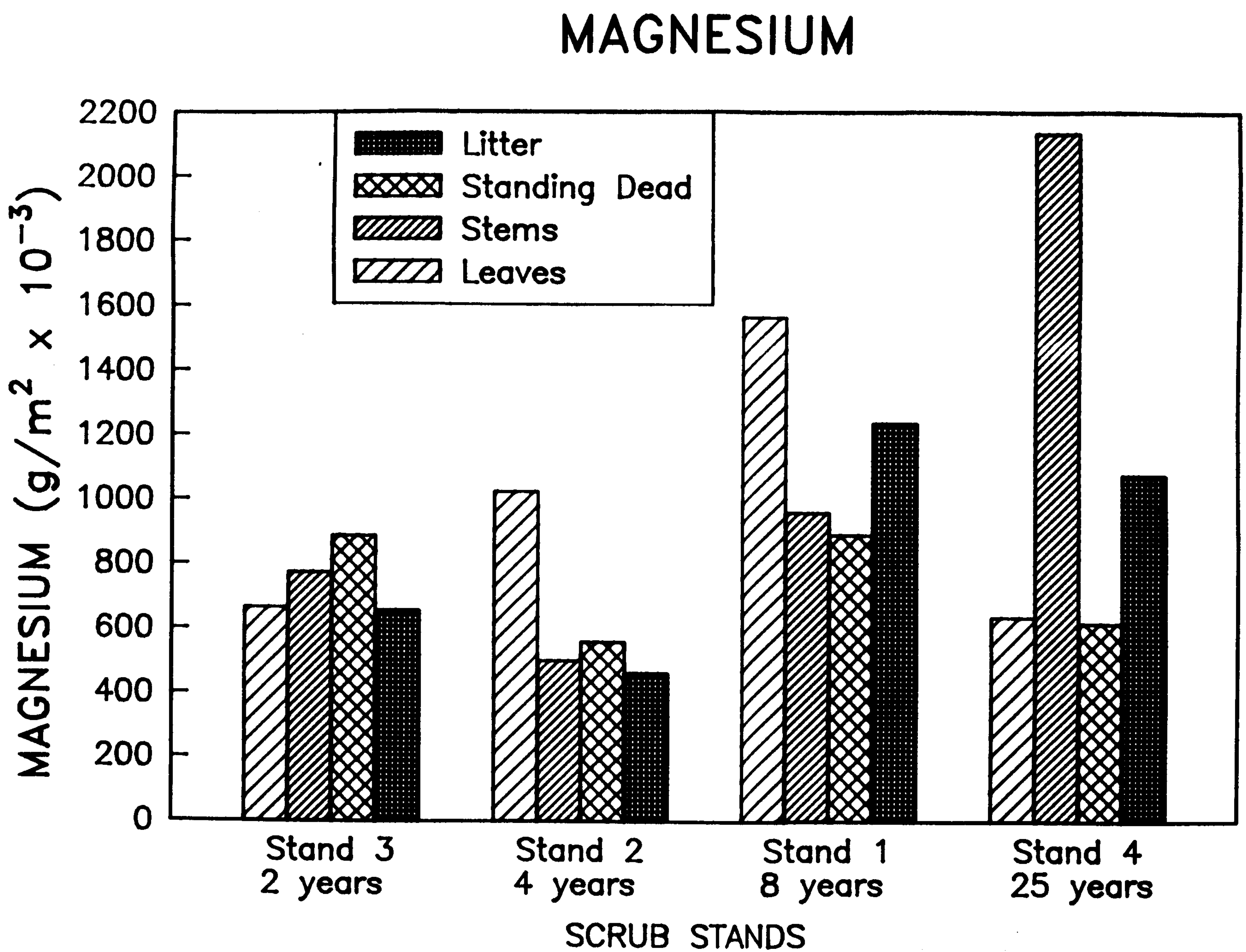


Figure 46. Standing crops of magnesium (Mg) in biomass and soil of scrub stands.

Table 38. Summary of standing crops of potassium (K) (g/m^2) in biomass and soil of the scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	3.019	3.312	3.837	4.375
Saw palmetto rhizomes	16.560	28.691	31.621	2.178
Total live	19.579	32.004	35.458	6.553
Litter and standing dead	4.222	0.677	2.328	1.479
Total above ground	23.801	32.681	37.786	8.032
Soil 0-15 cm	3.339	11.092	5.728	5.360
Soil 15-30 cm	2.279	4.417	2.261	1.845
Soil Total 0-30 cm	5.618	15.509	7.989	7.205

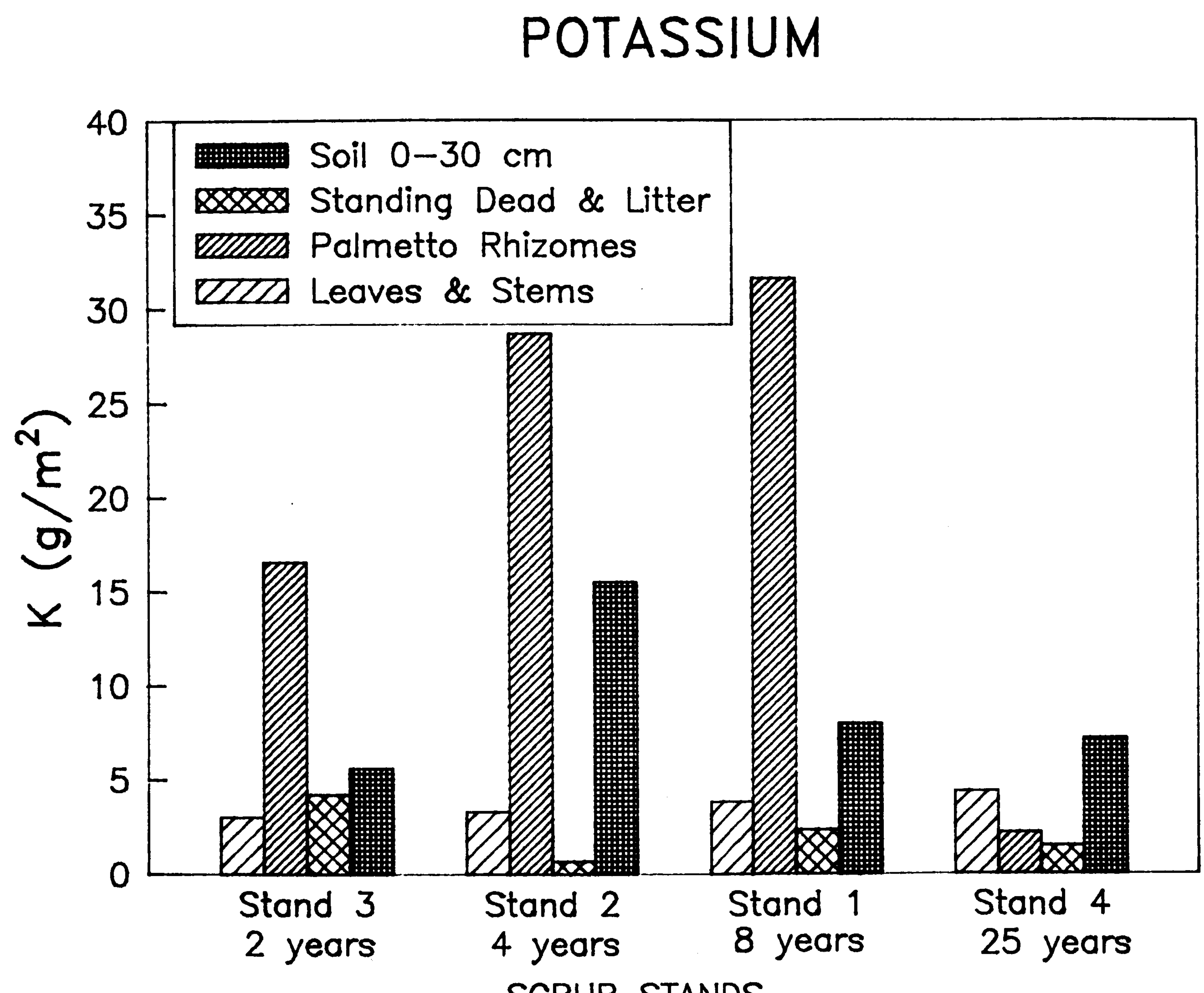


Figure 47. Standing crops of potassium (K) in biomass and soil of scrub stands.

