Publication No. 03-100-129

HABITAT FACTORS INFLUENCING THE DISTRIBUTION OF SMALL VERTEBRATES ON UNMINED AND PHOSPHATE-MINED UPLANDS IN CENTRAL FLORIDA

Prepared by
University of South Florida

under a grant sponsored by

FIPR
Florida Institute of Phosphate Research

November 1996

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HABITAT FACTORS INFLUENCING THE DISTRIBUTION OF SMALL VERTEBRATES ON UNMINED AND PHOSPHATE-MINED UPLANDS IN CENTRAL FLORIDA

FINAL REPORT

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November 1996

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PERSPECTIVE

Dry ("xeric") upland habitats in Florida are critical to the existence of several animal and plant species. Acreages of such lands have shrunk dramatically due to urban, agricultural and industrial development. Although phosphate mining causes a drastic disturbance. of the land, it may be possible, with proper reclamation techniques, to restore the essential features of critical upland habitats and restore the wildlife populations they support. An important goal of the FIPR reclamation research program is to gain a better understanding of the factors important to restoration of wildlife habitat on phosphate mined lands and developing methodology for accomplishing the rehabilitation of these habitats.

This study (FIPR Project No. 92-03-100R) was begun in 1993 by Dr. Henry Mushinsky and Dr. Earl McCoy of the University of South Florida to examine the kinds and numbers of small vertebrate species found on reclaimed lands in comparison to those found on unmined scrub, sandhill and scrubby flatwoods habitats in the central Florida phosphate region. This project provides valuable information on the recolonization of various small vertebrates on mined lands plus guidelines on habitat characteristics that are associated with various vertebrate species. They are currently working on a follow-on project (FIPR Project No. 95-03-115), "Wildlife Usage of Mesic Flatlands and Its Bearing on Restoration of Phosphate Mined Lands in Central Florida," which extends their research to mesic (moist) flatwoods, prairies and related flatlands. It should be completed in late 1997.

In related work, Laurie Ann Macdonald, a former graduate student of Dr. Mushinsky, recently completed a five year study of gopher tortoises relocated from a development site in Hernando County to reclaimed mined lands at the Tenoroc State Reserve (now the Tenoroc Fish Management Area) in Polk County, Florida (FIPR Publication No. 03-105-126, "Reintroduction of Gopher Tortoises (*Gopherus polyphemus)* to Reclaimed Phosphate Lands"). The research at Tenoroc has shown that reintroduced gopher tortoises can be successfully reestablished on sandy, open habitat on reclaimed lands, and the study has provided important clues as to how site characteristics and relocation tactics can be optimized.

Two additional ongoing projects, "Development of Seed Sources and Establishment Methods for Native Upland Reclamation" (USDA Natural Resources Conservation Service, FIPR Project 96-03-120) and "Post-Mine Reclamation of Upland Communities" (Jones, Edmunds & Associates, FIPR Project 96-03-122), should provide additional information on rebuilding important site characteristics and reestablishing native plants on reclaimed lands.

Steven G. Richardson, FIPR Reclamation Research Director

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ACKNOWLEDGMENTS

This research could not have been completed without the support of the Florida Institute for Phosphate Research (FIPR) and the cooperation of the phosphate industry in Florida. We thank Richard Coleman, Florida Lake Management Society, for introducing us to the Institute and for his expressed interest in our study of unmined and previously mined lands in Florida. We thank Dr. Steven Richardson, FIPR Research Director for Reclamation, for his active participation during all phases of our research. Tim King, Florida Game and Fresh Water Fish Commission, graciously shared his knowledge of the history of unmined and previously mined lands throughout central Florida; we are indebted to him for all his many contributions to this research project. We also thank the other members of the FIPR Reclamation Technical Advisory Committee for their assistance and advice.

Numerous individuals employed by the phosphate industry helped us to identify study sites, provided us with access to the previously mined lands, and generally supported our research efforts. In particular, we thank Rosemarie Garcia (Cargill Fertilizer), Bob Goodrich (IMC-AGRICO), John Kiefer (CF Industries), Tom Myers (Cargill Fertilizer), Candy Pederson (Mobil Mining and Minerals), Selwyn Presnell (IMC-AGRICO), Robert Shirley (CYTEC) and Ted Smith (IMC-AGRICO) for their cooperation and assistance with this project. We may have inadvertently omitted other persons who should have been acknowledged, and we apologize for any such omissions. Ted Smith and two anonymous reviewers commented on the first draft of this report and helped us to improve the presentation of our data.

Individuals from other industries and managers of public lands also helped us obtain access to sites used for this study. In particular, we thank Glen Cross (Fishhawk Investment Corporation), Rob Heath (Hillsborough County Parks and Recreation Department), Danon Moxley (Florida Game and Fresh Water Fish Commission), George Shahadi (Williams Acquisitions Holding Company), Greg Walk (Southeast Landfill), and Karen Zwolak (Tampa Electric Company) for their cooperation and assistance with this project. In addition, a group of private land owners allowed us access to their properties for our study. We agreed not to identify any specific individual who allowed us access to their private land, but we do wish to thank them collectively.

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EXECUTIVE SUMMARY

The principal causes for the loss of species on Earth today are pollution, which alters habitats so that they are uninhabitable for some species, and outright destruction of habitats -- such as by clearcutting ancient forests, strip mining, and urbanization -- which alters the habitats so that they are uninhabitable for virtually all species. Reclamation of human-altered habitats is a method used to reduce the long-term effects of habitat disturbance on the native flora and fauna. Before any reclamation efforts are made, however, one must have clear aims in mind. "Restoration" of habitats, which may be considered the ultimate form of reclamation, is accomplished by creating both structural and functional attributes of a damaged ecosystem. True restoration attempts to put back exactly what was thought to have been there prior to any disturbance. We believe that restoration is not a reasonable goal for the reclamation of lands previously mined for phosphate. A second possible purpose for reclamation is to aim for a product which is similar to, but somewhat less than, full restoration. This second level of reclamation is termed "rehabilitation." We believe that rehabilitation is a reasonable goal for the reclamation of phosphate-mined lands.

"Representativeness" is the presence of the range of ecological variation in a particular habitat. We use the term representativeness to indicate that "rehabilitated phosphate-mined lands will include typical or common vertebrate species as well as rare vertebrate species, in their typical relative abundances, to present the full range of the biota." The goal of such an approach is to produce a system of rehabilitated phosphate-mined lands that, collectively, encompass the broad range of vertebrate species typically found in areas that have not been mined or otherwise significantly modified. We believe that the concepts of rehabilitation and representativeness together provide a reasonable framework for the reclamation of phosphate-mined lands in Florida. Rather than placing extreme importance on rare and/or endangered or threatened species, representativeness emphasizes the value of preserving overall biodiversity.

We studied three kinds of unmined upland habitats and two kinds of previously-mined lands. The three kinds of upland habitats were sandhill, scrub, and scrubby flatwoods; the two kinds of previously-mined lands were those mined prior to the mandatory reclamation laws of 1975 and those mined since 1975. We studied the three unmined habitats and two previously-mined lands to determine the number of species present (species richness) and relative abundances of resident vertebrates. We then compared the lists of species found on previously-mined lands to lists of species from unmined upland habitats. In all, we selected 60 study sites in Hillsborough, Polk, and Manatee Counties, covering a total area of about 900 square miles. Thirty sites were previously-mined lands; of these, 14 were mined prior to 1975 and 16 thereafter. The mined sites had received various amounts of reclamation effort. Thirty study sites were unmined upland habitats; of these, 8 were sandhill, 15 were scrub, and 7 were scrubby flatwoods. All 30 unmined upland habitats were within the vicinity of mined lands. All 60 sites were classified according to their size (small, large), distance to seasonal water (near, far), distance to permanent water (near, far), and distance to upland habitat (near, far), and the habitats (upland habitat, wetland,

citrus grove, pasture, farm, active mine, inactive mine, reclaimed land, old field, residential) immediately surrounding the sites were recorded. The 30 mined sites were classified according to the type of soil (overburden, sand tailings), the type of vegetation reclamation (woody species, herbaceous species, topsoil from upland habitats), and the year(s) in which reclamation occurred.

We sampled most species of amphibians, reptiles, mammals, and birds at the 60 study sites. Amphibians, reptiles and mammals (called quadrupeds, hereafter) were captured by trapping at each site. Birds were not captured, rather they were censused twice each year by observation, to determine both resident breeding bird populations and migratory bird populations. "Resident species" were those species who spent a majority of time and reproduced in their respective habitats. Resident species were identified from existing information on species' distributions and from information we gathered by trapping and observing quadrupeds and birds in unmined habitats within the vicinity of past phosphate mining operations. Resident species are those species that exist primarily in the upland habitats we studied. For example, an alligator may walk through scrub or sandhill once or a few times during a year, but it is not a resident of either habitat; whereas a bluejay that nests in the sandhill habitat is a resident of that habitat. Resident species comprise a subset of the total pool of species known to occur in sandhill, scrub, and/or scrubby flatwoods habitats. To determine how successful the various resident species have been in establishing colonies at previously-mined sites, we collected information on quadrupeds and birds at both unmined and mined sites. Species that were found at unmined sites but were missing or underrepresented at mined sites were termed "focal species." Focal species are a subset of the resident species. Focal species would be the likely target species for future efforts to entice wildlife to establish residency at reclaimed sites,

During our study we collected data on the vegetation and soil conditions at each study site. Vegetation composition was measured within plots near the traps we constructed to capture quadrupeds. We compiled a list of plant species present at each site. Vegetation density (percent of a prescribed field of view filled with vegetation) was measured at each plot. We made measurements of ground cover and tree canopy. Vertical canopy cover (the amount of tree canopy overhead) was determined with a hand-held densimeter. Horizontal canopy cover was estimated by visually scoring the percent cover of a board placed at pre-selected heights above the ground while being viewed from the ground at a constant distance from the board. We performed a series of tests on soils sampled from selected plots used for the vegetation analyses. We measured soil chemistry, soil texture, sand particle size, soil compaction, and root density. Standard statistical methods, mostly non-parametric, were used to analyze the data. Specific tests used include Spearman's Rank Correlation Analysis, Mann-Whitney U-test, Kolmogorov-Smirnov One-and Two-sample Tests for Goodness of Fit, and G-test of Independence. To assess species associations, we used the Variance Ratio Test and Monothetic Devisive Cluster Analysis.

Our analysis of soil texture revealed relatively little variation among sandhill, scrub, and scrubby flatwoods sites. Soils at mined sites known to have been reclaimed with overburden and with mixed overburden/sand tailings contained less sand than those known to have been reclaimed with sand tailings alone. Only sand tailings tended to have sand in similar percentages to unmined soils. Mined sites tended to have much higher percentages of very coarse and coarse sand than did unmined sites, whereas unmined sites tended to have much higher percentages of very fine sand. Overall, the sand tailings/overburden were more like the unmined soils in sand particle size than were either sand tailings or overburden alone. Soil compaction could not be shown to differ among the types of unmined sites. Soil compaction was similar for unmined and mined soils at the surface; below the surface, however, compaction was greater for the mined soils than the unmined soils. Root density near the surface was greater in mined soils than in unmined soils, but below the surface root density was higher in unmined soils than in mined soils. Soil chemistry varied substantially among the types of unmined sites. Levels of phosphorus, organic matter, and nitrogen tended to be higher in sandhill soils than in scrub or scrubby flatwoods soils. Unmined and mined soils were very different in their chemistries, with the exception of nitrogen content. The levels of potassium and phosphorous were consistently higher at the mined sites than the unmined sites. None of the types of mined soils were very much like unmined soils in their overall chemistries.

The percentages of the vegetation in the various categories of life form coverage (grasses, forbs, lichens, woody vegetation) at sandhill sites were different than those at either scrub or scrubby Flatwoods sites. Mined sites also differed from unmined sites; mined sites had a much smaller percentage of woody vegetation and litter and a much larger percentage of grasses, sedges, and legumes. None of the revegetation treatments, such as planting woody, woody/herbaceous, or only herbaceous vegetation, could be distinguished from one another. Mined sites tended to be dominated by only a few life-form categories.

For foliage layering (canopy density at different heights), sandhill sites could be distinguished from scrub sites, but not from scrubby flatwooods sites. Foliage layering at mined sites was quite different from that at unmined sites; woody vegetation at mined sites was much shorter in stature and lacked a middle canopy. Our findings indicate that sites revegetated with woody vegetation could not be distinguished from unmined sites with a high degree of certainty, whereas all of the other revegetation treatments were clearly different from unmined habitats. Mined sites tended to be dominated by only a few foliage layers. Horizontal and vertical canopy closure are measures of the complexity of foliage layers. Both horizontal and vertical closure were similar among the kinds of unmined sites. Mined sites were very different than unmined sites in both kinds of canopy closure, being far more "open." Not surprisingly, mined sites replanted with woody and woody/herbaceous vegetation tended to have greater horizontal canopy closure than sites replanted with only herbaceous plants. Mined sites where topsoil had been applied to the ground surface were most similar to unmined sites just above the ground level, but at higher levels, all four kinds of revegetation treatments differed substantially from unmined sites. Mines sites replanted with herbaceous, herbaceous/woody, only herbaceous vegetation, or covered with topsoil all had much less canopy closure than unmined sites. Trees greater than 1m in height, were denser at sandhill and scrub sites than at scrubby flatwoods sites. Saw palmettos were denser at either scrub or scrubby flatwoods sites than at sandhill sites. With minor exceptions, all height classes of trees, saw palmettos, and snags were denser at unmined than at mined sites. Trees at sites planted with woody vegetation and sites treated with topsoil tended to be denser, at heights below 1m, than at herbaceous and woody/herbaceous sites. Tree densities at sites treated with topsoil clearly were most like densities at unmined sites, at heights above 1 m.

The list of resident species includes 10 amphibians, 35 reptiles, 26 mammals (of which 7 are trappable), and 69 birds. The species actually captured (amphibians, reptiles, mammals) or observed (birds) include nine resident amphibian species (90% of all resident amphibian species), 24 resident reptile species (69% of all resident reptile species), seven resident mammal species (100% of all trappable resident mammal species), and 39 resident bird species (57% of all resident bird species). This group of 79 species (65% of all resident species) is the group from which focal species were selected.

The list of focal species includes five amphibians, five lizards/turtles, three snakes, one mammal, and 15 birds. One of the bird species, *Lanius ludovicianus* (loggerhead shrike), actually was more common at mined than unmined sites, and is not included in subsequent analyses. The remaining group of 28 species is the group used to document differences between the vertebrate compositions of unmined and mined sites. Our findings indicate that (1) unmined and mined sites differ dramatically, (2) quadrupeds and birds are found at substantially different suites of unmined sites, and (3) quadrupeds and birds are found at more similar suites of mined sites than unmined sites. Interestingly, regardless of which of the three groups of sites (unmined, mined, unmined and mined combined) are employed, numbers of resident species are related positively and strongly to representation of focal species, both for quadrupeds and birds.