Table 39. Summary of standing crops of sodium (Na) (g/m^2) in biomass and soil of the scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	0.510	1.218	1.012	1.037
Saw palmetto rhizomes	8.959	15.522	17.105	1.179
Total live	9.468	16.740	18.117	2.215
Litter and standing dead	0.604	0.414	0.651	0.563
Total above ground	10.072	17.153	18.769	2.777
Soil 0-15 cm	2.983	7.070	3.629	3.683
Soil 15-30 cm	2.815	4.772	2.925	2.808
Soil Total 0-30 cm	5.798	11.842	6.554	6.491

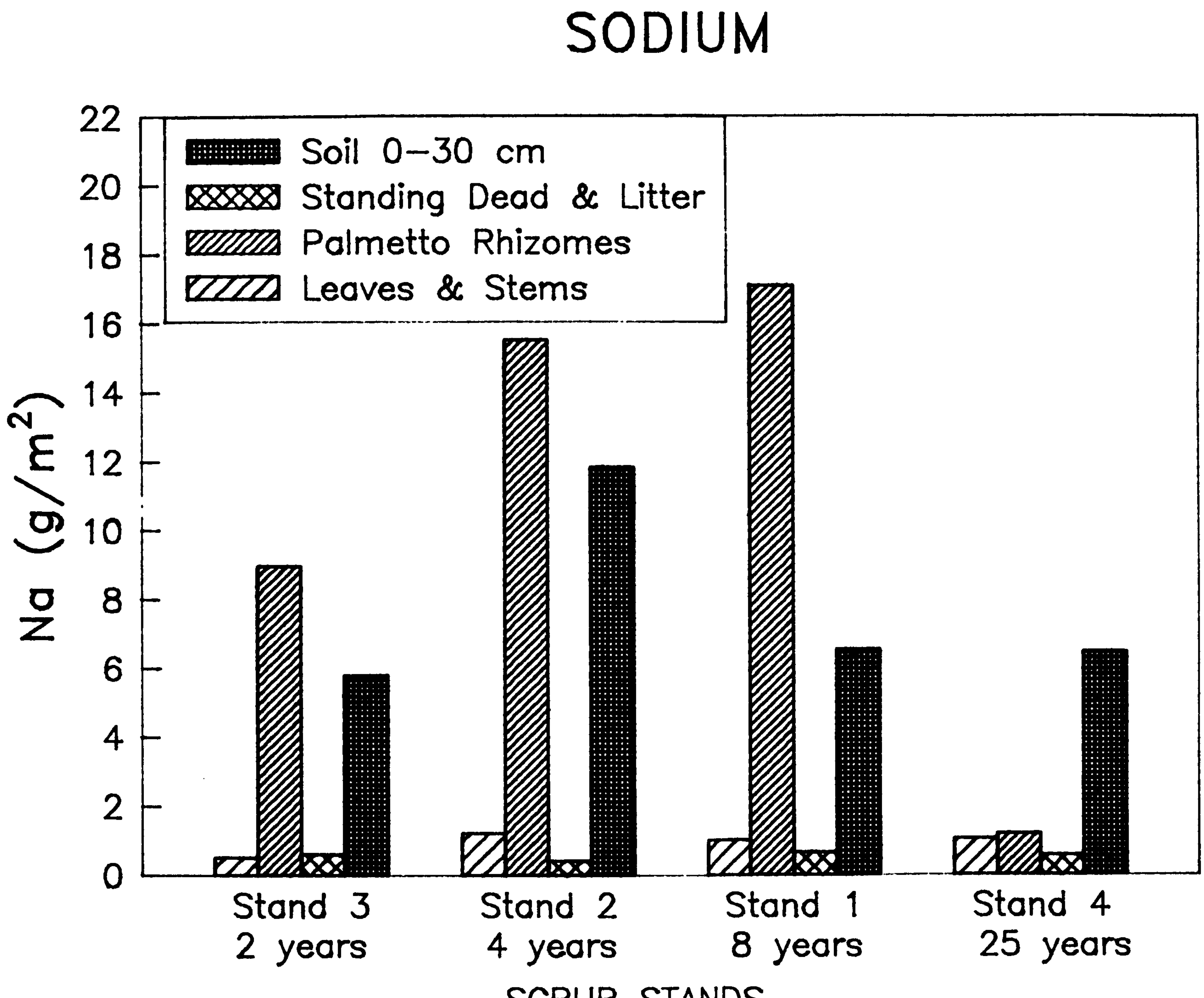


Figure 48. Standing crops of sodium (Na) in biomass and soil of scrub stands.

pool. Stand 4 with relatively little saw palmetto rhizome biomass had a greater pool of sodium in the soil than in biomass.

Aluminum was different from the other elements in that its standing crop in soil was much greater than that in living and dead biomass (Table 40, Figure 49).

DISCUSSION

This study has provided considerable information pertinent to understanding the dynamics of oak scrub on Merritt Island. Such information is applicable to determining impacts of KSC operations and land use management strategies (e.g., prescribed fire) in comparison to expected natural changes or characteristics of the extensive oak scrub type. The information discussed in more detail below includes:

1. Characterization of the community compared to others throughout Florida in terms of species composition and structure.

2. Response of the community to fire and the effects of fire on stand composition and structure.

3. Effects of fire-caused changes on habitat quality for certain scrub endemic animals.

4. The dynamics of biomass changes in relation to litter and fuel accumulation as compared to different aged stands and to other similar community types.

5. The dynamics of nutrient budgets in relation to soils and biomass pools in different aged stands and in comparison to other community types.

Community Composition

Scrub stands sampled in this study should be classified as oak scrub as used by the Florida Natural Areas Inventory (Duever 1983a). This term is more descriptive and accurate than terms previously applied such as "scrubby flatwoods" since oak scrub lacks any pine canopy or "coastal scrub" since oak scrub occurs inland on Merritt Island well out of the salt spray zone. Along the soil moisture-depth to water table gradient, oak scrub grades into saw palmetto scrub. Saw palmetto scrub is a better term than previous terms such as "pineless flatwoods." Currently, data are not available to determine whether saw palmetto scrub historically had a pine overstory or whether it might develop one in the future, therefore, saw palmetto scrub should be differentiated from pine flatwoods.

Table 40. Summary of standing crops of aluminum (Al) (g/m^2) in biomass and soil of the scrub stands.

Category	Stand 3 2 years	Stand 2 4 years	Stand 1 8 years	Stand 4 25 years
Leaves and stems	0.0105	0.0065	0.0391	0.0298
Saw palmetto rhizomes	0.0441	0.0764	0.0842	0.0058
Total live	0.0545	0.0829	0.1233	0.0356
Litter and standing dead	0.0226	0.0368	0.0729	0.0221
Total above ground	0.0772	0.1197	0.1961	0.0578
Soil 0-15 cm	1.2780	1.5340	1.2290	1.6690
Soil 15-30 cm	1.9640	1.5570	0.6230	1.7600
Soil Total 0-30 cm	3.2420	3.0910	1.8520	3.4290