The size and isolation of a site are important to numbers of resident species. For the total number of vertebrate species, large unmined sites tended to rank higher than small unmined sites. For numbers of quadruped species, small mined sites tended to rank higher than large mined sites. Distance from seasonal water and distance from permanent water did not influence ranking of sites. For all vertebrate species, unmined sites located near other upland habitat ranked higher than unmined sites far from other upland habitats. For numbers of bird species, ungrazed unmined sites ranked higher than grazed unmined sites.

Focal species have different habitat requirements than non-focal species. Among the quadrupeds, the preference for specific types of breeding sites was an important factor in determining which amphibians were included on the list of focal species. The preference for substrate and vegetation structure by other focal quadrupeds was important to those species. The gopher tortoise probably has not been able to recolonize most of the mined sites because the mined sites are isolated and not connected to sources of recolonization. Among birds, we found that vegetation structure alone could distinguish nearly all focal from non-focal resident species. The focal species all prefer wooded areas, some favoring areas with extensive tree canopy and others favoring areas with shrubs or low canopy. The non-focal resident species almost all prefer open areas that are conducive to ground foraging.

Specific aspects of vegetation structure are important to focal species representation at a site. Relatively abundant woody ground cover, relatively abundant mid-canopy, relatively dense pine trees, and relatively sparse upper-canopy had positive influences on representation of quadrupeds at unmined sites; relatively-abundant non-runner oak trees, however, had a negative influence. Relatively abundant mid-canopy and relatively dense pine trees had a positive influence on representation of birds at unmined sites; relatively-dense ground layer, however, had a negative influence. Relatively abundant woody ground cover and grasses, and relatively dense trees had positive influences on representation of quadrupeds at mined sites; but none of the categories of foliage strata were related to representation of quadrupeds at mined sites. Relatively abundant woody ground cover, relatively dense saw palmettos, and relatively dense upper-canopy had positive influences on representation of birds at mined sites. Although neither density of all trees nor density of any particular kind of tree were related to representation of birds at mined sites, for all heights combined, density of both all trees and of non-runner oak trees were related positively to representation of birds at mined sites, for heights greater than 2m.

All of the results, taken together, indicate the following. At unmined sites, the presence of focal species is strongly associated with the presence of woody ground cover which, in turn, is strongly associated with a relatively high density of pine trees and low density of oak trees, and a relatively extensive mid-canopy layer. At mined sites, focal species were once again strongly associated with the presence of woody ground cover. The mid-canopy layer is missing at mined sites, however. When the preferred vegetation structure is absent at mined sites, quadrupeds respond positively to the presence of grass and birds respond to the density of saw palmetto and tall non-runner oak trees. Both groups of vertebrates are using the only habitat structure available to them in mined sites.

We ranked the mined sites by the numbers of focal species present (representativeness) and compared those rankings with the reclamation procedures used. Sites reclaimed with sand tailings and overburden tended to rank higher than sites reclaimed with either sand tailings or overburden alone, for quadrupeds. Sites revegetated with woody plants tended to rank higher than sites revegetated with herbaceous plants, for birds. The importance of habitat structure for both groups of vertebrates, again, is indicated by these results. Quadrupeds spend much time on, and in, the ground; therefore, soil texture, composition, and chemistry, are likely to influence their distributions. For many species of birds, woody plants provide a source of food and shelter as well as a place to build nests. Interestingly, various soil characteristics of mined sites also could influence birds and other vertebrates dependent on plant cover. The highly-compacted nature of soils at mined sites, as indicated by both penetrometer readings and the relative paucity of roots below the surface, could hinder the development of woody vegetation.

To gain further insight into which physical and vegetational aspects of our study sites influenced focal species representation, we focused on the “best” unmined and mined sites. The best mined sites (n = 19) supported at least one focal species, and the best unmined sites was the smallest group of sites that collectively contained all of the quadruped (n = 7) or bird (n = 15) focal species.

Representation of focal quadrupeds at the best unmined sites (the smallest group of sites (n = 7) that supported all focal quadruped species) tended to be greater at those sites with relative-large amounts of legume ground cover, shrub layers above the ground, and vertical canopy closure up to two meters in height. Representation of focal quadrupeds tended to be lower at those sites with relatively high total densities of trees and tree snags. The profile of the habitat preferred by quadrupeds is one with much structure from ground level to about two meters. In the shade of a dense upper tree canopy such structure does not develop. Such a situation may be found, for example, under a dense stand of live oak trees, or an oak hammock. Representation of focal quadrupeds at the best mined sites (any site that supported at least on focal quadruped species) tended to be greater at those sites with relatively-large amounts of woody ground cover, vertical canopy closure up to four meters in height, and relatively high total densities of trees and tree snags. Representation of focal quadrupeds tended to be lower at those sites with relatively-large amounts of legume ground cover. The results from the mined sites parallel those from the unmined sites: they both indicate the importance of cover at a height relevant to ground-dwelling species. At mined sites, trees are not sufficiently dense to shade out ground cover, as occurs on unmined sites. The relationship between representation of focal quadrupeds and density of saw palmetto strongly reinforces this last suggestion. At the best unmined sites, high density of saw palmetto, at a height of 0-2m, is associated with relatively-poor representation of focal quadrupeds, but at the best mined sites, high density of saw palmetto is associated with relatively-good representation. Those quadrupedal focal species which can adjust to the unusual structure on mined sites are able to use those sites.

Representation of focal birds at the best unmined sites (the 15 sites that collectively supported all of the focal bird species) tended to be greater at those sites with relative-large amounts of wiregrass cover and relatively-high densities of pine trees, especially those 0-2m high. Representation of focal birds tended to be lower at those sites with relatively-high densities of moderately-tall saw palmetto and oak trees. Representation of focal birds at the best mined sites (those 19 sites that supported at least on focal species) tended to be greater at those sites with relative-large amounts of ground vegetation, relatively-high densities of saw palmetto and non-runner oak trees, and substantial vertical canopy closure and relatively-high densities of trees up to two meters. The absolute height of the upper canopy also increased focal bird representation. Cover, provided by habitat structure, is important in different ways at unmined and mined sites. At the unmined sites, cover may become too dense, reducing the numbers of individuals of focal bird species or even eliminating them; while at the mined sites cover is rarely, if ever, too dense, and focal bird species respond positively to increased cover. Our observations are supported by the fact that representation of focal birds at the mined sites that supported at least one focal bird species was related negatively to time since initial reclamation. Older reclaimed sites tended to have increased upper canopy, and very sparse lower layers.

INTRODUCTION

Philosophy of Rehabilitation

The principal causes for the loss of species on Earth today are pollution, which alters habitats so that they are uninhabitable for some species, and outright destruction of habitats -- such as by clearcutting ancient forests, strip mining, and urbanization -- which alters the habitats so that they are uninhabitable for virtually all species (see Cairns 1991a). Fragmentation of habitats also may have devastating effects on populations of organisms isolated in remnant patches of a formerly widespread habitat. Because isolated remnant populations often are composed of relatively few individuals, their probabilities of extinction are great (Caughley and Gunn 1996). Reclamation of human-altered habitats is a method used to reduce the long-term effects of habitat disturbance on the native flora and fauna. "Restoration" of habitats, which may be considered the ultimate form of reclamation, is defined as recreating both structural and functional attributes of a damaged ecosystem (Cairns 1991 b). Restoration of habitats may be considered resetting an "ecological clock." The acid test of our knowledge about ecosystems is not whether we can analyze them on paper, but rather whether we can put them together in practice and ultimately make them work-- that is, whether we can restore them (Bradshaw 1983).

Before any reclamation efforts are made, one should have clear aims in mind. If we are resetting an ecological clock, for instance, then we should know the appropriate setting for that clock. Knowing how to reset the clock is a difficult task. For example, should the clock be set to the time just before the disturbance occurred (approximating the condition prior to the most recent disturbance) or the present time (approximating the condition that would have existed if no disturbance had occurred) (see Cairns 1991 b)? Some reclamation efforts may have relatively limited aims, while others may have aims that are broader and more difficult to circumscribe. For example, a limited reclamation aim may be to increase the carrying capacity of the Kissimmee River for large mouth bass, whereas a broad reclamation aim may be to restore the Kissimmee River to its 1950 condition (see Loftin et al. 1990). Clearly, these two aims require very different approaches, the former requires only enhancing the food chain for a top predator, the latter requires a thorough understanding of the entire river system including the flood plain.

Although we have already used and defined the term "restoration," we wish to clarify some potentially confusing terminology, because we do not see restoration as a reasonable goal of many reclamation efforts. Any process of reclamation may have any one of three purposes (Bradshaw 1987). The first is restoration, in which an attempt is made to put back exactly what was thought to have been there prior to any disturbance. Achieving true restoration is a difficult task, and largely depends upon the degree and duration of disturbance. Because of the nature of the disturbance created by surface mining for phosphate matrix, including the processing of the phosphate matrix which produces the "waste" sand tailings used for reclamation, it is not likely that phosphate-mined lands will be restored completely. We believe that restoration, therefore, is not a reasonable goal for the reclamation of phosphate-mined lands. The second possible purpose for reclamation is to aim for a product which is similar to, but somewhat less than, full restoration (Bradshaw 1987). This second level of reclamation is termed “rehabilitation,” thereby indicating that the disturbed lands have been reclaimed as closely as possible to full restoration. Given enough time, rehabilitation may lead to full restoration -- that is, habitats capable of supporting the full range of flora and fauna typical of that specific habitat type -- but the aims of rehabilitation are not necessarily to duplicate any pre-disturbance conditions. We believe that rehabilitation is a reasonable goal for the reclamation of phosphate-mined lands. The third possible purpose for reclamation of phosphate-mined lands is to make no attempt to restore what was present prior to the disturbance. Instead, there is a replacement of the original ecosystem by another, probably different one (Bradshaw 1987). For example, phosphate-mined lands designated for agricultural or recreational use may be reclaimed by planting species of grasses, shrubs, and trees which are not necessarily designed to attract wildlife or to mimic natural systems.

Many possible ways exist for judging the success of rehabilitation efforts on phosphate-mined lands in Florida. For example, some individuals may wish to focus on reclamation of lands to support endangered or threatened species known to have occurred in the area prior to the mining disturbance. Other individuals may wish to create habitats for the rarest of species, thinking that these, like the endangered or threatened species, deserve our greatest attention. In contrast, some individuals may wish to create habitats that will support the most common species, and such reclamation efforts may ignore the rare and/or threatened species. Other individuals may wish to reclaim the habitat to support the greatest numbers of species, regardless of their natural distributions or local abundances. Lastly, there are some individuals who may wish to create habitats that will support species of interest to hunters, such as deer or quail. While all of these potential ways of judging success have some merit, we believe that they all reflect a limited vision for the future well-being of the reclaimed habitats. We focus our attention on a relatively-broad measure of success, “representativeness.”

A Way of Judging Reclamation Success: Representativeness

One of the criteria used to evaluate the conservation value of a natural habitat is “representativeness” (Margules and Usher 1981). Representativeness is the representation of the range of ecological variation in a particular habitat, and is better thought of as an approach to conservation rather than as a simple criterion for judging natural areas (Smith and Theberge 1986). The concept of representativeness was the basis for establishing biosphere preserves to conserve natural habitats throughout the world (UNESCO 1974). Among the many aims of the Man and Biosphere (MAB) program were those designed to provide a sample of ecosystems in a natural state so as to maintain ecological diversity, conserve genetic resources, and facilitate education and research (IUCN 1978). The conserved areas are representative of the included habitats. We have circumscribed the concept of representativeness (Margules and Usher 1981) to fit phosphate-mined lands, in particular: “rehabilitated phosphate-mined lands should include typical or common vertebrate species as well as rare vertebrate species, in their typical relative abundances, to represent the full range of the biota." Following this concept will produce a system of rehabilitated phosphate-mined lands that, collectively, encompass the broad range of vertebrate species typically found in areas that have not been mined or otherwise significantly modified.

We believe that the concepts of rehabilitation and representativeness together provide a reasonable framework for the reclamation of phosphate-mined lands in Florida. Rather than placing extreme importance on rare and/or endangered or threatened species, representativeness emphasizes the value of preserving overall biodiversity. The concept of representativeness as applied to our specific rehabilitation effort facilitates maintenance of heterogeneous gene pools, the perpetuation of the full diversity of plant and animal species, and the opportunity to expand and connect the fragmented patches of vertebrate habitats, both "natural" and rehabilitated. By "natural," we mean typical and representative, and that the plants and animals living in the habitat are essentially complete or intact, and function as they would in the absence of humans (Margules 1986).

Upland Habitats and Their Vertebrate Species in Central Florida

There is ample evidence of a serious decline in the quality and quantity of habitats for wildlife in Florida during this century. Some precious habitats, for example coastal dunes, mangroves, most wetlands, and the Everglades, are afforded protection by State and Federal regulations. Most upland habitats, however, are not protected and are extremely vulnerable to human activities. [We use "upland habitats" to mean natural, or at least relatively-unmodified, xeric lands -- specifically sandhill, scrub, and scrubby flatwoods.] Urbanization, agricultural, and mining efforts have altered much of central Florida during the past 50 years. For example, by 1981, upland habitats in central Florida had been reduced to about 65% of their original coverage (Christman 1988). The reduction now approaches 85% throughout south-central Florida, as a result of the expansion of the citrus industry there during the past decade. Because of the loss of so much of the original upland habitats, and the likelihood that loss will continue, one might argue that rehabilitation (i.e., returning lands as closely as possible to pre-disturbance conditions) of modified upland habitats should be a primary focus of reclamation efforts in Florida. [We use "modified upland habitats" to mean xeric lands that have been significantly altered by urbanization, agriculture, mining, or other human uses.]

Upland habitats contain a diverse array of organisms. Some of the unusual organisms included on lists of species from central Florida's upland habitats are now also found on lists of threatened and/or endangered species. For example, over 12% of the non-weedy plants in scrubs (about 300 species) are listed as endangered or threatened species. Among the listed vertebrates in upland habitats in central Florida are two amphibians, the gopher frog *(Rana capito),* and the striped newt *(Notophthalamus perstriatus),* several reptiles, the gopher tortoise *(Gopherus polyphemus),* the scrub lizard *(Sceloporus woodi),* the sand skink *(Neoseps reynoldsi),* the Florida pine snake *(Pituophis melanoleucus mugitus),* the short-tailed snake *(Stilosoma extenuatum),* the eastern indigo snake *(Drymarchon corais couperi),* two bird species, the Florida scrub jay *(Aphelocoma* *coerulescens coerulescens),* and the southeastern American kestrel *(Falco sparverius paulus),* and two small mammals, the Florida mouse *(Podomys floridanus),* and Sherman's fox squirrel (Sciurus *niger shermani).* Several of these vertebrates occur in Florida and nowhere else on Earth.