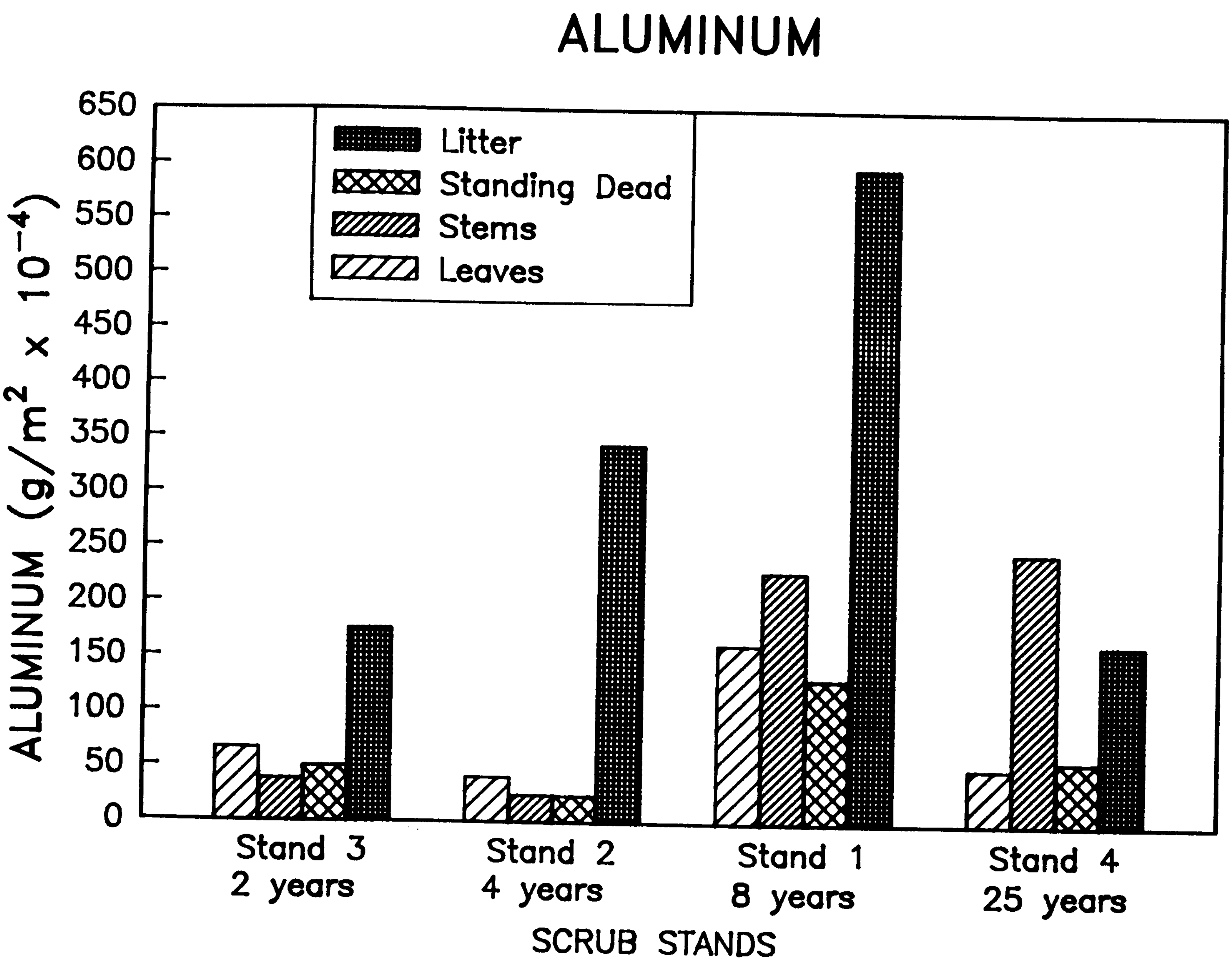


Figure 49. Standing crops of aluminum (Al) in biomass and soil of scrub stands.

Some unique features of oak scrub vegetation on Merritt Island should be recognized. Few open areas occur in undisturbed oak scrub vegetation on Merritt Island unlike the openings described in classic sand pine scrub (Webber 1935, Mulvania 1931). Many of the endemic species of scrub plants occurring on the Lake Wales Ridge (Abrahamson et al. 1984) do not occur in oak scrub on Merritt Island. Even though rosemary and scrub hickory occur on Cape Canaveral and in the vicinity of False Cape, they are absent from the inland stands sampled in this study. Compared to "scrubby flatwoods" at Archbold Biological Station on Lake Wales Ridge, oak scrub on Merritt Island lacks scrub palmetto (Sabal etonia) and myrtle oak replaces Quercus inopina. Ground cover by Cladonia lichens or Selaginella is less common in oak scrub on Merritt Island than that on Lake Wales Ridge (Abrahamson et al. 1984).

The post-fire response of oak scrub vegetation on Merritt Island is similar to that reported by Abrahamson (1984a,b) for "scrubby flatwoods" on the Lake Wales Ridge. Oak scrub is dominated by sprouting species that recover after fire. Little change in species composition or species richness occurs. Cover in the ground layer (<0.5 m) recovers fairly rapidly. Open spaces do not persist for long and therefore there is little opportunity for invasion by new species. Herbaceous species are not a major component of oak scrub on Merritt Island and show no growth or invasion response that persists to two years post-fire. Scrub vegetation is thus much different from pine-wiregrass savannas where frequent fire maintains high species diversity (Walker and Peet 1983). Fire is also thought to maintain species diversity in many other shrublands (Christensen 1985, Gill and Groves 1981, Kruger 1983).

Community beta diversity in Merritt Island oak scrub did not change with fire indicating that the rate of turnover of species along the gradient is unchanged. Beta diversity values for scrub are similar to those reported for mallee (semiarid shrub Eucalyptus) communities in Australia (Whittaker et al. 1979b) and mesquite grassland in Texas (Whittaker et al. 1979a). Longer vegetation gradients such as those in cove forests of the Cumberland Plateau in Tennessee (Schmalzer 1982) have substantially greater beta diversities.

Similar responses to fire occur in the Pine Barrens of New Jersey (Boerner 1981, Buchholz 1982), however; more of the species in the pine barrens are fire resistant, surviving fire. Sprouting species are also of importance in California chaparral (Hanes 1971), pocosins in the Carolinas (Christensen et al. 1981), and other shrublands (Gill and Groves 1981, Kruger 1983).

Our findings concur with those of Abrahamson (1984a,b) in that recovery after fire in oak scrub is not a successional development in the classical sense since the species present before the fire are those that come back immediately post-fire.

Even the oldest scrub stand sampled here showed no invasion by hammock species, only structural changes from continued height and biomass growth. This agrees with the lack of successional change in scrub communities found by Givens et al. (1984), Veno (1976), and Peroni and Abrahamson (1986).

Community Structure

Fire has substantial and long-lasting effects on community structure. Unlike the patchy fires reported for "scrubby flatwoods" at Archbold Biological Station, the fires which burned Stands 2 and 3 on Merritt Island were essentially complete. Oak scrub will not burn under all conditions; attempts to burn Stand 1 by aerial ignition in the winter of 1983 (a wet winter) failed (P. Schmalzer pers. obs.). Total cover in the greater than 0.5 m layer requires ca. 6 years to reach 100%; mean height also requires 4 to 6 years to exceed 1 m. Initially, this rate of recovery of canopy cover appears slower than that on Lake Wales Ridge "scrubby flatwoods." However, Abrahamson (1984a, b) did not consider cover in height classes and thus when he states that "scrubby flatwoods" recovered its preburn coverage in two years after fire it is without reference to height classes. Also, the fire at Archbold burned about 30 to 60% of the vegetation along transects while those on Merritt Island burned nearly 100%. Rates of height growth for individual species (Abrahamson 1984a, b) seem comparable between the two sites.

These structural changes have implications for the suitability of this habitat for scrub endemic animals, particularly Florida scrub jay. Scrub jays prefer oak-dominated scrub about 1 to 3 m in height where open areas (sand or vegetation <15 cm) occur (Breininger 1981, Cox 1984). At the rates shown here for oak scrub on Merritt Island, 4 to 6 years are required for scrub mean height to reach 1 m and height is less than 3 m at 25 years although some individual oaks exceed 3 m at 25 years of age. Open areas are, however, uncommon in undisturbed oak scrub and do not persist long after fire. A fire rotation of three years or less if uniformly (and successfully) applied would produce suboptimal habitat for scrub jays but so would complete fire suppression. A mosaic of burned areas providing openings and more mature scrub providing height would apparently be preferable to uniform treatment. Christensen (1985) stated that it may be important to incorporate variability into management strategies for shrublands in general.

Biomass

Live biomass (excluding saw palmetto rhizomes) in these stands of oak scrub (970-2300 g/m^2) is comparable to that (1050 g/m^2) reported by Hough (1982) for the saw palmetto-gallberry understory of slash pine forests. They are also in the same range (500-4000 g/m^2) as pocosins (Wilbur and Christensen 1983). Chaparral is also similar with biomass ranging from 1440 g/m^2 for coastal sage scrub to 7624 g/m^2 for Ceanothus chaparral (Gray 1982) as are other shrublands (Rundel 1983). The oak scrub component of pine barrens vegetation has a biomass of about 500 g/m^2 2 to 3 years after wildfire; however, the presence of a pitch pine canopy (1000-2000 g/m^2) makes the total biomass of pine barrens communities greater (Boerner 1981).

Saw palmetto rhizomes accumulated considerable biomass (220-3210 g/m^2) in the stands studied. Hough (1982) reported a mean of 560 g/m^2 for palmetto rhizomes in the saw palmetto-gallberry understory of slash pine stands; three of four stands studied here exceed that. Saw palmetto rhizomes are a unique element of the scrub community. They are generally unaffected by fire (Burton and Hughes 1961) forming a persisting element of aboveground biomass. Functionally, these rhizomes appear to combine elements of an aboveground stem with that of an underground root system, a situation with some parallels in the lignotubers of Eucalyptus species in the mallee scrub of Australia and other Mediterranean type shrublands (Walter 1979, James 1984). Christensen (1985) indicates that basal bud burls or lignotubers are common in shrublands where periodic intense fires occur and may account for a considerable portion of shrub biomass. Belowground biomass data on scrub vegetation at Archbold Biological Station suggests that it is equal or greater than aboveground (Johnson et al. 1986).

Litter accumulation in oak scrub (440-1200 g/m^2) is less than that reported (1860 g/m^2) for slash pine/saw palmetto-gallberry vegetation (Hough 1982) perhaps because of no needle fall from canopy trees. Pine barrens have more similar litter standing crops with 530 g/m^2 one year post-fire to 1030 g/m^2 in a control site (Boerner 1983). Chaparral also has generally comparable standing crops of litter (620-2030 g/m^2) (Gray 1982). Litter production and decomposition in oak scrub appear to reach equilibrium in about 8 years. McNab et al. (1978) report that the forest floor loading of slash pine/palmetto stands increases rapidly for 5 years post-fire and then decreases to equilibrium at 20 years; lack of decay resistant pine litter accounts for the more rapid equilibrium in oak scrub.