With proper rehabilitation, phosphate mining may constitute only a temporary disturbance to upland habitats. Some research suggests that primary succession on unreclaimed spoil piles culminates in xeric or mesic oak forests that support a diverse array of vertebrates, indicating that many vertebrate species will recolonize mined lands after mining has ceased (Schnoes and Humphrey 1987). Of course, a source of animals must be present for recolonization to occur. In central Florida, there is a large pool of resident vertebrates (Layne et al. 1977) to serve as potential colonists. Unfortunately, we know very little about rates of colonization of reclaimed habitats, and there are no established procedures for reintroduction of vertebrates to reclaimed lands (Humphrey et al. 1985). In particular, we do not know how the rare or unusual species respond to rehabilitation efforts or even if they can be reintroduced into rehabilitated habitats.

Problems, Solutions, and Products of the Research
(Slightly Modified from the Research Proposal)

- Problems
  - Determine identities and inherent variation of resident vertebrate species on unmined lands. [Existing unmined lands must serve as the source for species to colonize mined lands.]
  - Determine identities and inherent variation of resident vertebrate species on mined lands.
  - Determine identities of the experimental variables correlated with the distribution of "focal species" (i.e., species found less often on mined lands than on unmined lands) on mined lands.

- Solutions
  - Identify and establish study sites throughout central Florida to allow us to gather data on resident vertebrates and to assess the inherent variation in vertebrate populations on unmined and mined lands.
  - Evaluate the information on resident vertebrates in light of the variables we deem important to the biologies of these species (size of patch, distance of patch to nearest water, distance of patch to nearest upland habitat, and vegetation structure and composition).
  - Establish a series of correlations between the measured environmental variables and the presence or absence of the focal species.

- Products
  - Lists of the relative abundances of vertebrate species at our study sites.
  - Lists of the physical variables correlated with the presence/absence of focal species at our study sites.

STUDY SITES AND STUDY SPECIES

Phosphate Mining Terminology

To reduce confusion about some of the terminology used in the process of mining phosphate and the process of reclaiming phosphate-mined lands we are using the following definitions.

- Clay Settling Pond. A reservoir created by earthen dams and filled with water laden with fine clay particles. Water used to process the phosphate matrix (defined later) is pumped into the settling ponds where the clay settles out of the water. Clay is a "waste" product and the water is recycled through the processing plant. The depth of the settling pond may be as great as 10m. Reclamation (defined later) of clay settling ponds is accomplished by consolidation of the top few meters of their surfaces. Sand tailings (defined later) may be pumped into the clay settling ponds to facilitate clay consolidation.

- Phosphate matrix. The stratum of phosphate, sand, and clay in which Florida phosphate is found. This ore-bearing stratum is found an average of 25 feet below the Earth's surface.

- Reclamation. Lands mined for phosphate after 1 July 1975 are subject to the mandatory reclamation requirements of the State of Florida. The requirements include returning mined lands to a condition of potential beneficial use. The aims of the reclamation guidelines emphasize restructuring and stabilizing new land forms in a timely manner to eliminate the visual scars of mining, to eliminate safety hazards, and to control water quality. Specific requirements include reduction of precipitous slopes both on land and in water to a more aesthetically pleasing rolling topography with fewer hazards to animals and humans, to remove all physical evidence of mining from the ground (machinery, pipes, etc.), to alleviate any potentially hazardous waters from exiting the mined area and entering other streams or lakes, and to stabilize the newly contoured land by establishing a ground cover of vegetation.

- Sand tailings. Sand separated from the phosphate matrix or ore as the ore is processed. Sand tailings are used to fill in the pits created by the mining process.

- Overburden. The earth which lies above the phosphate matrix and which must be removed before the matrix is mined.

- Topsoil. The material at the surface of the earth that supports plant growth. "Topsoiling" is the process of removing topsoil (and sometimes plant material, as well) from an area about to be mined and spreading it on a regraded mined area. Covering the surface of a reclaimed site with topsoil hastens the establishment of a plant cover (Feiertag et al. 1989).

- **Replanting.** Reclaimed phosphate-mined lands are planted with grasses, shrubs, and trees as part of the reclamation procedure.

Rationale for Site and Species Selection

We focused our attention on several groups of vertebrate species. The first such group was the local pool of resident species. This local pool establishes the possible boundaries of rehabilitation efforts. For example, if species X is extremely rare in unmined areas, then it may be unrealistic to expect to establish large populations of species X in rehabilitated areas. To establish the pool of local resident species, we reviewed all existing information on species' distributions and collected additional information from field samples and observations within the general area of past and present phosphate mining operations. To determine which elements of the species pool have successfully colonized previously-mined lands, we collected information from field samples and observations on the previously-mined lands themselves. With this information in hand, we were able to identify species -- "focal species" -- from the local pool of resident species that were under-represented on previously-mined lands. This procedure follows from our notion that rehabilitated lands should represent the range of biological variation of the region in which the rehabilitation is occurring. We do not expect an individual rehabilitated site to contain the full range of variation, but, we do expect a series of sites taken collectively to come closer to achieving that end. The information necessary for making appropriate comparisons between upland habitats and previously-mined lands was obtained from two principal sources. One source was documented occurrences of vertebrates within the central Florida region, such as confirmed lists of species from Development of Regional Impact Statements (DRl's). The other source of information was direct sampling.

We also focused our attention on several groups of sites. Considering the history of phosphate mining, and changes in the laws that govern the reclamation of phosphate-mined lands in central Florida, we decided that our study sites should include two categories of previously-mined lands, those mined prior to the mandatory reclamation laws of 1975 and those mined since 1975. We recognize that a considerable period of time may pass between mining and reclamation, and that a great variation exists in the procedures used to reclaim phosphate-mined lands. Considering the previously-mined lands in this fashion, however, recognizes the various time periods some lands have had for recolonization and the various reclamation methods that may have been employed since 1975. Our experience has taught us that there is inherent variation among upland habitats, as well. To incorporate known sources of variation important to vertebrates residing in a given patch of land, either previously-mined or not, we determined the size of the patch, the distance of the patch to the nearest upland habitat, the distance of the patch from the nearest permanent body of water and to the nearest seasonal wetlands. The importance of size and isolation to colonization is widely acknowledged. A great deal of research has shown that succession and disturbance interact to create a mosaic of habitats which are colonized most rapidly when the habitat patches are relatively large and relatively near sources of potential colonists. Colonization and extinction, caused primarily by habitat dynamics, are primary causes of the positive species-area relationship (Seagle and Shugart 1985). Small populations, even when protected from human interference, appear unusually prone to extinction (Simberloff 1986), especially when they are isolated. Relatively large patches of habitat tend to be colonized more rapidly, offer species greater protection from extinction, and support more species than equally-isolated smaller patches of habitat. A minimum of seven replicates of the two kinds of previously-mined sites and the three ostensible kinds of upland habitats -- sandhill, scrub, scrubby flatwoods -- was used in the study, and these replicates were spread out as much as possible among categories of size and distance.

Site Selection

To select our study sites we consulted with Mr. Tim King (Florida Game and Freshwater Fish Commission, Lakeland Office) and numerous representatives of the phosphate industry. They provided much information about the current usage and past histories of many sites throughout central Florida and led us to many potential study sites for our research. Other possible sites were selected by examination of topographic and other available maps. After having identified a list of potential sites, we surveyed the sites by helicopter. We followed the helicopter surveys with visits to all potential sites to determine their suitability. We then did whatever was necessary to identify the owners of the properties we had selected for our study to obtain their permission to use that site. Obtaining permission to use some public and private lands for our research proved to be a time consuming process.

The phosphate industry supported our efforts to use mined lands for our vertebrate surveys. As well, we identified unmined sites on lands owned by various phosphate companies and were encouraged to use these sites for study. We were, however, unable to locate a sufficient diversity of unmined sites on industry owned lands to satisfy our desired number of replicates of each habitat type. Therefore, numerous unmined sites were located on other privately or publicly owned lands.

We focused our study on three types of upland habitat including scrub, sandhill, and scrubby flatwoods. The most xeric of the three upland habitats we studied is scrub, followed by sandhill, and scrubby flatwoods. Scrubby flatwoods often surround scrub habitat, however, without any intervening sandhill habitat. In other words, the current distribution of the three habitats is patchy, reflecting, in part, their irregular establishment during past times of elevated sea levels. The distribution of scrub in Florida reflects the interaction of soil conditions, physiography, fire periodicity, landscape patterns, and characteristics of scrub vegetation (Myers 1990). The major concentrations of inland peninsular scrubs occur on a series of sand ridges and ancient sand dunes extending mostly north to south through central Florida. Most scrub soils are entisols (soils with little or no horizon), and typically bright white. Regardless of their origins, soils supporting scrub are excessively well-drained, siliceous sands virtually devoid of silt, clay, and organic matter. The predominant vegetation of scrub includes a layer of evergreen oak trees such as myrtle oak *(Quercus myrtifolia),* sand live oak *(Q. geminata),* scrub oak *(Q. inopina),* and Chapman's oak *(Q. chapmanii);* sand pine *(Pinus clausa);* and rosemary *(Ceratiola ericoides).* Both the sand pine and rosemary may be found in relatively thick stands or in isolated patches. Herbaceous ground cover is relatively sparse, but lichens may cover broad areas of the scrub floor. Fire periodicity ranges from 15 to about 100 years, but most scrubs burn once every 40 to 80 years (Myers 1990).

The gradation from scrub to scrubby flatwoods is, in places, so imperceptible that the distinction of the two types as separate habitats is not compelling (Myers 1990). The two habitats are similar both floristically and structurally. The term "scrubby flatwoods" is used to describe scrubs that either lack a pine overstory or support slash pine *(Pinus elliottii)* and/or longleaf pine *(Pinus palustris),* rather than sand pine. Scrubby flatwoods occur on sites that are somewhat higher and better drained than flatwoods or dry prairies, but lower and less well drained than scrub or sandhills (Abrahamson and Hartnett 1990). The typically gray entisols of scrubby flatwoods are sufficiently well drained to prevent the accumulation of standing water, even in very wet years, yet they have a higher water table than scrub or sandhill. Scrubby flatwoods may represent an ecotone between flatwoods and scrub habitats, but because of its extensive distribution, is considered a separate habitat type (Abrahamson and Hartnett 1990).

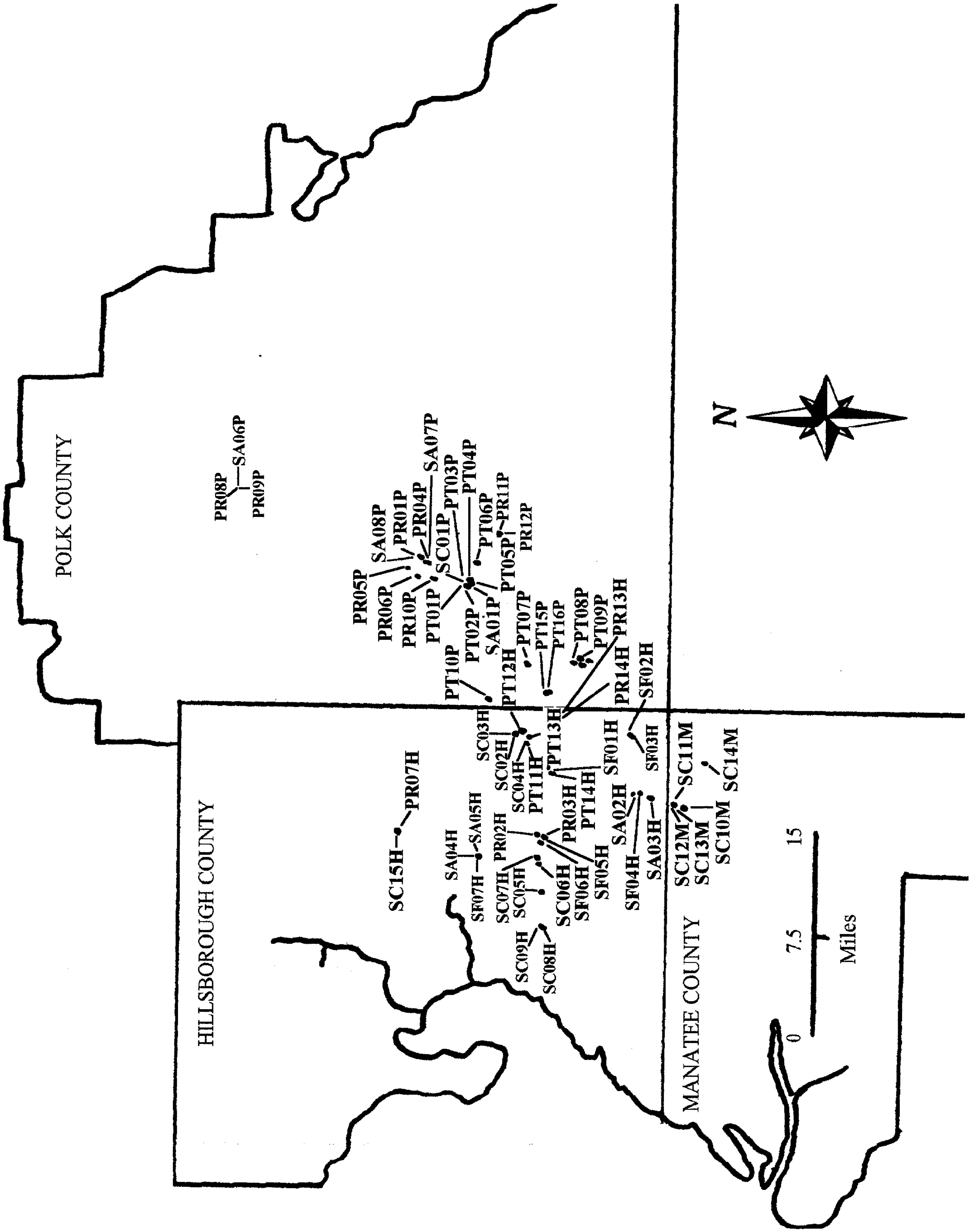
Sandhill, the third upland habitat we studied, is a type of "high pineland" characterized as an upland savanna-like habitat. Sandhill habitat usually appears as an open overstory of longleaf pine/deciduous oak trees, and a ground cover of perennial grasses and herbaceous plants. In central Florida, the longleaf pine *(Pinus palustris)* may be associated with turkey oak *(Quercus laevis)* and/or bluejack oak *(Q. incana),* but other oaks are found on sandhills in other portions of the southeast United States. The ground cover in sandhill plays a major role in the functional dynamics of this habitat. Typically a carpet of wiregrass (often *Aristida beyrichiana)* -- but other grasses may be included -- creates a matrix for numerous herbaceous plants, shrubs, and saw palmetto *(Serenoa repens).* A thick carpet of wiregrass helps spread the fire through the sandhill. Fire periodicity in sandhill is frequent, perhaps every 5-10 years. Sandhill soils lack any appreciable horizon, and like scrub soils, are classified as entisols. Sandhill soils may be gray or yellowish in coloration.

In all, we selected 60 study sites (Table 1) in Hillsborough, Polk, and Manatee counties (Figure 1). Thirty study sites were previously-mined lands (hereafter referred to as "mined sites"); of these, 14 were thought to have been mined prior to 1975 and 16 thereafter. The mined sites had received various amounts of reclamation effort. Thirty study sites were patches of upland habitats (hereafter referred to as "unmined sites'); of these, 8 were classified sandhill, 15 scrub, and 7 scrubby flatwoods. Principal components analysis (Ludwig and Reynolds 1988, p. 223), based on tree species' densities, revealed that most sandhill sites were indeed well-separated floristically from scrub and scrubby flatwoods sites, but that scrubby flatwoods sites floristically were a circumscribed subset within the bounds described by the scrub sites. We measured the size and distances from permanent water, other upland habitat, and seasonal water (i.e., temporary wetlands

TABLE 1. Study sites. Sites are grouped by cluster (geographical grouping of sites that were within 2Km of one-another; see Figure 1), within county, within habitat designation (descriptions in text). Asterisks indicate clusters in which both unmined and mined sites occur.

SITE	R, T, S	HABITAT	COUNTY	CLUSTER
SA02H	21E, 32S, 21	Sandhill	Hillsborough	R
SA03H	21E, 32S, 24	Sandhill	Hillsborough	R
SA04H	21E, 30S, 30	Sandhill	Hillsborough	E
SA05H	21E, 30S, 29	Sandhill	Hillsborough	E
SA01P	24E, 30S, 21	Sandhill	Polk	D*
SA06P	25E, 27S, 29	Sandhill	Polk	A*
SA07P	24E, 30S, 03	Sandhill	Polk	C*
SA08P	24E, 29S, 26	Sandhill	Polk	C*
SC02H	22E, 31S, 02	Scrub	Hillsborough	H*
SC03H	22E, 31S, 02	Scrub	Hillsborough	H*
SC04H	22E, 31S, 09	Scrub	Hillsborough	H*
SC05H	20E, 31S, 13	Scrub	Hillsborough	K
SC06H	21E, 31S, 18	Scrub	Hillsborough	L
SC07H	21E, 31S, 18	Scrub	Hillsborough	L
SC08H	20E, 31S, 17	Scrub	Hillsborough	J
SC09H	20E, 31S, 17	Scrub	Hillsborough	J
SC15H	21E, 29S, 21	Scrub	Hillsborough	B*
SC10M	21E, 33S, 10	Scrub	Manatee	T
SC11M	21E, 33S, 10	Scrub	Manatee	T
SC12M	21E, 33S, 10	Scrub	Manatee	T
SC13M	21E, 33S, 10	Scrub	Manatee	T
SC14M	22E, 32S, 16	Scrub	Manatee	U
SC01P	24E, 30S, 22	Scrub	Polk	D*
SF01H	22E, 31S, 17	Scr. Fltwds.	Hillsborough	N*
SF02H	22E, 32S, 22	Scr. Fltwds.	Hillsborough	S
SF03H	22E, 32S, 22	Scr. Fltwds.	Hillsborough	S
SF04H	21E, 32S, 23	Scr. Fltwds.	Hillsborough	R
SF05H	21E, 31S, 21	Scr. Fltwds.	Hillsborough	M*
SF06H	21E, 31S, 17	Scr. Fltwds.	Hillsborough	M*
SF07H	21E, 30S, 29	Scr. Fltwds.	Hillsborough	E
PR02H	21E, 31S, 16	Mine < 1975	Hillsborough	M*
PR03H	21E, 31S, 16	Mine < 1975	Hillsborough	M*
PR07H	21E, 29S, 28	Mine < 1975	Hillsborough	B*
PR13H	22E, 31S, 23	Mine < 1975	Hillsborough	P
PR14H	22E, 31S, 26	Mine < 1975	Hillsborough	P
PR01P	24E, 29S, 34	Mine < 1975	Polk	C*
PR04P	24E, 29S, 34	Mine < 1975	Polk	C*
PR05P	24E, 29S, 27	Mine < 1975	Polk	C*
PR06P	24E, 29S, 32	Mine < 1975	Polk	C*
PR08P	24E, 27S, 26	Mine < 1975	Polk	A*
PR09P	24E, 27S, 25	Mine < 1975	Polk	A*
PR10P	24E, 30S, 05	Mine < 1975	Polk	C*
PR11P	25E, 30S, 29	Mine < 1975	Polk	G
PR12P	25E, 30S, 29	Mine < 1975	Polk	G
PT11H	22E, 31S, 10	Mine > 1975	Hillsborough	H*
PT12H	22E, 31S, 10	Mine > 1975	Hillsborough	H*
PT13H	22E, 31S, 10	Mine > 1975	Hillsborough	H*
PT14H	22E, 31S, 18	Mine > 1975	Hillsborough	N*
PT01P	24E, 30S, 16	Mine > 1975	Polk	D*
PT02P	24E, 31S, 16	Mine > 1975	Polk	D*
PT03P	24E, 30S, 22	Mine > 1975	Polk	D*
PT04P	24E, 30S, 22	Mine > 1975	Polk	D*
PT05P	24E, 30S, 21	Mine > 1975	Polk	D*
PT06P	24E, 30S, 22	Mine > 1975	Polk	D*
PT07P	23E, 31S, 10	Mine > 1975	Polk	I
PT08P	23E, 31S, 27	Mine > 1975	Polk	Q
PT09P	23E, 31S, 34	Mine > 1975	Polk	Q
PT10P	23E, 30S, 30	Mine > 1975	Polk	F
PT15P	23E, 31S, 18	Mine > 1975	Polk	O
PT16P	23E, 31S, 18	Mine > 1975	Polk	O

FIGURE 1. Study sites. Site designations are the same as in Table 1.



emerging during the rainy season) of each site (see **METHODS),** to ensure that we obtained a variety of sizes and distances (Table 2).

Species Selection

The vertebrate species that are likely to colonize rehabilitated mined lands in abundances similar to those in upland habitats in central Florida are the resident species. Resident species, then, are a subset of the greater local pool of species known to occur in sandhill, scrub, or scrubby flatwoods. We expected to find a considerable overlap in the vertebrate species composition of these upland habitats, but several species occur primarily in one habitat and are less common in the others. Some species from the local pool of species occasionally may use one or more of the three habitat types, but do not establish residency in these habitats. Numerous bird and snake species, for example, may traverse the upland habitats, even periodically, but are not considered to be residents. We used several sources to construct our list of resident vertebrate species. We considered a species to be a resident of the upland habitats if two of the three sources agreed that it was so; other species found in these habitats are considered non-resident, or transient, species. Note that we did not necessarily use the same source for each taxonomic grouping -- amphibian, reptile, mammal, bird -- or habitat type. Lists of both resident and transient in the region are given in Appendix 1. Sources used to construct lists of local resident species follow.

Layne, J. N., J. A. Stallcup, G. E. Woolfenden, M. N. McCauley, and D. J. Worley. 1977. Fish and wildlife inventory of the seven-county region included in the Central Florida phosphate areawide environmental impact study. Prepared by Archbold Biological Station for the Fish and Wildlife Service. [All groupings of vertebrates in all habitats.]

Christman, S. P. 1988. Endemism and Florida's interior scrub habitat. Final Project Report submitted to Florida Game and Fresh Water Fish Commission, Division of Wildlife, Nongame Section, Tallahassee. [All groupings of vertebrates in the scrub habitat.]

Ashton, R. E., Jr., and P. S. Ashton. 1988. Handbook of reptiles and amphibians of Florida, Part 3, The amphibians. Windward Publishing Co., Miami. [Amphibians in all habitats.]

Ashton, R. E., Jr., and P. S. Ashton. 1985. Handbook of reptiles and amphibians of Florida, Part 2, Lizards, turtles and crocodilians. Windward Publishing Co., Miami. [Lizards and turtles in all habitats.]

Ashton, R. E., Jr., and P. S. Ashton. 1981. Handbook of reptiles and amphibians of Florida, Part 1, The snakes. Windward Publishing Co., Miami. [Snakes in all habitats.]

TABLE 2. Summary of the physical characteristics of the 60 study sites. Entries are the numbers of sites within categories.

SITE TYPE	SIZE		DISTANCE TO					
			Permanent Water		Upland		Seasonal Water	
	<25ha	>25ha	<300m	>300m	<300m	>300m	<300m	>300m
Unmined	18	12	22	8	24	6	22	8
Mined	20	10	23	7	9	21	24	6

Stout, I. J., D. R. Richardson, and R. E. Roberts. 1988. Management of amphibians, reptiles, and small mammals in xeric pinelands of peninsular Florida. In: Szaro, R. C., K. E. Severson, and D. R. Patton (eds.), Management of Amphibians, Reptiles, and Small Mammals in North America. USDA Forest Service, General Technical Report RM-166. [Some small mammals in all habitats.]

Brown, L. B. 1993. Mammals of Florida. Windward Publishing Co., Miami. [Some small mammals, including bats, and large mammals in all upland habitats.]

Kale, H. W, II, and D. S. Maehr. 1990. Florida's birds, a handbook and reference. Pineapple Press, Sarasota. [Birds in all habitats.]

We compared the lists of species from mined sites to those from unmined sites. This comparison provided us with information about the number and types of species that colonize previously-mined lands without any particular help. Species which are found much more commonly -- locally -- in patches of upland habitats than on previously-mined lands are the focal species. To determine which of the resident vertebrate species actually might be present at our sites, we supplemented our own data with information on species distributions gathered from certain other sources. We reviewed all Development of Regional Impact (DRI) and final reports on file in the FIRP library or the Florida Game and Fresh Water Fish Commission Office, both in Bartow, but tabulated only data from on-site sampling that were included in those reports. Many DRI's reported data obtained from pre-existing information (i.e., field guides to the mammals, birds, amphibians and reptiles of North America); because these sources do not identify specific habitats, we did not use them. DRI and final reports used to construct lists of local resident species follow (site numbers are from Table 1).

Evaluation of Xeric Habitat Reclamation at a Central Florida Phosphate Mine, prepared by Tim King, Brian Toland and Jim Feiertag, Office of Environmental Services, Florida Game and Fresh Water Fish Commission, Lakeland, Florida for IMC Fertilizer Co., July 1992. [Includes information about sites SC01P and PT03P.]

Boyette Tract Wildlife Assessment, prepared by Post Buckley Schuh, and Jernigan, Inc., November 1989. [Includes information about sites SC05H, SC07H, SF05H, SF06H, PR02H, and PR03H.]

Kingsford Mine Extension, prepared by Gurr and Associates, Inc., June 1986, updated April 1987. [Includes information about sites SC02H and PT13H.]

Noralyn/Phosphoria Mine Extension, prepared by Gurr and Associates, Inc., June 1985. [Includes information about sites SA01P, SC01P, PTP01 , PT03P, PT04P, PT05P, and PT06P.]

Haynsworth Conceptual Reclamation Plan, prepared by Brewster Phosphates Inc., October 1981. [Includes information about sites PT08P, PT09P, PT15P, and PT16P.]

Bonny Lake Mine Conceptual Reclamation Plan, prepared by W. R. Grace and Co., October 1981. [Includes information about sites SA07P, PR04P, PR05P, PR06P, and PR10P.]

Fishawk Ranch, prepared by Florida Land Design and Engineering, November 1988. [Includes information about sites SA04H, SA05H, and SF07H.]

Hillsborough County Mines, prepared by IMC Fertilizer Co., June 1990. [Includes information about sites SA02H, SA03H, SA04H, SF02H, SF03H, and SF04H.]

Lonesome Mine, prepared by Brewester Phosphates Inc., August 1973. [Includes information about sites SF01H and PT14H.]

Big Four Mine, prepared by Amax Phosphate, Inc., October 1981. [Includes information about sites PR13H and PR14H.]

Kingsford Mine (Hillsborough Tract), prepared by Conservation Consultants Inc., February 1974. [Includes information about sites SC02H, SC03H, SC04H, PT11H, PT12H, and PT13H.]

We identified focal species in the following manner. The actual ratio of unmined:mined sites at which a species occurred was compared against a 1:1 ratio with the Binomial Distribution. The magnitude of the deviation from a 1:1 ratio (the Binomial Test score) was used to rank all species ("Sites Scores"). Those species for which the ratio was not 1:1, at $p = 0.10$, were the focal species. Note that the p-value used for identifying focal species was chosen purposely to reduce the size of the set of species included to those that strongly satisfy the criterion of differential distribution between unmined and mined sites. The p-value can be increased as much as one wishes, so that, when it is high enough, all species will be included. Each focal species' sites score was adjusted by a scaling factor, which was the relative difference in abundance of the species between the unmined and mined sites at which it occurred (1 indicated no difference and 4.5 indicated maximum difference). The sites scores, multiplied by the scaling factors, also were used to rank species ("Adjusted Sites Scores").

METHODS

Personnel

Following, we list the key personnel involved in designing, and executing our research. A brief description of the role played by each person is included.

Henry R. Mushinsky and Earl D. McCoy, Professors of Biology, University of South Florida, were co-principal investigators for this research project. They were responsible for the administration of the research, hiring research assistants and other personnel, selection of study sites, installation of trap arrays, analyzing the data collected, and preparation of reports.

Robert A. Kluson, Ph.D. was hired for the post-doctoral position for our research. Dr. Kluson had experience in soil science and botany. He has been involved in site selection, installation of trap arrays, and collecting data. His expertise and contributions proved highly valuable for soil and vegetation analyses.

Robert Musi, M.S. was hired as a research assistant. Robert had considerable ornithological experience in Florida and was responsible for censusing birds at each study site. Rob also helped with the site selection process, installation of trap arrays, developing methods for bird surveys, and data collection.

Pablo Delis, M.S. was hired temporarily during the summer of 1993 to review sources of information on the distribution of vertebrates in central Florida.

Charlotte Vandaveer, B.S. was employed intermittently during 1994 and 1995 to assist with vegetation sampling of the study sites. Charlotte has considerable experience working in xeric habitats and proved to be a valuable field assistant.

A group of undergraduate students from the University of South Florida were employed periodically to construct funnel traps which are used in conjunction with the drift fences and pitfall traps.

Survey Methods: Size, Distances, and Other Physical Variables

The size and distances to permanent water, other upland habitat, and seasonal water were determined from examination of recent maps and aerial photographs, followed by field observations, using a combination of Global Positioning System (GPS), compass, and tape measurements. Sites less than 25 hectares (62.5 acres) are considered “small,” while sites larger than 25 hectares are considered “large.” We created similar dichotomies for each of the three distance measures. Distances less than 300 meters from permanent water, or other upland habitat, or seasonal wetlands are considered “near,” while distances greater than 300 meters are considered “far” for each category. The size and distance measurements used to create these categories were derived from our previous studies of upland habitats in Florida (e.g., McCoy and Mushinsky 1994).