Standing dead biomass forms a conspicuous element in Merritt Island oak scrub communities (570-860 g/m^2). In the 2 year old stand, it was 89% of live biomass and at 25 years age it was 25% of live biomass. Pine barrens have similar amounts of standing dead material (530-750 g/m^2) after wildfire but much less in unburned sites (30 g/m^2) (Boerner 1981). Chaparral communities accumulate considerable standing dead material (250-1140 g/m^2) in 20 year old stands (Gray 1982). Christensen (1985) states that the dead-to-live ratio increases with the age since the last fire in most shrub communities. In oak scrub the ratio of litter plus standing dead to total live was 48.8% in a two year old stand and

66.0% in a 25 year old stand. However, this is due in part to there being fewer saw palmetto rhizomes in the oldest stand sampled.

Biomass Chemistry

Total Kjeldahl nitrogen concentrations reported here in saw palmetto leaves, stems, and rhizomes, gallberry leaves and stems, standing dead material, and litter are greater than those reported by Hough (1982) for these components in the understory of slash/longleaf pine stands. TKN concentrations are higher in scrub oaks than those reported (0.5-1.0%) for oaks at Archbold Biological Station (A. Johnson, pers. com.). Concentrations are in the general range reported for chaparral and coastal sage scrub species (Gray 1983) and various European ericads (Marrs 1978) but slightly higher than most shrub species in an oak-pine forest (Woodwell et al. 1975).

Nitrogen standing crop in live biomass and palmetto rhizomes are also greater than those in the understory of slash/longleaf pine stands (Hough 1982) due to the higher concentrations found here. The size of the nitrogen pool in litter (14.7 g/m^2) (Hough 1982) is generally similar. Chaparral has similar amounts of nitrogen in live biomass (41.7 g/m^2), litter (20.5 g/m^2), and dead wood (6.3 g/m^2); the pools in coastal sage scrub are less (Gray 1983). Rundel (1983) reported above-ground nitrogen pools of 3.4 g/m^2 to 41.1 g/m^2 and litter pools of 2.5 to 23.0 g/m^2 for a variety of shrublands.

Total phosphorus concentrations reported here in saw palmetto, gallberry, litter, and standing dead material are very similar to those reported by Hough (1982). Phosphorus concentrations in oaks are similar to those (<0.1%) at Archbold Biological Station (A. Johnson, pers. comm.). Concentrations are in the same range as chaparral and coastal sage scrub species (Gray 1983), European ericads (Marrs 1978), and oak-pine species (Woodwell et al. 1975).

Phosphorus pools in live biomass in scrub are similar to those in the understory of slash/longleaf pine stands (Hough 1982); the standing dead plus litter pool is less than the forest floor of those pine stands (1.06 g/m^2) while scrub has generally greater amounts in saw palmetto rhizomes. Similar amounts of phosphorus occur in live biomass (2.89 g/m^2), litter (0.60 g/m^2), and dead wood (0.46 g/m^2) in chaparral (Gray 1983). For a variety of shrublands, Rundel (1983) reported aboveground phosphorus pools of 0.14 g/m^2 to 2.9 g/m^2 and litter pools of 0.1 g/m^2 to 2.2 g/m^2.

Calcium concentrations reported here are similar to those reported by Vickers et al. (1975) (Table 8). Considerable seasonal variation occurred in calcium concentration in the two periods (August and April) sampled by Vickers et al. Samples in this study were taken at a third time (January). Calcium concentrations are generally similar to those of Hough (1982). Scrub oaks at Archbold Biological Station have similar concentrations in leaves (0.5-1.0%) but slightly higher concentrations in stems (1.0-1.5%) (A. Johnson, pers. comm.). Concentrations are in the range of chaparral and sage scrub species (Gray 1983), of the ericaceous shrubs in an oak-pine forest (Woodwell et al. 1975), and those of European ericads (Marrs 1978).

Calcium pools in oak scrub are similar to those in the understory of slash/longleaf pine stands (Hough 1982). Chaparral has similar amounts of calcium in live biomass (33.81 g/m^2), litter (26.10 g/m^2), and dead wood (5.58 g/m^2) (Gray 1983).

Magnesium concentrations found here are similar to those of Vickers et al. (1975) (Table 8). These concentrations are also similar to those Hough (1982) reported for these species in slash/longleaf pine stands. Scrub oaks at KSC and Archbold Biological Station have similar concentrations (0.1-0.2%) (A. Johnson, pers. comm.). Magnesium concentrations are in the same range as chaparral and coastal sage scrub species (Gray 1983), European ericads (Marrs 1978), and ericaceous shrubs in an oak-pine forest (Woodwell et al. 1975).

Magnesium pools in oak scrub in palmetto rhizomes are greater then those reported by Hough (1982) while litter and live biomass pools are similar. Chaparral has a similar amount of magnesium in live biomass (4.24 g/m^2) but more litter (6.70 g/m^2) (Gray 1983).

Sodium concentrations found here are similar or less than those of Vickers et al. (1975) (Table 8). Sodium concentrations are in the same range as European ericads (Marrs 1978) and ericaceous shrubs in oak-pine forest (Woodwell et al. 1975).

Sodium pools in oak scrub are similar to those of the understory of slash/longleaf pine stands for live biomass (1.32 g/m^2) and litter (0.26 g/m^2) (Hough 1982), but palmetto rhizomes are a larger pool in scrub than in the pine stands (1.36 g/m^2).

Potassium concentrations are similar to those found by Vickers et al. (1975) (Table 8) and generally similar to those reported by Hough (1982). Scrub oaks at Archbold Biological Station have similar (<0.5%) concentrations (A. Johnson, pers. comm.). Concentrations are in the same range as chaparral species (Gray 1983), European ericads (Marrs 1978), and oak-pine species (Woodwell et al. 1975).

Oak scrub has similar amounts of potassium in live biomass, palmetto rhizomes, and litter when compared to the understory of slash/longleaf pine stands (Hough 1982). Chaparral vegetation has comparable or larger pools of potassium in live biomass (16.47 g/m^2), dead wood (2.68 g/m^2), and litter (4.70 g/m^2) (Gray 1983).

Aluminum concentrations are generally similar to those found by Vickers et al. (1975). Few studies report aluminum concentrations in vegetation.

Hough (1982) reported larger pools of aluminum in litter (1.42 g/m^2) but similar amounts in live understory biomass (0.07 g/m^2) and palmetto rhizomes (0.05 g/m^2) in slash/longleaf pine stands compared to the oak scrub studied here.

There are no apparent effects of fire on nutrient concentrations in live biomass in the two year old stand. If such changes occurred they did not persist. However, litter did show elevated potassium, calcium, and phosphorous in the youngest stand probably as the result of ash deposition from the fire. Sodium was not increased; it is a more mobile ion and any deposited in ash probably leached into the soil by two years post-fire.

Soil Chemistry

Soil chemical properties in scrub are strongly influenced by soil drainage. Wetter soils (water table closer to surface) have higher amounts of organic matter and consequently higher cation exchange capacity and nutrients. Compared to the effects of soil drainage, the effects of fire that can be detected 2 years post-burn are relatively minor. Greater effects of fire on these soils might be detected if stands were sampled sooner after a fire.

Soil pH is higher in the most recently burned stand. Increase in soil pH is one of the most common effects of fire on soil (Raison 1979, Wells et al. 1979, Rundel 1981, McKee 1982). pH increase generally results from the deposition of basic cations from ash and from the destruction of organic acids in the soil. The decline in available zinc in the most recently burned stand could result from the increased pH decreasing its availability.

Organic matter is reduced in the most recent burn. Reduction in organic matter in mineral soil can result directly from soil heating (Wells et al. 1979) or from increases in decomposition rates due to microclimate or nutrient availability changes influencing microbial activity (Rundel 1981). The decline in organic matter probably accounts for the decline in TKN; since organic matter and TKN are closely related in these soils. Abrahamson (1984a) detected only minor soil changes, primarily an increase in calcium in the surface soil, after fire in scrub at Archbold Biological Station.

Nutrient Standing Crops in Biomass and Soils

The importance of nutrient cycling in determining soil chemical properties is illustrated in that standing crops for biologically important elements are higher in the 0 to 15 cm layer than in the 15 to 30 cm layer. Aluminum which is not important for plant growth and copper which is required in only small amounts (Brady 1974) and more evenly distributed in the soil.

Nutrient standing crops are concentrated in biomass rather than soil to a high degree. For phosphorous, calcium, and potassium, biomass pools exceed those in the soil for all stands. Total Kjeldahl nitrogen is primarily in biomass except in one stand with a higher water table and more organic matter in the soil. Biomass pools of sodium exceed those in the soil except in one stand which has few saw palmetto rhizomes. Magnesium pools in biomass are greater than soil pools in two stands and less in the other two; soil pools are greater where organic matter is high and where there are few saw palmetto rhizomes. Only aluminum has consistently greater pools in soil than biomass.