We measured several other physical variables for each site. Because the quality of lands surrounding our study sites may influence the vertebrates that occur there, we characterized the lands surrounding each site. All surrounding lands within an area four times greater than the area of a site were classified into one of ten possible categories: upland habitat, wetland, citrus grove, pasture, farm, active mine, inactive mine, reclaimed land, old field, and residential. We also noted whether or not cattle were present at a site during our sampling. Some of the physical variables that we thought might be important to measure -- e.g., fire management, reclamation practices -- were historical in nature, and we attempted to get this historical information by sending out questionnaires to land owners/managers. The questionnaires sent to owner/mangers of mined sites consisted of the following nine specific items. (1) When was the site mined? (2) When was the site reclaimed? (3) How was the substrate at the site reclaimed? (4) Was any attempt made to reestablish a plant community at the site? (5) If so, when and how was the vegetation at the site reclaimed? (6) Has the site been managed? (7) If so, when and how often has the site been managed? (8) Has the site been burned since it was reclaimed? (9) If so, when and how often has the site been burned? The questionnaires sent to owner/mangers of unmined sites consisted of the following seven specific items. (1) Has the site been logged? (2) If so, when did the logging take place? (3) Has the site been burned? (4) If so, when and how often has the site been burned? (5) If so, were the fires natural or a mangement tool? (6) Has the site been used for agriculture? (7) If so, when did the agricultural use take place? Because the historical data are based largely on personal recollection, we have no way of judging their reliability. Of course, we were also able to make our own judgments about the history of a particular site in many cases, from indications such as burn scars on trees and the types and size distributions of individual plants.

Survey Methods: Soils

Chemical and physical soil tests used representative soil samples for each randomly selected plot (see Survey Methods: Vegetation) from all sites. Soil profile studies used subsamples on a subset of 24 sites (12 reclaimed and 12 unmined). Two representative soil samples were obtained for each plot, at two depths (15 and 30cm), and consisted of pooled subsamples. Soil subsamples were collected with a probe (6cm diameter) along the constructed 10m line transect at 2m intervals. Profile studies were performed on separate subsamples under field conditions for each selected plot. Soil subsamples were evaluated along the constructed 10m line transect (see Survey Methods: Vegetation) at 5m intervals and to a 40cm depth at 7.5cm intervals.

Preparation of the representative soil samples from pooled subsamples was done in the lab by air-drying, mixing, and sieving (2mm). Then, a representative sample (100g) was collected for the chemical and physical analyses. Physical tests were conducted at the

Physical Geography Laboratory, Geography Department, University of South Florida, Tampa. Chemical tests were conducted at the Analytical Research Laboratory, Department of Soils and Water Science, University of Florida, Gainesville.

Physical tests included texture and sand particle size. The tests used standard methods (R. Brinkman, Associate Professor, Lab Director, Geography Department, University of South Florida, Tampa): texture by the Bouyoucos hydrometer method, for USDA size classes of sand (2-0.05mm), silt (0.05-0.002mm), and clay (<0.002mm); and sand particle size by dry sieving, with 10min of automated shaking, at full PHI intervals for USDA size classes of very coarse (2-1mm), coarse (1-0.50mm), medium (0.50-0.25mm), fine (0.25-0.10mm; actual interval measured was 0.25-0.125mm), and very fine (0.10-.005; actual interval measured was 0.125-0.063mm).

Chemical tests included pH, total nitrogen (N), available phosphorus (P) and potassium (K), electrical conductivity (i.e., total salts), and organic matter. The tests used standard methods (Research soil sample information sheet. August, 1994. Analytical Research Laboratory, Department of Soil and Water Science, Institute of Food and Agricultural Sciences, University of Florida, Gainesville): pH and electrical conductivity were determined in 2:1 water-soil ratio, total N by the Kjeldahl method (Personal Communication. February, 1995. J. Bartos, Lab Coordinator, Analytical Research Laboratory, Department of Soil and Water Science, Institute of Food and Agricultural Sciences, University of Florida, Gainesville), available P and K by the Mehlich-1 method, and organic matter by Walkley-Black dichromate method.

Soil profile studies included litter depth, compaction, and root density. Litter depth was measured at the subsampling locations with a ruler by hand clearing litter to the mineral soil . If bare ground was present, depth of nearest litter was measured. Compaction was measured with a cone penetrometer (Dickey-John Corp.) under dry and wet conditions. “Dry” means field moisture conditions, which varied across sampling dates. “Wet” means field capacity moisture, which was produced by drenching the ground with water to saturation. Wet measurements were intended to standardized compaction readings across sampling dates because compaction varies with soil moisture status (Mielke et al. 1994). Moisture status was monitored with a soil moisture meter (Lincoln Corp.). Root density was measured with the core break method (Bohm 1979). Soil cores were taken with a soil probe 3cm in diameter and 40cm in length, and then broken at pre-selected depths. Roots exposed at both sides of the breakage faces were counted, and the numbers of roots were then ranked on three-point scale (0 = none, 1 = 1-3, 2 = 4-10, 3 = > 10).

Survey Methods: Vegetation

The vegetation data were collected on plots measuring 10 X 10 meters. Plots were randomly placed within the delineated boundaries of each site. Randomization was accomplished by constructing imaginary x-y axes at the edge of a site. The shape of each site was generalized to a regular geometry to facilitate usage of the two axes. Distances along each axis were selected from a table of random numbers, to establish the starting point of each plot or transect . Three to five plots or transects were sampled at each plot, more at sites with high variability.

Life-form coverage along transects was measured by line-intercept on a 10m line transect across the middle of each plot. We determined percent ground cover from ground level to one meter above ground. We recorded life-form coverage as the relative amount of ground in a plot that was covered by one or more of the categories wiregrass, other grasses, legumes, forbs, woody species, litter, bare ground (= absence of a life-form), and mycophytes (= lichens + fungi), pteriphytes (= ferns + clubmosses), and mosses. [We recognize that one of these categories -- bare ground -- does not represent a "life form" in the strict sense of the phrase; it belongs with the other categories, however, because, in combination, all of the categories describe the entirety of ground cover.] For most analyses, the last three categories were combined into a single category called "crust." Only pre-dominant vegetation was counted, overlapping vegetation was not recorded. We complied a list of species at a site based on plant observations and collections made during all our visits to each site. All identified species were collected only initially for verification with identified specimens at the USF herbarium. Identifications of unknown specimens were conducted under the guidance of Dr. Richard Wunderlin of USF Department of Biology.

Foliage layer height profiles were characterized by visually analyzing the vegetation structure outside plots for seven different layers, Ground, Gap1, Shrub, Gap2, Middle-Canopy, Gap3, and Upper-Canopy strata. Height of each identified layer was estimated with a clinometer at each plot.

Canopy density within plots was measured in two ways. Total canopy cover over 1 and 2.5 m above ground level was determined with a hand-held densiometer (horizontal canopy density). The 2.5 m reading was taken by standing on a ladder. Readings are made at 0, 5 and 10m positions of each line transect in all four compass directions. Canopy density also was estimated by visually scoring the percent cover of a board (2 x 1 m) held at pre-selected heights and from a standardized 10m distance (vertical canopy density). We did this by viewing the board across each plot from N-S and E-W compass directions at 3.3 and 6.6m positions along the edge of the plot. The pre-selected board heights were 2, 4, and 6m above the ground, and the observer was positioned at a corresponding height with the use of a ladder.

Vegetation density was measured using the following procedures. Trees and shrubs were counted and classified according to height (< 0.5, 0.5-1.0, 1.0-2.0, > 2.0m) and DBH (< 10, 10-25, > 25cm) size classes within each plot. We selectively counted tree and shrub species useful for our vegetation classification (i.e., saw palmetto, *Quercus* spp., *Pinus* spp., and other tree species), as well as snags. The counting procedure for saw palmetto took into account the low-lying, branching growth habit of the species. Individual clumps were defined by locating the origin of connected branches, and counts were made of these clumps, instead of the separate branches that often can appear to be separate plants.

Survey Methods: Vertebrates

After we selected a study site, we installed a complete trap array (Christman 1982) there, to capture amphibians, reptiles, and mammals. At each site selected for our study, we carefully examined the general vicinity of the site prior to determining where the trap array would be placed. We placed each trap array in an setting that we considered to be typical and representative of the habitat we were sampling. Briefly, a trap array consists of four 7.5 meter long drift fences (an individual drift fence is a "wing") arranged in a plus shaped (+) and fitted with eight 20 liter buckets buried in the ground at each end of the fence. A gap of 15 meters is maintained between the centers of the north-south and east-west facing wings. For each array, eight funnel traps were constructed and placed near the middle on both sides of each wing. Most of the data reported herein on terrestrial vertebrates were collected from organisms captured in trap arrays. Although trap arrays capture many species of amphibians, reptiles, and mammals, and are probably the best single technique for sampling a wide variety of vertebrates, they are not perfect. They do not, of course, capture meso- and large mammals, or bats. Trap arrays have variable success in capturing tree frogs, large snakes, and arboreal lizards. We noted all other observations of the presence of vertebrate organisms including carcasses, scat, footprints, scrapemarks, and remnants of foraging activities that might help identify an organism. Gopher tortoises were surveyed at each site by taking one 100 X 7 meter belt transect parallel to each wing of a trap array, beginning at the end of each wing and extending distally form the trap array.

We divided each year of the study into six 2-month trapping sessions, and trapped each study site for 7 days during each session. Because traps were checked daily and were dispersed over a broad area, it was not possible to open and check all traps simultaneously. All traps were opened and checked during each two month trapping session, however, to assure consistency of our sampling effort.

Preliminary surveys for birds were conducted using several different methods to determine which method would produce the most reliable results under our field conditions. The methods we used were determined to provide the greatest return for the time invested. The plant cover on our study sites varied from open, weedy fields to dense upland forests. The size of a patch of habitat that served as a study site varied from 1 ha. to > 50 ha. The area surveyed for birds at each study site had to be sufficiently large to encompass the within-patch variation, while being sufficiently small to make conducting surveys practical. We adopted the following methods for our bird surveys.

- Area surveyed. One ha. square plots were established around each trap array. The boundaries of these plots were situated in a manner that allowed for maximum plant species diversity and established to include edge habitat and other features that would attract a variety of species.

- Time of surveys. All bird surveys were conducted between sunrise and 3 hours after sunrise, the period of the day when most species of birds are most active. We did not conduct evening surveys, hence we may have missed some observations of owls and other nocturnal species.

- Survey procedures. On open sites, with a visibility of > 50 m, the surveyor walked randomly around the plot searching for birds. On sites covered with very dense vegetation, with a visibility < 50 m, the surveyor stood quietly, searching and listening for birds. We did not use repeated transect lines or survey points.

- Duration of surveys. Open sites with sparse cover, such as sand tailings and pastures, were surveyed for 15 minutes. Sites with patches of open scrub and sandhill habitats with sparse understory cover were surveyed for 30 minutes. Sites with dense stands of pines with thick understories or very dense patches of scrub were surveyed for 60 minutes.

- Recording data. All bird species detected that were perceived to be using the habitat on that study site. We recorded as "using the habitat" any species observed perching in a tree or shrub, or hunting/foraging on the wing over the habitat (for example, hawks and swallows). Birds seen flying over the study site, but not perceived as using the habitat were not recorded.

- Establishing nesting. Nesting behavior was recorded if detected. Individual birds were determined to be nesting in the habitat if they exhibit certain behaviors. These behaviors include territorial defense by males (e.g., singing and fighting between males), courtship behavior (e.g., males perusing females and offering food to females), nest building (e.g., observing individuals carrying nest materials or actually building nests), and presence of fledglings.

We made no attempt to capture or mark any birds. Rather, to make quantitative estimates of the relative abundance of avian species, we tallied the number of times a given species was observed at a site.

Birds were censused twice each year to determine both resident breeding bird populations and migratory species at each study site. Surveys in March and April were used to determine breeding birds and surveys in December, January, and February were used to determine wintering birds. All bird surveys were conducted by the same person.

Logic and Statistical Analyses

The logic of the study led directly to the analyses we employed. We envisioned the study as a series of eight steps:

- Choose species and sites to be used in subsequent analyses

- Arrange and categorize species and sites

- Determine number of species per site and number of sites per species
- Determine number of individuals per species and number of individuals per site
- Identify patterns among species and among sites
- Derive explanations for the patterns, based on physical and vegetation variables
- At all steps, compare unmined sites to mined sites
- Synthesize the information to produce recommendations

Standard statistical methods, mostly non-parametric, were used to analyze the data. These methods included Spearman's Rank Correlation Analysis (Sokal and Rohlf 1995, p. 598); the Mann-Whitney U-test, a non-parametric method used in lieu of a one-way ANOVA (Sokal and Rohlf 1995, p. 427); Kolmogorov-Smirnov One- and Two-sample Tests for goodness of fit (Sokal and Rohlf 1995, p. 708; and the G-test of independence (Sokal and Rohlf 1995, p. 729). All analyses using these methods were performed with SYSTAT software. The Variance Ratio Test (Schluter 1984; Ludwig and Reynolds 1988, p. 132) and Monothetic Divisive Cluster Analysis (Ludwig and Reynolds 1988, p. 189) were used to assess species' associations. All analyses using these methods were performed with software supplied with Ludwig and Reynolds' (1988) book.

RESULTS

Size, Distances, and Other Physical Variables

All 60 sites were placed into categories of size (small, large), distance to seasonal water (near, far), distance to permanent water (near, far), and distance to other upland habitats (near, far), and the habitats (upland habitat, wetland, citrus grove, pasture, farm, active mine, inactive mine, reclaimed land, old field, residential) immediately surrounding the sites were recorded (Table 3). Presence/absence of cattle grazing during the study also was recorded (Table 3). The 30 mined sites were categorized further according to type of soil (overburden, sand tailings/overburden, sand tailings) andvegetation (topsoil from upland habitats, replanted woody taxa, replanted woody and herbaceous taxa, replanted herbaceous taxa) reclamation. The year(s) in which reclamation took place also were recorded (Table 4).

We were much less confident about the other historical information that we attempted to gather with the questionnaires, The number of responses was small for the unmined sites; thus, we had little information, other than our own observations, about burning, logging, and agricultural usage of these sites. Of the 30 unmined sites, 13 were reported to have been burned, but we think at least 15 of the sites had been burned recently enough to leave physical evidence of burning. Few of the responses supplied the actual dates on which the burns were thought to have occurred, and we suspect that virtually all of the sites have been burned in the not-too-distant past. Of the 30 unmined sites, 16 were reported to have been lagged, but we also suspect that virtually all of the sites have been logged at some time in the past. Of the 30 mined sites, only seven were reported to have been burned since they were reclaimed, and only four were reported to have been managed in any other way -- one was planted in sorghum to attract quail, one was sprayed with herbicides to control weeds, and two were replanted and watered. We judged that these data were inadequate for use in statistical analyses.