Belowground biomass was not measured in this study. Quercus inopina clones in scrub at Archbold Biological Station allocated about 70% of their biomass to belowground structures (Johnson et al. 1986). If scrub oaks and other shrubs in scrub at KSC are similar and have even half of their biomass below ground, then it is likely that the biomass pools of most biologically important elements in scrub exceed those in the mineral soil except perhaps on wet sites.

Belowground biomass data are available for relatively few shrub communities. Specht et al. (1958) found that roots in an Australian heath had three times the aboveground biomass at 25 years post-fire. In California chaparral, Kummerow et al. (1977) found less biomass belowground than above.

Nutrient Cycling Considerations

Are nutrient losses from the scrub system from fire significant in terms of preventing or slowing regrowth of the vegetation? Our data are not sufficient to answer the question since it would be necessary to quantify belowground biomass and nutrient pools, leaching and volatilization losses with fire, and post-fire nutrient uptake to provide a complete answer. We can compare nutrient deposition from precipitation (Table 41) to see if it is important relative to biomass pools.

Nitrogen is the element most often lost in significant quantities with fire. Nitrogen deposition in precipitation (0.072 $g/m^2/yr$, Table 41) is minor compared to the biomass

Table 41. Deposition of nutrients in precipitation on Merritt Island.[1]

	Calcium (Ca) (mg/m²/yr)	Magnesium (Mg) (mg/m²/yr)	Sodium (Na) (mg/m²/yr)	Potassium (K) (mg/m²/yr)	Ammonia-Nitrogen (NH_3-N) (mg/m²/yr)	Nitrate-Nitrogen (NO_3-N) (mg/m²/yr)
1984	376.1	450.1	1779.2	96.5	58.5	33.5
1985	335.8	244.8	904.8	48.7	24.0	27.9
$\overline{X}$	356.0	347.5	1342.0	72.6	41.3	30.7
SD	28.5	145.2	618.3	33.8	24.4	4.0

[1]Data are from a rain collector maintained at a central inland site on Merritt Island as part of the National Atmospheric Deposition Program (NADP) (Madsen et al. 1987).

pools. Biological nitrogen fixation in scrub has not been studied. Legumes are not common in these stands of oak scrub. Nitrogen fixation is associated with wax myrtle (Myrica cerifa) (Permar and Fisher 1983); however, the low percent cover of wax myrtle in scrub (1-2%) suggests that nitrogen additions by it are minor. Non-symbiotic nitrogen fixation must occur in scrub. Stimulation of nitrogen fixation after fire has been reported for loblolly pine (Pinus taeda) forests (Jorgensen and Wells 1971). Whether this occurs in scrub is unknown. In saw palmetto stands at Apollo Beach, NO_3-N increased in surface soils over the year following fire (Hinkle et al., unpublished); this may have been due to increased mineralization.

Calcium deposition by precipitation (0.36 $g/m^2/yr$, Table 41) is small compared to total biomass pools. Calcium imputs are more significant when compared to the amount of calcium in leaves and stems; calcium in palmetto rhizomes is not affected by fire. Since calcium is not volatilized in large amounts and is not as mobile in the soil as other cations, precipitation may supply enough to replace the losses from fire.

Magnesium in precipitation (0.35 $g/m^2/yr$, Table 41) is significant compared to biomass pools. Magnesium in leaf and stem biomass (1.4-2.8 g/m^2, Table 37) could accumulate from 4 to 8 years of precipitation.

Potassium deposition by precipitation (.073 $g/m^2/yr$, Table 41) is small compared to biomass pools. Potassium losses could occur since it is generally more mobile in the soil than calcium or magnesium. In contrast, precipitation deposition of sodium (1.34 $g/m^2/yr$) is relatively large compared to biomass pools and losses of it could be replaced.

A biological process (nitrogen fixation) is required to replace nitrogen lost in scrub fires. Nutrient uptake by plants or other processes may be important in limiting the losses of calcium and potassium (present in biomass in amounts large relative to additions in precipitation) and phosphorous (generally below detection limits in precipitation).

Fire Regimes and Long-term Considerations

Several properties of oak scrub place it among those systems which could be considered vulnerable to nutrient losses from fire. Oak scrub occurs on low nutrient soils and much of the nutrient capital is sequestered in biomass rather than the mineral soil; therefore, it qualifies as an oligotrophic system (Boerner 1982). Furthermore, additions of several major nutrients by precipitation are small relative to biomass pools suggesting that efficient nutrient accumulation, retention, and recycling are important to maintaining the stability of the system (Raison 1979).

Scrub species have evolved under regimes of low nutrient soils and repeated fires (Abrahamson 1984a,b). These species have characteristics that are considered adaptations to low nutrient soils including evergreen and sclerophylous leaves (Loveless 1961, 1962, Monk 1966) and other characteristics particularly the dominance of sprouting species that are considered adaptations to repeated fires (Keeley and Zedler 1978, Malanson 1985). However, the same shrub species dominate the understory of sand pine scrub which has a longer (ca. 40 yr) fire cycle (Austin 1976).

In this study we saw little change in species composition with fire, no obvious nutrient deficiencies in the post-fire vegetation, and only minor effects on the soil. This does not necessarily mean that a 3 year fire cycle can be applied to oak scrub without significant impacts. This study could consider only the impacts of a single fire event and not a changed fire regime. There is no convincing evidence that oak scrub had a natural fire regime of 3 years. The best estimates are considerably longer (ca. 10-25 yr) and more variable. Repeated burning on a 3 year cycle could eventually shift the species composition toward those components of the community best adapted to frequent fire (e.g., saw palmetto, wiregrass) and away from the scrub oaks (Davison and Bratton 1986). Long-term impacts on nutrient cycling processes cannot be ruled out on the basis of current data.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

1. Oak scrub is a shrub community dominated by several species of oaks, ericads, and saw palmetto. It is related to inland scrub communities but lacks many of the scrub endemic plants and has few natural openings. Depth to water table influences scrub composition; saw palmetto dominates on wetter sites while oaks dominate on drier sites.

2. Dominant species of the oak scrub community respond to fire by sprouting. Species composition and richness are little changed after fire. Saw palmetto reestablishes cover more rapidly then the oaks and therefore may temporarily assume greater dominance.

3. Major structural changes occur in scrub after fire. Shrub height is reduced and requires 4 to 6 years to exceed 1 m.

4. Reduction in shrub height affects the suitability of scrub for the endemic Florida scrub jay which prefers oak scrub 1 to 3 m in height. A 3 year fire rotation will maintain oak scrub below the optimal height for scrub jays.

5. Live biomass increases with time since fire. Litter biomass increases for about 8 years post-fire. Standing dead biomass and palmetto rhizomes are also important biomass

components. Biomass in oak scrub is similar to that in chaparral and other shrublands.

6. Nutrients concentrations in live biomass do not change with time since fire. Nutrient concentrations in biomass and nutrient standing crop are similar to those in other shrublands. Concentrations of potassium, calcium, and phosphorous are higher in the most recently burned stand probably as a result of ash deposition.

7. Soil chemical properties are strongly influenced by soil drainage; the wetter soils have higher organic matter, greater cation exchange capacity, TKN, and higher concentrations of many nutrients. Effects of fire on scrub soil present 2 years post-fire are relatively minor but include increased pH and decreased organic matter, TKN, and available zinc.

8. Biomass pools of major nutrients (P, K, Ca, TKN, Na) exceed those in the soil in most cases. Concentration of nutrients in biomass may increase the vulnerability of this vegetation to nutrient losses. However, the importance of standing dead biomass, saw palmetto rhizomes, and probably belowground biomass as nutrient pools may help buffer the system against nutrient losses.

9. Deposition rates of nitrogen, phosphorous, calcium, and potassium in precipitation are low compared to biomass pools while deposition of magnesium and sodium is greater relative to amounts in biomass. Nitrogen fixation and mechanisms that retain and recycle nutrients may be important to the persistence of scrub on low nutrient soils.

10. Imposition of a continued regime of burning on a 3 year cycle may have impacts not indicated by the recovery of scrub from a single fire event. Scrub vegetation is adapted to fire and recovers after burning; however, there is no evidence that it had a natural 3 year fire cycle. The best estimates are for a considerably longer fire cycle (ca. 10-25 yrs) and one that was more variable in time of fire return and less uniform (more patchy) in space than the one currently being imposed. The potential exists that repeated burning on a 3 year cycle could eventually shift the species composition of oak scrub toward the most fire tolerant species present (saw palmetto, wiregrass) and away from the oaks. This fire regime could have a long-term impacts on nutrient pools and dynamics not predictable based on current data. Of more immediate and definite concern is the impact of a 3 year fire cycle to structural features, particularly shrub height, in scrub. Burning on a 3 year cycle will keep shrub height less than 1 m in scrub and thus less than the preferred height for the Florida scrub jay. Since KSC supports the largest remaining population of this species effects of the burning program on it must be of concern.