Soils

An analysis of soil texture is presented in Figure 2 (individual site data are in Appendix 1). Texture varied little among the three types of unmined sites, at either of the two sampled depths. Although mean percent-sand was very similar among the types of unmined sites, we were still able to detect a substantial difference between scrub (SC) and scrubby flatwoods (SF) sites at both the 0-15cm and 15-30cm horizons (Mann-Whitney U-test, $p < 0.10$), and between sandhill (SA) and scrubby flatwoods sites at the 15-30cm horizon (M-W U-test, $p < 0.10$). All other comparisons between types of unmined sites yielded p-values in excess of 0.10. [Note that in all subsequent analyses in thys section, trends will be identified at a p-value of 0.10, and that the analyses themselves are M-W U-tests, unless otherwise specified.] Mean percent-sand tended to be lower at mined sites than at unmined sites at both the 0-15cm and 15-30cm horizons. Soils at mined sites known to have been reclaimed with overburden (OB) and with mixed sand tailings/overburden (STOB) contained less sand than those known to have been reclaimed with sand tailings

TABLE 3. Size, isolation, and cattle usage of study sites. Small sites are < 25ha and large sites are > 25ha, near sites are < 300m and far sites are > 300m. Surrounding habitats (SURR. HABS.) are: 1 = citrus grove, 2 = pasture, 3 = wetland, 4 = farm, 5 = active mine, 6 = inactive mine, 7 = upland habitat, 8 = reclaimed land, 9 = old field, 10 = residential.

SITE	SIZE	DISTANCE TO			SURR. HABS.	GRAZING
		SEASONAL WATER	PERMANENT WATER	UPLAND		
SA01P	Small	Far	Near	Near	5,7	No
SA02H	Small	Far	Near	Near	2,7	Yes
SA03H	Small	Near	Near	Near	2,7,8	Yes
SA04H	Large	Far	Near	Near	2,7	Yes
SA05H	Small	Near	Near	Near	3,7	Yes
SA06P	Small	Near	Near	Far	1,3,8	No
SA07P	Small	Near	Near	Far	3,5	No
SA08P	Small	Near	Near	Near	1,2,3,6,7	Yes
SC01P	Small	Near	Near	Near	3,5,7	No
SC02H	Large	Far	Near	Near	1,2,7	No
SC03H	Large	Near	Near	Near	1,3,6	No
SC04H	Large	Near	Near	Near	2,3	No
SC05H	Small	Near	Near	Near	2,3,4,9	No
SC06H	Large	Far	Far	Near	2,7	No
SC07H	Large	Near	Near	Near	3,4,9	No
SC08H	Small	Near	Near	Near	3,4,7	No
SC09H	Small	Far	Near	Far	4,10	No
SC10M	Large	Near	Near	Near	2,3,7	Yes
SC11M	Large	Near	Far	Near	2,3,7	Yes
SC12M	Large	Near	Far	Near	2,3,7	Yes
SC13M	Large	Near	Near	Near	2,7,10	Yes
SC14M	Small	Near	Near	Near	2,3,7,10	No
SC15H	Small	Near	Far	Far	3,4,10	No
SF01H	Small	Far	Far	Far	2,7,8	Yes
SF02H	Small	Near	Far	Near	2,3,7	No
SF03H	Small	Near	Far	Near	1,2,3,7	Yes
SF04H	Small	Near	Near	Far	2,3,4,7	Yes
SF05H	Large	Near	Far	Near	3,8,9	No
SF06H	Large	Far	Near	Near	7,9	No
SF07H	Small	Near	Near	Near	2,3,7	Yes
PR01P	Small	Near	Near	Near	2,3,7	Yes
PR02H	Large	Near	Near	Far	3,7	No
PR03H	Small	Far	Near	Far	3,7	No
PR04P	Small	Near	Near	Near	3,5,7	Yes
PR05P	Small	Near	Near	Near	3,7,8	Yes
PR06P	Large	Near	Near	Near	3,5,8	No
PR07H	Small	Near	Far	Far	3,6	No
PR08P	Large	Near	Near	Far	3,8	No
PR09P	Small	Near	Near	Far	3,7	No
PR10P	Large	Far	Near	Far	3,6,8	No
PR11P	Large	Near	Far	Far	2,8	No
PR12P	Small	Near	Far	Far	2,8	No

TABLE 3 (CONTINUED).

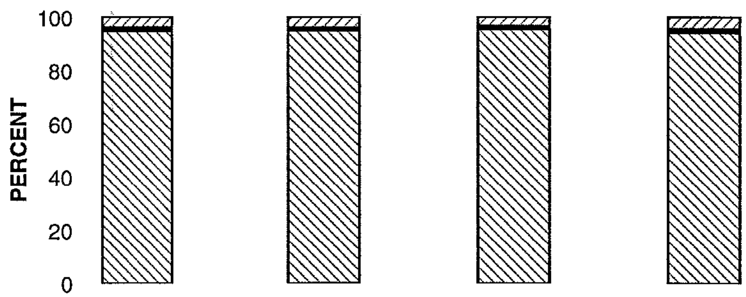
SITE	SIZE	DISTANCE TO			SURR. HABS.	GRAZING
		SEASONAL WATER	PERMANENT WATER	UPLAND		
PR13H	Large	Near	Near	Far	3,5	No
PR14H	Small	Far	Near	Far	3,5	No
PT01P	Large	Far	Far	Near	3,5	No
PT02P	Large	Near	Near	Near	3,5	No
PT03P	Small	Near	Far	Near	3,5,8	No
PT04P	Small	Near	Near	Far	3,5,8	No
PT05P	Small	Near	Near	Far	5,7	No
PT06P	Small	Near	Near	Far	3,5,8	No
PT07P	Small	Near	Near	Far	2,3	No
PT08P	Small	Far	Far	Far	2	No
PT09P	Large	Near	Near	Far	2,3	No
PT10P	Small	Near	Near	Far	3,5	No
PT11H	Small	Near	Near	Near	2,3,8	No
PT12H	Large	Far	Near	Far	1,3,8	No
PT13H	Small	Near	Far	Near	1,2,8	No
PT14H	Small	Near	Near	Far	2,3	Yes
PT15P	Small	Near	Near	Far	3,6,8	No
PT16P	Small	Near	Near	Far	3,6,8	No

TABLE 4. Treatment history of mined study sites. Open spaces indicate data were unavailable. Soil treatments are : OB = overburden, ST = sand tailings. Vegetation treatments are: RW = replanted woody taxa, RH = replanted herbaceous taxa, T = topsoil from upland habitats.

SITE	YEAR TREATED	SOIL TREATMENT	VEGETATION TREATMENT
PR01P	1983	OB	RW
PR02H	<1975	OB	RW,RH
PR03H	<1975	OB	RH
PR04P			
PR05P	1983	OB	RW,RH
PR06P	1991	ST	RH
PR07H		ST	RH
PR08P	1987	ST	RW,RH
PR09P	<1975	ST	RW,RH
PR10P	1979	OB	RW,RH
PR11P	1978	ST	RW,RH
PR12P	1978	ST	RW,RH
PR13H	1981	ST	RW,RH
PR14H	1984	ST	RW,RH
PT01P		ST	T
PT02P		ST	T
PT03P	1990	OB	T
PT04P	1987	OB	T
PT05P	1987	OB	T
PT06P	1987	OB	T
PT07P	1985	ST	RW,RH
PT08P	<1975	OB,ST	RW,RH
PT09P	1993	OB,ST	RH
PT10P	1986	OB	RW,RH
PT11H	1986	OB,ST	RW,RH
PT12H	1993	ST	RW
PT13H	1986	OB,ST	RW,RH
PT14H		OB	RW,RH
PT15P	1994	ST	RW,RH
PT16P	1994	ST	RW,RH

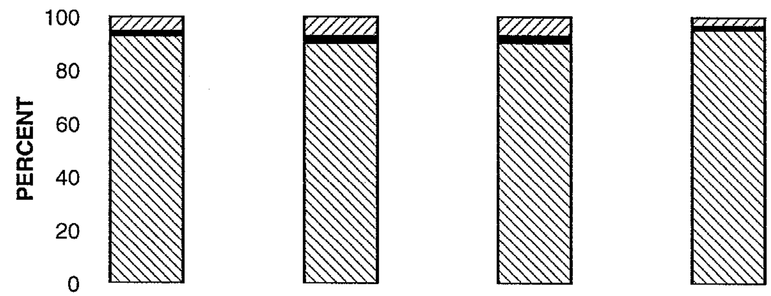
FIGURE 2. Soil texture. Means are displayed for the 0-15cm level (upper left) and 15-30cm level (lower left) at unmined sites, and for the 0-15cm level (upper right) and 15-30cm level (lower right) at mined sites.

UNMINED SITES : 0-15cm LEVEL



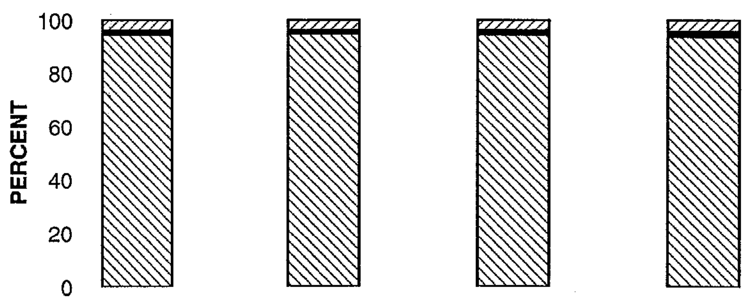
	ALL SITES	SA SITES	SC SITES	SF SITES
%SAND	94.9	95.1	95.5	94.1
%SILT	1.4	1.1	1.2	1.6
%CLAY	3.7	3.8	3.3	4.3

MINED SITES: 0-15cm LEVEL



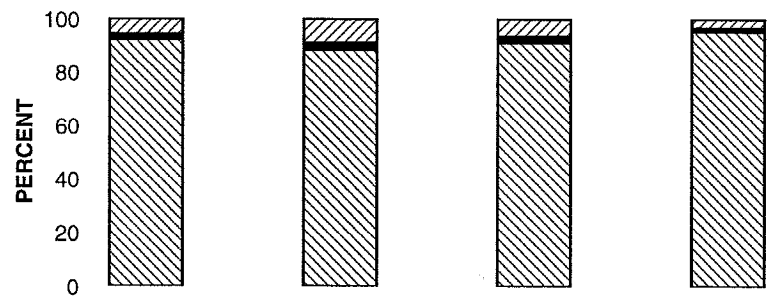
	ALL SITES	OB SITES	STOB SITES	ST SITES
%SAND	92.9	90.4	90.3	95.4
%SILT	1.8	2.4	2.6	1.2
%CLAY	5.3	7.2	7.1	3.4

UNMINED SITES: 15-30cm LEVEL



	ALL SITES	SA SITES	SC SITES	SF SITES
%SAND	94.6	95.1	94.7	93.9
%SILT	1.5	1.1	1.4	1.7
%CLAY	3.9	3.8	3.9	4.4

MINED SITES: 15-30cm LEVEL



	ALL SITES	OB SITES	STOB SITES	ST SITES
%SAND	92.5	88.6	91.3	95.5
%SILT	2.0	2.7	2.4	1.3
%CLAY	5.5	8.7	6.3	3.2

(ST) alone, at both the 0-15cm and 15-30cm horizons. [Note that the STOB soil treatment was used at only four sites, so the power of the statistical analysis is not great.] Only sand tailings tended to have sand in similar percentages to unmined soils, at both depths. Reductions in percent-sand in mined soils must be accompanied, of course, by increases in percent-silt and/or percent-clay. Overall, percent-clay tended to increase more than percent-silt in mined soils. Only sand tailings tended to have similar percentages of silt and clay to unmined soils, at both depths.

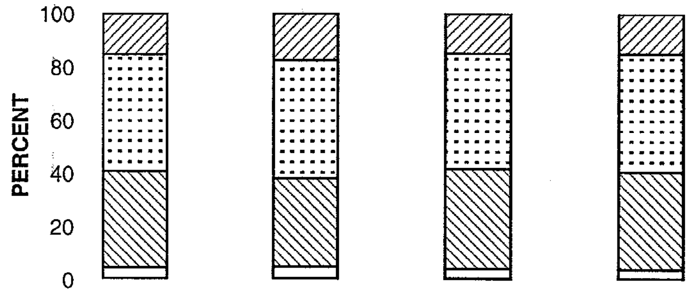
An analysis of sand particle size distribution is presented in Figure 3 (individual site data are in Appendix 1). We detected no differences among the types of unmined sites at the 0-15cm horizon. At the 15-30cm horizon, however, sandhill sites tended to have a higher percentage of very coarse sand than did scrub sites. Mined sites tended to have much higher percentages of very coarse and coarse sand than did unmined sites, whereas unmined sites tended to have much higher percentages of very fine sand, at both the 0-15cm and 15-30cm horizons. We detected a variety of differences in sand particle size among the types of mined sites, particularly in the percentages of fine and very fine sand at both horizons, and in the percentages of very coarse and coarse sand at the 15-30cm horizon. Overall, the sand tailings/overburden were more like the unmined soils in sand particle size than were either the sand tailings or overburden alone.

Analyses of soil compaction (penetrometer resistance), measured at both field moisture (usually near zero detectable moisture) and wetted conditions are presented in Figure 4 (individual site data are in Appendix 1). [Note that soil compaction was measured at a relatively-small subset of sites, so the power of the statistical analysis is not great.] Compaction at field moisture could not be shown to differ very much among the three types of unmined sites, except at 30cm below the surface, and deeper. Here, sandhill soils tended to have lower compaction than scrub and scrubby flatwoods soils. Compaction in wetted conditions gave similar results, but, in this case, sandhill soils tended to have lower compaction than scrubby flatwoots soils at 22.5cm below the surface, and deeper. Soil compaction, either at field moisture or in wetted conditions, was similar for unmined and mined soils at the surface, but at any level farther down, the compaction tended to be greater for the mined soils than the unmined soils. Soil compaction, either at field moisture or in wetted conditions, was similar for the three types of mined soils both at the surface, and at 30cm below the surface, and deeper. Soil compaction tended to be greater for sand tailings/overburden than for sand tailings at intermediate depths (7.5-22.5cm). Individually, compaction of any of the three types of mined soils mirrored the general differences in compaction between mined and unmined soils.