11. On the landscape pattern of vegetation at KSC it would be possible to devise fire management plans which combine longer fire rotations in oak scrub and shorter fire rotations in the more fire-prone saw palmetto scrub as suggested by Breininger et al. (1986).

LITERATURE CITED

Abrahamson, W.G. 1984a. Post-fire recovery of Florida Lake Wales Ridge vegetation. Amer. J. Bot. 71:9-21.

Abrahamson, W.G. 1984b. Species responses to fire on the Florida Lake Wales Ridge. Amer. J. Bot. 71:35-43.

Abrahamson, W.G., A.F. Johnson, J.N. Layne, and P.A. Peroni. 1984. Vegetation of Archbold Biological Station, Florida: An example of the Southern Lake Wales Ridge. Florida Scientist 47:209-250.

Adrian, F.W., R.C. Lee, Jr., and J.E. Sasser. 1983. Upland management plan for Merritt Island National Wildlife Refuge. USFWS/MINWR. Titusville, Florida.

Austin, D.F. 1976. Florida scrub. Florida Naturalist 49(4):2-5.

Baker, D.E. and M.C. Amacher. 1982. Nickel, copper, zinc, and cadmium. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:323-346. American Society of Agronomy, Inc., Madison, Wisconsin.

Baldwin, E., C.L. Bush, R.B. Hinton, H.F. Huckle, P. Nichols, F.C. Watts, and J.A. Wolfe. 1980. Soil survey of Volusia County, Florida. USDA Soil Conservation Service. Washington, D.C. 207pp. and maps.

Boerner, R.E.J. 1981. Forest structure dynamics following wildfire and prescribed burning in the New Jersey Pine Barrens. Amer. Midl. Nat. 105:321-333.

Boerner, R.E.J. 1982. Fire and nutrient cycling in temperate ecosystems. Bioscience 32:187-192.

Boerner, R.E.J. and R.T.T. Forman. 1982. Hydrologic and mineral budgets of New Jersey Pine Barrens upland forests following two intensities of fire. Can. J. For. Res. 12:503-510.

Barnhisel, R. and P.M. Bertsh. 1982. Aluminum. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil anlysis, part 2. Chemical and microbial properties. Agronomy 9:275-300. American Society of Agronomy, Inc., Madison, Wisconsin.

Brady, N.C. 1974. The nature and properties of soils. Eighth edition. Macmillan Publishing Company, Inc., New York. 639pp.

Breininger, D.R. 1981. Habitat preferences of the Florida scrub jay (Aphelocoma coerulescens coerulescens) on Merritt Island National Wildlife Refuge, Florida. M.S. Thesis. Florida Institute of Technology, Melbourne. 159pp.

Breininger, D.R., P.A. Schmalzer, D.A. Rydene, and C.R. Hinkle. 1986. Burrow and habitat study of the gopher tortoise in scrub and flatwoods habitat types. Final report to Florida Game and Fresh Water Fish Commission. Project no. GFC 84-016.

Brooks, H.K. 1981a. Geologic map of Florida. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville.

Brooks, H.K. 1981b. Physiographic divisions (State of Florida). Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville.

Brown, D.W., W.E. Kenner, J.W. Crooks, and J.B. Foster. 1962. Water resources of Brevard County, Florida. Report of Investigations no. 28. Florida Geological Survey. Tallahassee. 104pp.

Buckholz, K. 1983. Initial responses of pine and oak to wildfire in the New Jersey Pine Barrens Plains. Bull. Torrey Bot. Club 110:91-96.

Burton, G.W. and R.H. Hughes. 1961. Effects of burning and 2,4, 5-T on gallberry and saw palmetto. J. Forestry 59:497-500.

Chaki, S. 1974. Study of beach ridges, Cape Canaveral, Florida. Coastal Reserach Notes 4(2):5-7.

Chapman, H.D. 1965. Cation exchange capacity. In: C.A. Black (ed.). Methods of soi analysis, part 2. Chemical and microbial properties. Agronomy 9:891-901. American Society of Agronomy, Inc., MAdison, Wisconsin.

Christensen, N.L. 1979. Shrublands of the southeastern United States. Pp. 441-449. In: R.L. Specht (ed.). Heathlands and related shrublands of the world, A. Descriptive studies. Elsevier Scientific Pub. Co. Amsterdam.

Christensen, N.L. 1985. Shrubland fire regimes and their evolutionary consequences. Pp. 85-100. In: S.T.A. Pickett and P.S. White (eds.). The ecology of natural disturbance and patch dynamics. Academic Press, Inc., Orlando, Florida. 472pp.

Christensen, N.L., R. Burchell, A. Liggett, and E.R. Simms. 1981. The structure and development of pocosin vegetation. Pp. 43-61. In: C.J. Richardson (ed.). Pocosin wetlands: an integrated analysis of coastal freshwater bogs in North Carolina. Hutchinson Ross Pub. Co., Stroadsburg, Pennsylvania.

Cox, J.A. 1981. Distribution, habitat, and social organization of the Florida scrub jay, with a discussion of the evolution of cooperative breeding in new world jays. Ph.D. Dissertation. University of Florida, Gainesville.

Davison, K.L. and S.P. Bratton. 1986. The vegetation history of Canaveral National Seashore, Florida. CPSU Technical Report 22. U.S. National Park Service Cooperative Park Studies Unit, Institute of Ecology, University of Georgia, Athens. 75pp.

Duever, L.C. 1983a. Natural communities of Florida's inland sand ridges. The Palmetto 3(3):3-5.

Duever, L.C. 1983b. Natural communities of Florida's coastal dunes. The Palmetto 3(4):4-5.

Eastern Space and Missile Center. 1982. Weather meterological handbook ESMC pamphlet 105-1. Department of the Air Force, Eastern Space and Missile Center, Patrick Air Force Base, Florida.

Fullerton, S.C. 1985. STAT80 Users Guide, Release 2.9k. Statware. Salt Lake City, Utah.

Gambrell, R.P. and W.H. Patrick, Jr. 1982. Manganese. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:313-322. American Society of Agronomy, Inc., Madison, Wisconsin.

Gauch, H.G., Jr. 1977. ORDIFLEX--A flexible computer program for four ordination techniques: weighted averages, polar ordination, principal components analysis, and reciprocal averaging. Release B. Ecology and Systematics, Cornell University, Ithaca, New York. 185pp.

Gill, A.M. and R.H. Groves. 1981. Fire regimes in heathlands and their plant-ecological effects. Pp. 61-84. In: R.L. Specht (ed.). Ecosystems of the world. Vol. 9B. Heathlands and related shrublands, analytical studies. Elsevier Scientific Pub. Co., Amsterdam.

Gilliam, F.S. 1982. Effects of fire on components of nutrient dynamics in a lower coastal plain watershed ecosystem. Ph.D. Dissertation. Duke University, Durham, North Carolina. 261pp.

Givens, K.T., J.N. Layne, W.G. Abrahamson and S.C. White-Schuler. 1984. Structural changes and successional relationships of five Florida Lake Wales Ridge plant communities. Bull. Torrey Bot. Club 111:8-18.

Gray, J.T. 1982. Community structure and productivity in Ceanothus chaparral and coastal sage scrub of southern California. Ecol. Monogr. 52:415-435.

Gray, J.T. 1983. Nutrient use by evergreen and deciduous shrubs in southern California. I. Community nutrient cycling and nutrient-use efficiency. J. Ecology 71:21-41.

Hamilton, D.B., A.K. Andrews, G.T. Auble, R.A. Ellison, A.H. Farmer, and J.E. Roelle. 1985. Environmental systems and management activities on the Kennedy Space Center, Merritt Island, Florida: results of a modeling workshop. US Fish Wildlife Serv., Western Energy Land Use Team, Fort Collins, Colorado. WELUT-85/W05. 130pp.

Hanes, T.L. 1971. Succession after fire in the chaparral of southern California. Ecol. Monogr. 41:27-52.

Harper, R.M. 1914. Geography and vegetation of northern Florida. Pp. 163-437 in 6th Annual Report of the Florida State Geol. Survey, Tallahassee. 451pp.

Harper, R.M. 1921. Geography of central Florida. Pp. 71-304 in 13th Annual Report of the Florida State Geol. Survey, Tallahassee.

Harper, R.M. 1927. Natural resources of southern Florida. Pp. 27-192 in 18th Annual Report of the Florida State Geol. Survey. Tallahassee.

Healy, H.G. 1975. Terraces and shorelines of Florida. USDI Geological Survey and Florida Department of Natural Resources Bureau of Geology. Tallahassee, Florida.

Hough, W.A. 1981. Impact of prescribed fire on understory and forest floor nutrients. USDA Forest Service Research Note SE-303. Southeastern Forest Experiment Station, Asheville, North Carolina. 4pp.

Hough, W.A. 1982. Phytomass and nutrients in the understory and forest floor of slash/longleaf pine stands. Forest Science 28:359-372.