Analyses of soil moisture, root density, and litter depth are presented in Figure 5 (individual site data are in Appendix 1). [Note that soil moisture, root density, and litter depth were measured at a relatively-small subset of sites, so the power of the statistical analysis is not great.] Root density tended to be higher in scrubby flatwoods soils than in sandhill and scrubby flatwoods soils at the surface, but lower in scrubby flatwoods soils than in the other two types at 37.5cm below the surface, and deeper. Root density also tended to be higher in sandhill soils than in scrub soils at intermediate depths (15-22.5cm). Litter depth was

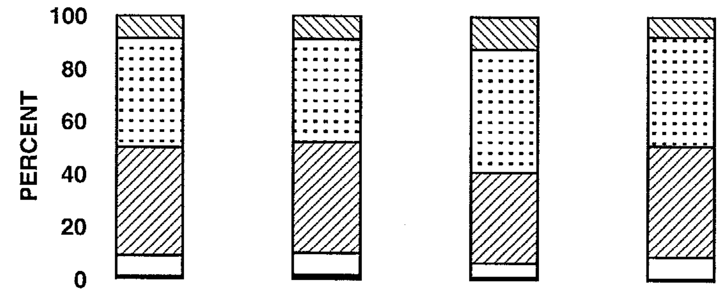
FIGURE 3. Sand particle size. Means are displayed for the 0-15cm level (upper left) and 15-30cm level (lower left) at unmined sites, and for the 0-15cm level (upper right) and 15-30cm level (lower right) at mined sites.

UNMINED SITES: 0-15cm LEVEL



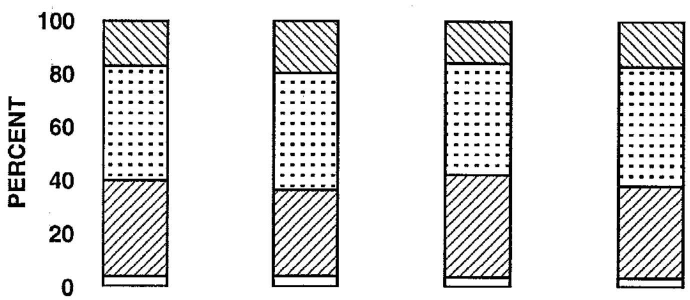
	ALL SITES	SA SITES	SC SITES	SF SITES
%VERY COARSE	0.4	0.4	0.4	0.4
%COARSE	4.1	4.5	3.7	3.6
%MEDIUM	36.3	33.3	37.6	36.7
%FINE	44.0	44.5	43.6	44.6
%VERY FINE	15.2	17.3	14.7	14.7

MINED SITES: 0-15cm LEVEL



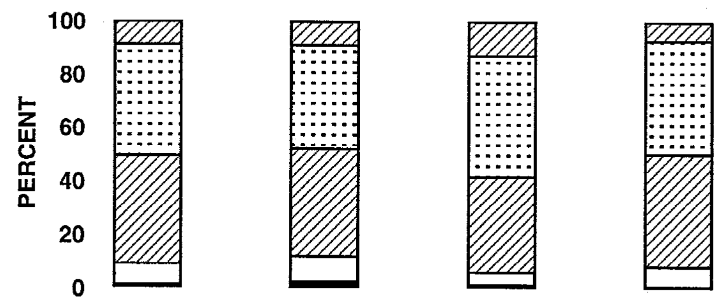
	ALL SITES	OB SITES	STOB SITES	ST SITES
%VERY COARSE	1.4	2.1	1.2	1.0
% COARSE	7.9	8.3	5.6	8.3
%MEDIUM	40.8	41.9	34.4	41.9
%FINE	41.5	39.2	46.7	41.5
%VERY FINE	8.4	8.5	12.1	7.3

UNMINED SITES: 15-30cm LEVEL



	ALL SITES	SA SITES	SC SITES	SF SITES
%VERY COARSE	0.2	0.2	0.1	0.2
%COARSE	3.8	3.9	3.7	3.3
%MEDIUM	35.9	32.3	38.3	34.6
%FINE	43.3	44.2	42.1	44.9
%VERY FINE	16.8	19.4	15.8	17.0

MINED SITES: 15-30cm LEVEL



	ALL SITES	OB SITES	STOB SITES	.ST SITES
%VERY COARSE	1.3	2.4	1.1	0.7
%COARSE	7.8	9.6	4.9	7.5
%MEDIUM	40.4	40.1	35.7	42.0
%FINE	41.9	39.0	45.6	42.8
%VERY FINE	8.6	8.9	12.7	7.0

FIGURE 4A. Soil compaction at unmined sites. Open bars are mean compaction (penetrometer resistance) readings under normal field conditions, closed bars are mean compaction readings under wetted conditions. Soil moisture data are displayed in Figure 5B.

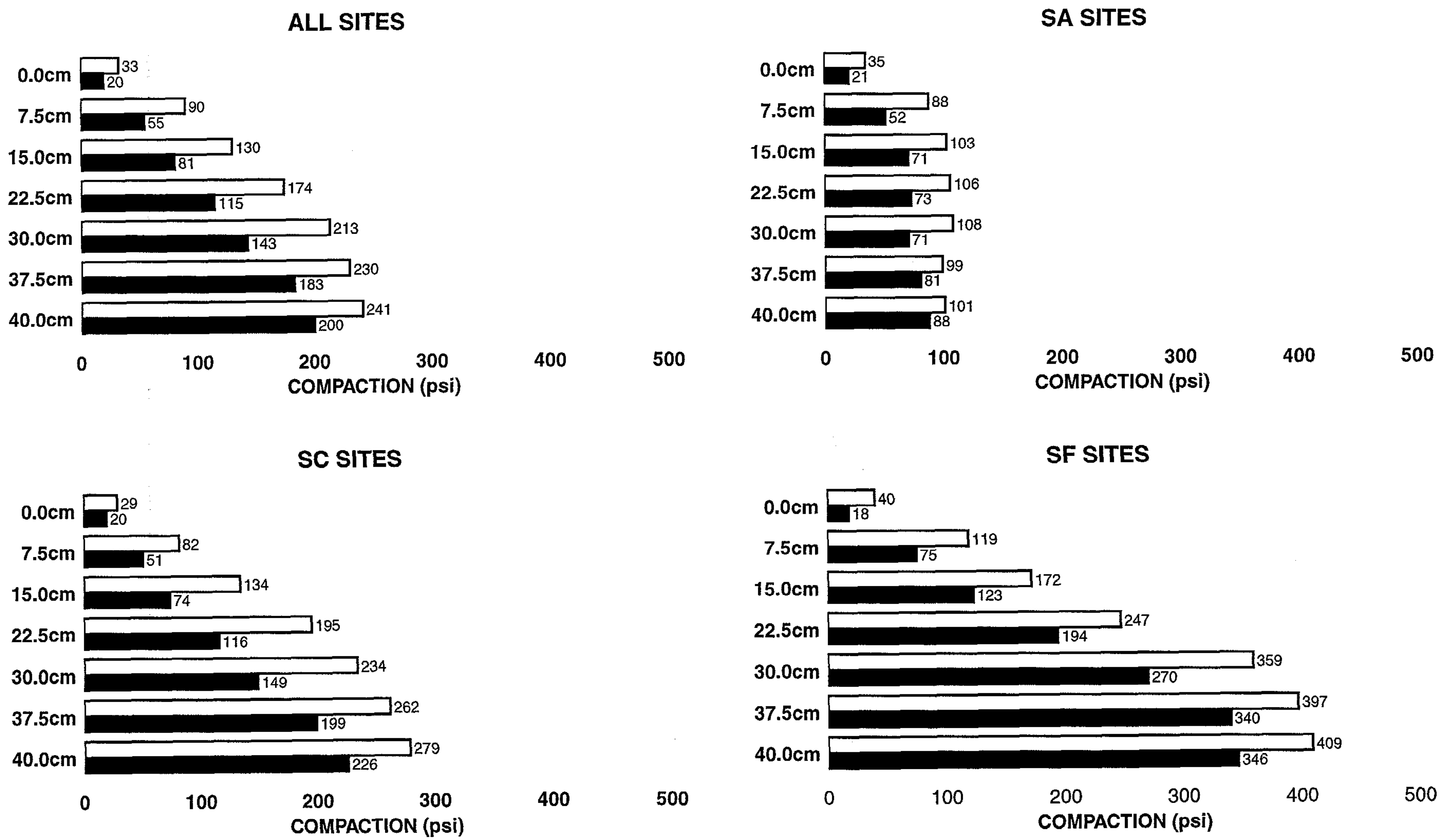


FIGURE 4B. Soil compaction at mined sites. Open bars are mean compaction (penetrometer resistance) readings under normal field conditions, closed bars are mean compaction readings under wetted conditions. Soil moisture data are displayed in Figure 5D.

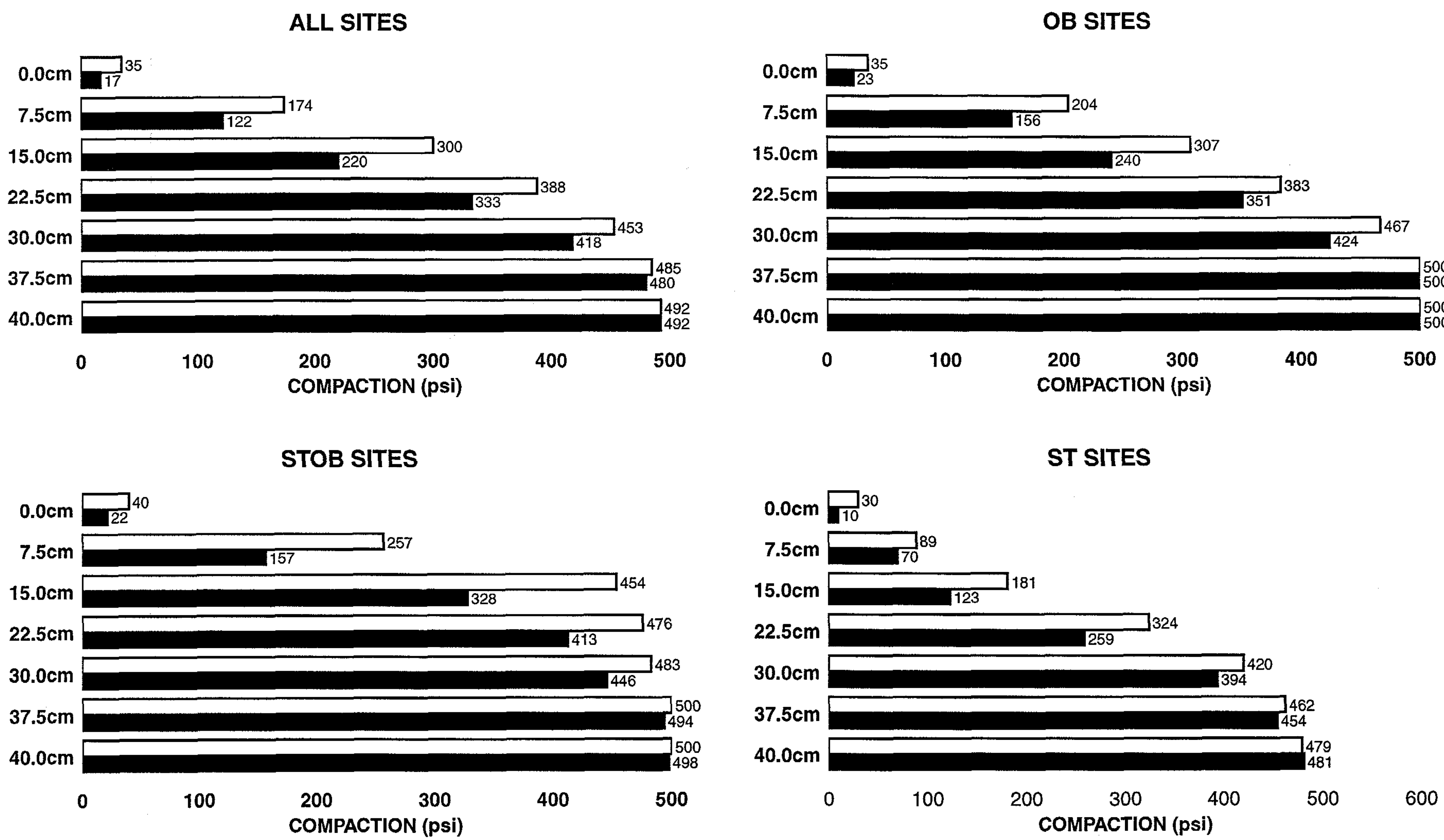


FIGURE 5A. Mean litter depth (closed bars) and root density (open bars) at unmined sites.

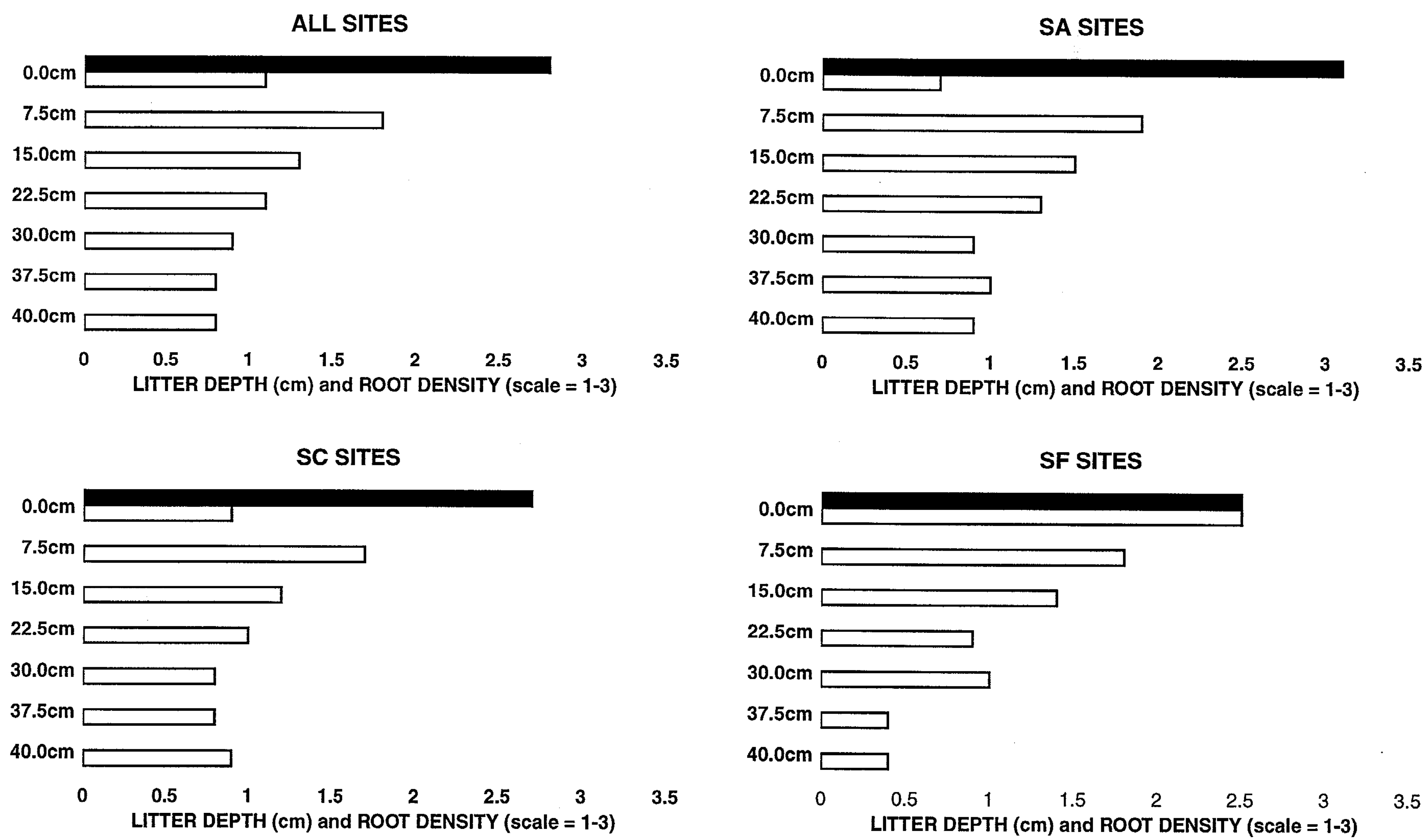


FIGURE 5B. Soil moisture at unmined sites. Closed bars are %saturation (see text) under normal field conditions; open bars are %saturation under wetted conditions.