Hoyt, J.H. and V.J. Henry, Jr. 1970. Origin of capes and shoals along the southeastern coast of the United States. Geol. Soc. Amer. Bull. 82:59-66.

Huckle, H.F., H.D. Dollar, and R.F. Pendleton. 1974. Soil survey of Brevard County, Florida. USDA Soil Conservation Service, Washington, DC. 123pp. and maps.

James, S. 1984. Lignotubers and burls-their structure, function, and ecological significance in Mediterranean ecosystems. Bot. Rev. 50:225-266.

Johnson, A.F. 1982. Some demographic characteristics of the Florida rosemay <u>Ceratiola ericoides</u> Michx. Amer. Midl. Nat. 108:170-174.

Johnson, A.F. and W.G. Abrahamson. 1982. <u>Quercus inopina</u>: a species to be recognized from south-central Florida. Bull. Torrey Bot. Club 109:392-395.

Johnson, A.F., W.G. Abrahamson, and K.D. McCrea. 1986. Comparison of biomass recovery after fire of a seeder (<u>Ceratiola ericoides</u>) and a sprouter (<u>Quercus inopina</u>) species from couth-central Florida. Amer. Midl. Nat. 116:423-428.

Jorgenson, J.R. and C.G. Wells. 1971. Apparent nitrogen fixation in soil influenced by prescribed burning. Soil Sci. Soc. Am. Proc. 35:806-810.

Kalisz, P.J. and E.L. Stone. 1984. The longleaf pine islands of the Ocala National Forest, Florida: a soil study. Ecology 65:1743-1754.

Keeley, J.E. and P.H. Zedler. 1978. Reproduction of chaparral shrubs after fire: a comparison of sprouting and seeding strategies. Amer. Midl. Nat. 9:142-161.

Keeney, S.R. and S.W. Nelson. 1982. Nitrogen-inorganic forms. In: A.L. Page, L.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:643-698. American Society of Agronomy, Inc. Madison, Wisconsin.

Knight, H. 1966. Loss of nitrogen from the forest floor by burning. Forestry Chronicle 42:149-152.

Knudsen, D., G.A. Peterson, and P.F. Pratt. 1982. Lithium, sodium, and potassium. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:225-246. American Society of Agronomy, Inc., Madison, Wisconsin.

Kruger, F.J. 1983. Plant community diversity and dynamics in relations to fire. Pp. 446-472. In: F.J. Kruger, D.T. Mitchell, and J.U.M. Jarvis (eds.). Mediterranean-type ecosystems: the role of nutrients. Springer-Verlag. New York.

Kummerow, J., D. Krause, and W. Jow. 1977. Root systems of chaparral shrubs. Oecologia 29:163-177.

Kurz, H. 1942. Florida dunes and scrub vegetation and geology. Florida Geol. Surv. Bull. 23:15-154.

Laessle, A.M. 1942. The plant communities of the Welaka area. Univ. of Fla. Publ., Biol. Sci. Series 4:1-143.

Laessle, A.M. 1958a. The origin and successional relationship of sandhill vegetation and sand pine scrub. Ecol. Monogr. 28:361-387.

Laessle, A.M. 1958b. A report on successional studies of selected plant communities on the University of Florida Conservation Reserve, Welaka, Florida. Quart. J. Fla. Acad. Sci. 21:101-112.

Lanyon, L.E. and W.R. Heald. 1982. Magnesium, calcium, strontium, and barium. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:247-262. American Society of Agronomy, Inc., Madison, Wisconsin.

Lee. R.C., Jr., W.P. Leenhouts, and J.E. Sasser. 1981. Fire management plan Merritt Island National Wildlife Refuge. USFWS/MINWR. Titusville, Florida.

Lewis, W.M., Jr. 1974. Effects of fire on nutrient movement in a South Carolina pine forest. Ecology 55:1120-1127.

Loveless, A.R. 1961. A nutritional interpretation of sclerophylly based on differences in the chemical composition of sclerophyllous and mesophytic leaves. Annals of Botany 25:168-184.

Loveless, A.R. 1962. Further evidence to support a nutritional interpretation of sclerophylly. Annals of Botany 26:551-561.

Madsen, B.C. 1980. A continuation of baseline studies for environmental monitoring Space Transportation System at John F. Kennedy Space Center. Vol.II. Chemical studies: rainfall and soil analysis. NASA Contract No. NAS10-8986. NASA Contract Report 163122. John F. Kennedy Space Center, Florida.

Madsen, B.C., T.W. Dreschel, and C.R. Hinkle. 1987. An evaluation of rain chemistry for the John F. Kennedy Space Center, Florida and the University of Central Florida, Orlando, Florida. Draft NASA Technical Memorandum.

Malanson, G.P. 1985. Simulation of competition between alternative shrub life history strategies through recurrent fires. Ecological Modelling 27:271-283.

Marrs, R.H. 1978. Seasonal changes and multivariate studies of the mineral element status of several members of the Ericaceae. J. Ecology 66:533-545.

McKee, W.H., Jr. 1982. Changes in soil fertility following prescribed burning on Coastal Plain pine sites. USDA Forest Service Research Paper SE-234. Southeastern Forest Exp. Stn. Ashville, North Carolina. 23pp.

McLean, E.O. 1982. Soil pH and lime requirement. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbiological properties. Agronomy 9:199-224. American Society of Agronomy, Inc., Madison, Wisconsin.

McNab, W.H., M.B. Edwards, Jr., and W.A. Hough. 1978. Estimating fuel weights in slash pine-palmetto stands. Forest Science 24:345-358.

Monk, C.D. 1966. An ecological significance of evergreenness. Ecology 47:504-505.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York. 547pp.

Mulvania, M. 1931. Ecological survey of the Florida scrub. Ecology 12:528-540.

Myers, R.L. 1985. Fire and the dynamic relationships between Florida sandhill and sandpine scrub vegetation. Bull. Torrey Bot. Club 112:241-252.

NASA. 1979. Final environmental impact statement for the Kennedy Space Center. National Aeronautics and Space Administration. John F. Kennedy Space Center, Florida.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:539-579. American Society of Agronomy, Inc., Madison, Wisconsin.

Norusis, M.J. 1986a. SPSS/PC+ for the IBM PC/XT/AT. SPSS, Inc., Chicago, Illinois.

Norusis, M.J. 1986b. SPSS/PC+ advance statistics for the IBM PC/XT/AT. SPSS, Inc., Chicago, Illinois.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorous. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:403-430. American Society of Agronomy, Inc., Madison, Wisconsin.

Olson, R.V. and R. Ellis, Jr. 1982. Iron. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:301-312. American Society of Agronomy, Inc., Madison, Wisconsin.

Osmond, J.K., J.P. May, and W.F. Tanner. 1970. Age of the Cape Kennedy barrier-and-lagoon complex. J. Geophysical Research 75:469-479.

Perkin-Elmer Corporation. 1982. Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer Corporation. Norwalk, Connecticut.

Permar, T.A. and R.F. Fisher. 1983. Nitrogen fixation and accretion by wax myrtle (Myrica cerifera) in slash pine (Pinus elliottii) plantations. Forest Ecology and Management 5:39-46.

Peroni, P.A. and W.G. Abrahamson. 1986. Succession in Florida sandridge vegetation: a retrospective study. Florida Scientist 49:176-191.

Poppleton, J.E., A.G. Shuey, and H.A. Sweet. 1977. Vegetation of central Florida's east coast: a checklist of the vascular plants. Florida Scientist 40:362-389.

Provancha, M.J., P.A. Schmalzer, and C.R. Hinkle. 1986. Vegetation types. John F. Kennedy Space Center, Biomedical Operations and Research Office (Maps in Master Planning format, 1:9600 scale, digitization by ERDAS, Inc.).

Raison, R.J. 1979. Modification of the soil environment by vegetation fires, with particular reference to nitrogen transformations: a review. Plant and Soil 51:73-108.

Rhoades, J.D. 1982. Soluble salts. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of soil analysis, part 2. Chemical and microbial properties. Agronomy 9:167-179. American Society of Agronomy, Inc., Madison, Wisconsin.

Richardson, D.R. 1977. Vegetation of the Atlantic Coastal ridge of Palm Beach County, Florida. Florida Scientist 40:281-330.

Richter, D.D. 1980. Prescribed fire: effects on water quality and nutrient cycling in forested watersheds on the Santee Experimental Forest in South Carolina. Ph.D. Dissertation. Duke University, Durham, North Carolina. 194pp.

Richter, D.D., C.W. Ralston, and W.R. Harms. 1982. Prescribed fire: effects of water quality and forest nutrient cycling. Science 215:661-663.

Rundel, P.W. 1981. Fire as an ecological factor. Pp. 501-538. In: O.L. Lange, P.S. Nobel, C.B. Osmond, and H. Ziegler (eds.). Physiological plant ecology. I. Responses to the physical environment. Springer-Verlag. New York.

Schmalzer, P.A. 1982. Vegetation of the Obed Wild and Scenic River, Tennessee and a comparison of reciprocal averaging ordination and binary discriminant analysis. Ph. D. Dissertation. The University of Tennessee, Knoxville. 236pp.

Schmalzer, P.A. and C.R. Hinkle. 1985. A brief overview of plant communities and the status of selected plant species at John F. Kennedy Space Center, Florida. Report submitted to Biomedical Office, KSC.

Schuman, G.E., M.A. Stanley, and D. Knudsen. 1973. Automated total nitrogen analysis of soil and plant samples. Soil Sci. Soc. Amer. Proc. 37:480-481.

Snyder, J.R. 1984. The impact of wet season and dry season prescribed fire on Miami Rock Ridge Pineland, south Florida. Ph.D. Dissertation. The University of Florida, Gainesville. 153pp.

Specht, R.L., P. Rayson, and M.E. Jackman. 1958. Dark Island heath (Ninety-mile Plain, South Australia). VI. Pyric succession: changes in composition, coverage, dry weight, and mineral nutrient status. Australian Journal of Botany 6:59-88.

Stout, I.J. 1980. A continuation of base-line studies for environmentally monitoring Space Transportation Systems (STS) at John F. Kennedy Space Center. Vol.I. Terrestrial community ecology. NASA Contract No. NAS 10-8986. NASA Contract Report 163122.

Sweet, H.C. 1976. A study of a diverse coastal ecosystem of the Atlantic Coast of Florida: Botanical studies on Merritt Island. Final report to NASA/KSC, Grant No. NGR 10-019-004. 258pp.

Systat. 1984. Systat: The system for statistics. Systat, Inc., Evanston, Illinois.

Technicon Industrial Systems. 1973. Nitrate and nitrite in water and wastewater. Industrial method no. 100-70W. Technicon Industrial Systems. Tarrytown, New York.

Technicon Industrial Systems. 1983a. Ammonia in water and wastewater. In: Multi-test cartridge method no. 696-82W: 1D-4D. Technicon Industrial Systems, Tarrytown, New York.

Technicon Industrial Systems. 1983b. Nitrogen, total Kjeldahl, in water and wastewater. In: Multi-test cartridge no. 696-82W:1C-5C. Technicon Industrial Systems, Tarrytown, New York.

Technicon Industrial Systems. 1983c. Ortho-phosphorous. In: Multi-test cartridge no. 696-82W: 1B-4B. Technicon Industrial Systems, Tarrytown, New York.

Technicon Industrial Systems. 1983d. Phosphorous, total, in water and wastewater. In: Multi-test cartridge method no. 696-82W:1A-9A. Technicon Industrial Systems, Tarrytown, New York.

Veno, P.A. 1976. Successional relationships of five Florida plant communities. Ecology 57:498-508.

Vickers, D.H., R.S. White, and I.J. Stout. 1975. Elemental analysis of selected Merritt Island plants. Florida Scientist 38:163-171.

Walker, J. and R.K. Peet. 1983. Composition and species diversity of pine-wiregrass savannas of the Green Swamp, North Carolina. Vegetatio 55:163-179.

Walter, H. 1979. Vegetation of the earth and ecological systems of the geo-biosphere. Springer-Verlag, New York. 274pp.

Watts, W.A. 1971. Post-glacial and interglacial vegetational history of southern Georgia and central Florida. Ecology 52:676-690.

Watts, W.A. 1975. A late Quaternary record of vegetation from Lake Annie, south-central Florida. Geology 3:344-346.

Watts, W.A. 1980. The Late Quaternary vegetation history of the southeastern United States. Ann. Rev. Ecol. Syst. 11:387-409.

Webber, H.J. 1935. The Florida scrub, a fire-fighting association. Amer. J. Bot. 22:344-361.

Wells, C.G., R.E. Campbell, L.F. DeBano, C.E. Lewis, R.L. Fredrikson, E.C. Franklin, R.C. Froelich, and P.H. Dunn. 1979. Effects of fire on soil. USDA Forest Service, General Technical Report WO-7. 34pp.

White, W.A. 1958. Some geomorphic features of central peninsular Florida. Geological Bulletin No. 41. Florida Geological Survey. Tallahassee. 92pp.

White, W.A. 1970. The geomorphology of the Florida peninsula. Geological Bulletin No. 51. Bureau of Geology, Florida Department of Natural Resources. Tallahassee. 164pp.

Whittaker, R.H., L.E. Gilbert, and J.H. Connell. 1979a. Analysis of two-phase pattern in a mesquite grassland, Texas. J. Ecology 67:935-952.

Whittaker, R.H., W.A. Niering, and M.D. Crisp. 1979b. Structure, patter and diversity of a mallee community in New South Wales. Vegetatio 39:65-76.

Wilbur, R.B. and N.L. Christensen. Effects of fire on nutrient availability in a North Carolina Coastal Plain pocosin. Amer. Midl. Nat. 110:54-61.

Wolfe, J.A. 1962. Analytical procedures for plant and soil samples used in vegetation studies related to movement of radioactive wastes. Botany Department, The University of Tennessee. AEC Contract No. AT-(40-)-2077. Knoxville. 58pp.

Woodwell, G.M., R.H. Whittaker, and R.A. Houghton. 1975. Nutrient concentrations in plants in the Brookhaven oak-pine forest. Ecology 56:318-332.

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15. Supplementary Notes

16. Abstract

Oak scrub is a shrub vegetation type dominated by *Quercus myrtifolia*, *Q. chapmanii*, *Q. virginiana* var. *geminata*, *Serenoa repens*, and ericaceous shrubs occurring on well-drained sites on John F. Kennedy Space Center, Merritt Island, Florida.

Four stands of scrub vegetation, 2, 4, 8, and 25 years since fire, were sampled in 1983 with permanent 15 m line transects and percent cover by species was determined. Biomass was harvested on 1 m^2 plots associated with the line transects. Plant tissue samples were analyzed for total Kjeldahl nitrogen (TKN), total phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and aluminum (Al). Soil samples were taken from the 0 to 15 cm and 15 to 30 cm layers at each transect and analyzed for pH, conductivity, organic matter, cation exchange capacity (CEC), exchangeable Ca, Mg,K, Al, nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N), available copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and P. Transects were resurveyed in 1985 for vegetation parameters.

Ordination analysis indicated that species were distributed along a gradient related to water table depth. Between the two sample periods some shifts in dominance in transects of the younger stands occurred with saw palmetto increasing

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Effects of fire on composition, biomass, and nutrients in oak scrub vegetation on John F. Kennedy Space Center, Florida

16. Abstract (continued).

importance in some and oaks in others primarily due to height growth. Species richness changed little with time since fire. Mean total cover in the greater than 0.5 m stratum, mean height, and mean maximum height increased with time since fire. Mean total cover in the less than 0.5 m stratum decreased after year 2. Live biomass increased with time since fire. Litter biomass increased for at least 8 years after fire. Standing dead biomass formed a major component of total biomass but did not change significantly in total amount of time. Saw palmetto rhizomes were a significant and persistent component of scrub biomass.

Tissue concentrations in live biomass of TKN, total P, Ca, Mg, Na, K, and Al showed no trends with time since fire. Tissue concentrations were similar to those reported for other ericaceous shrubs and chaparral species. Litter concentrations of Ca, K, and total P were elevated in the 2 year old stand probably as a results of ash deposition.

Nutrient pools in biomass were calculated from biomass data and tissue nutrient concentrations. Litter, standing dead material, and saw palmetto rhizomes were major pools for many nutrients. Live stem biomass became important in the oldest stand. Standing crops were similar to those in other shrublands such as chaparral.

Soil chemical properties were closely related to water table depth. Wetter soils had higher organic matter content, greater cation exchange capacity, and higher concentrations of many nutrients. Effects of fire on scrub soils include increased pH and decreased organic matter, TKN, and available Zn.

Soil nutrient pools were calculated from nutrient concentrations and bulk density. Biomass pools of P, Ca, and K were greater than those of the soil in all stands. Biomass pools of TKN, Na, and Mg exceeded those in the soil except in wetter sites or where saw palmetto rhizomes were few. Aluminum pools were consistently greater in the soil than in biomass.

Deposition rates of nitrogen, Ca, P, and K in precipitation were low relative to biomass pools while the amounts of sodium and magnesium in precipitation were greater relative to biomass. Biological nitrogen fixation and mechanisms which retain and recycle nutrients in the system may be important to the persistence of oak scrub.

Long-term fire effects of a changed fire regime (e.g., the 3 yr cycle now being applied) could be greater than what is seen after recovery from a single fire event and could include shifts in dominance to the species best adapted to frequent fire and changes in nutrient cycling. The effects of frequent fire in oak scrub of most concern are the structural changes, particularly reduction in height. Burning on a 3 year cycle maintains shrub height in oak scrub less than 1 m but the endemic Florida scrub jay (dependent on oak scrub and related communities) prefers oak scrub greater than 1 m as habitat.