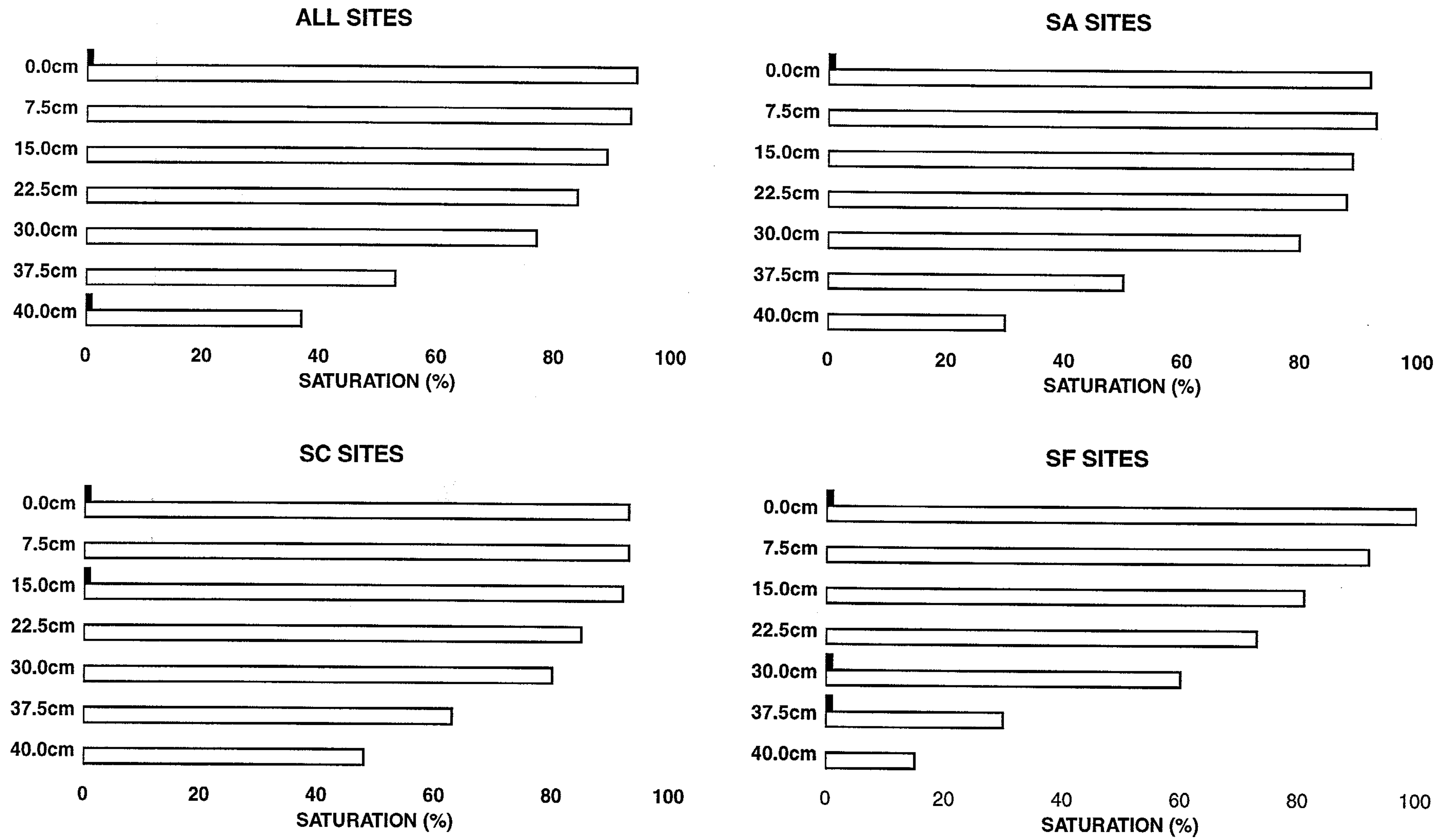


FIGURE 5C. Mean litter depth (closed bars) and root density (open bars) at mined sites.

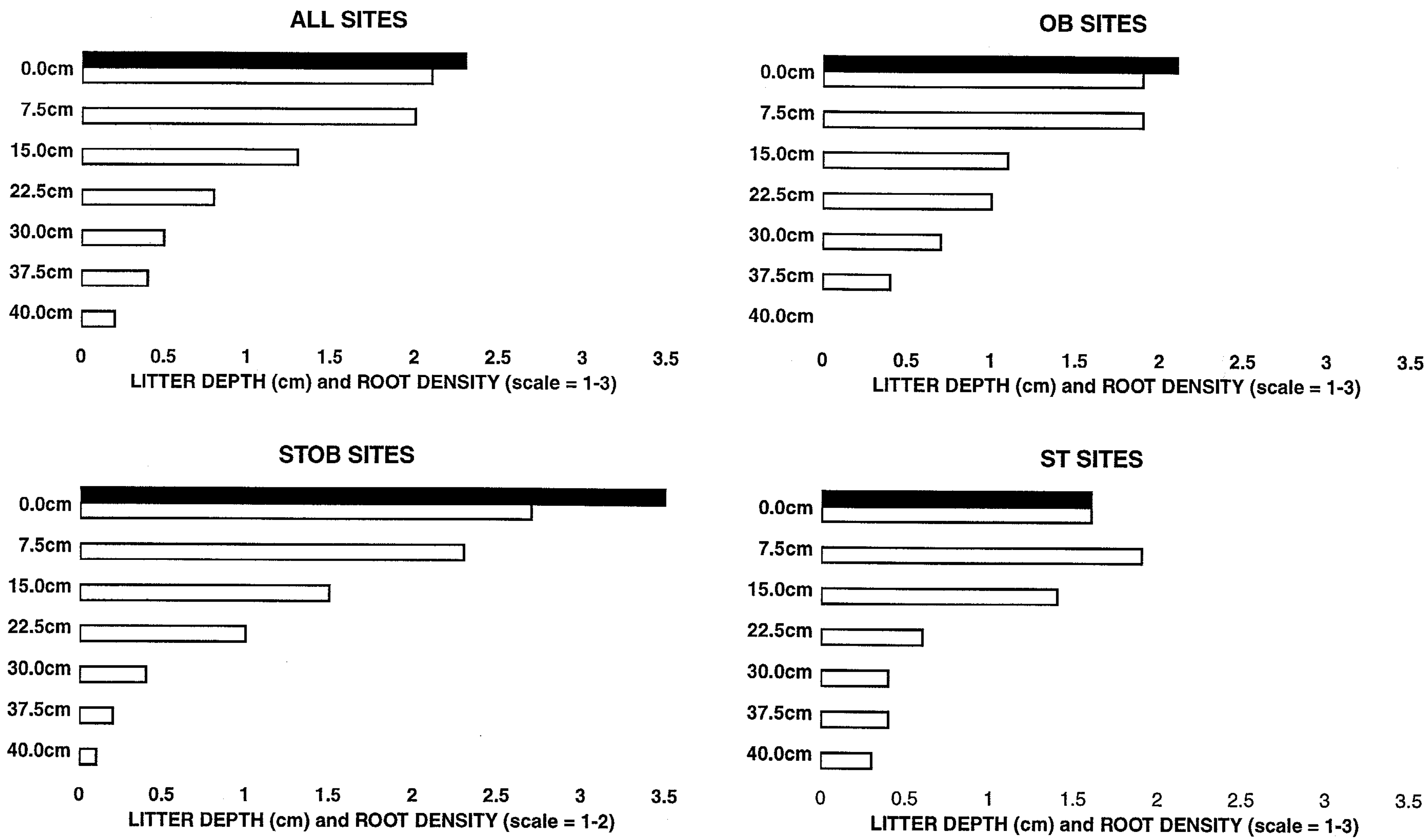
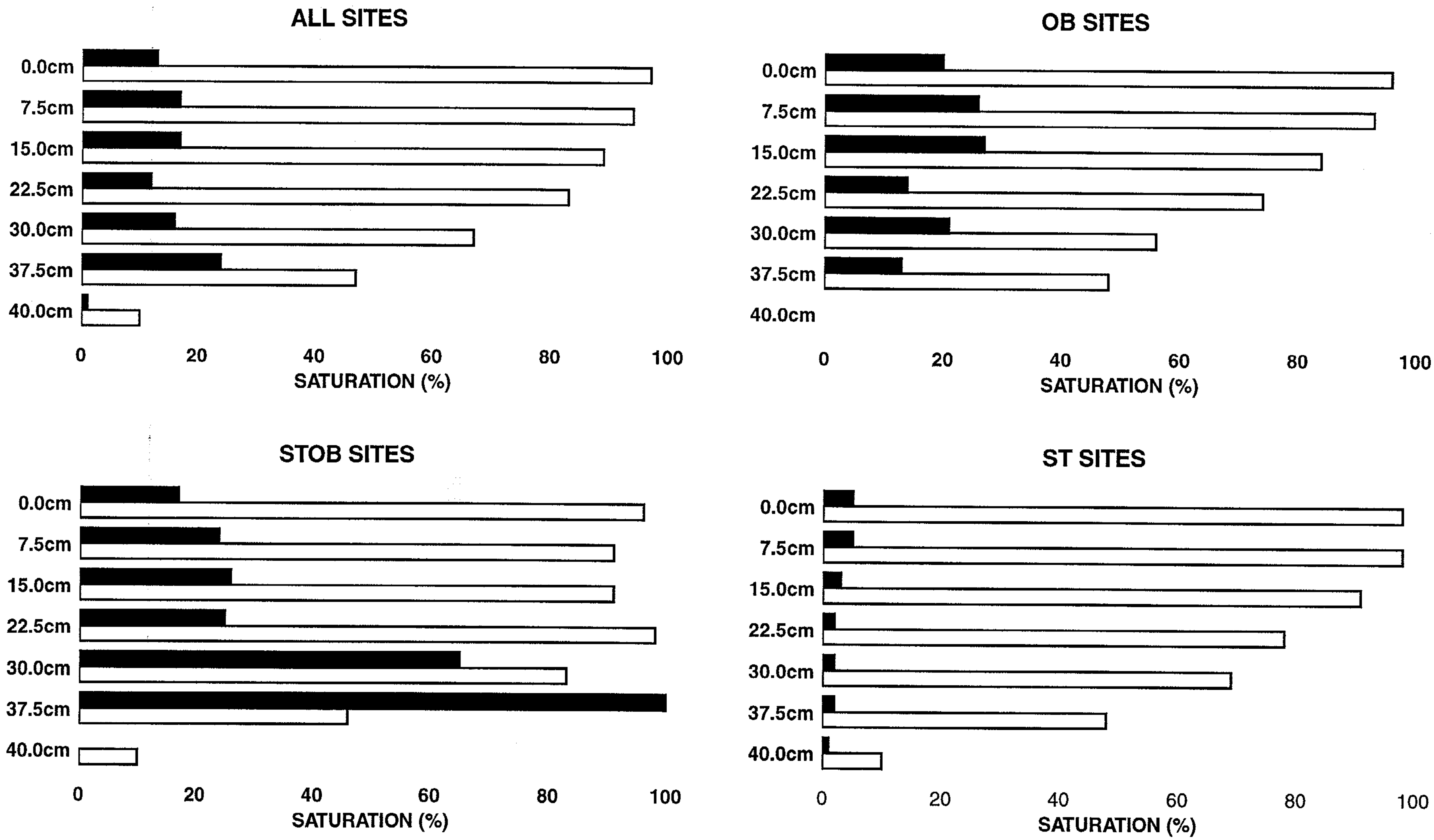


FIGURE 5D. Soil moisture at mined sites. Closed bars are %saturation (see text) under normal field conditions; open bars are %saturation under wetted conditions.



very similar among the three types of unmined sites. Root density tended to be higher in mined soils than in unmined soils from the surface to a depth of 15cm, and higher in unmined soils than in mined soils at 22.5cm below the surface, and deeper. Litter depth was similar between unmined and mined sites. Root density tended to be higher for sand tailings/overburden than for sand tailings and overburden near the surface, whereas root density tended to be higher for overburden than for the other two types at 37.5cm below the surface and for sand tailings/overburden alone at 40cm below the surface. Litter depth tended to be greater at sand tailings/overburden sites than at sand tailings sites. Root density tended to be higher in sand tailings/overburden than in unmined soils near the surface, and lower in sand tailings and sand tailings/overburden at 30cm below the surface and deeper (in overburden as well, at 40 cm). Litter depth tended to be lesser at sand tailings sites than at unmined sites.

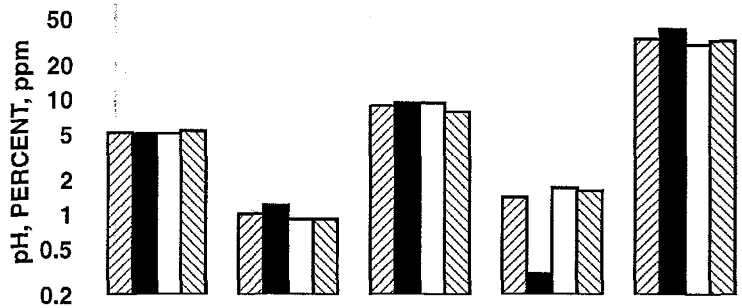
An analysis of soil chemistry is presented in Figure 6 (individual site data are in Appendix 1). [Note that the data for electrical conductivity are not presented in the figure, because they were always either 0.0 or 0.1 mmho/cm. Note also that data on soil chemistry often were highly-variable, so the power of the statistical analysis is not great.] Unlike soil texture, soil chemistry varied substantially among the types of unmined sites. Levels of phosphorus, organic matter, and nitrogen tended to be higher in sandhill soils than in scrub and scrubby flatwoods soils, at both horizons. Levels of organic matter and nitrogen also tended to be higher in scrubby flatwoods soils than in scrub soils, at the 15-30cm horizon. Unmined and mined soils were very different in their chemistries, with the exception of nitrogen content. Unmined soils tended to have lower pH, lower potassium content, lower phosphorus content, higher organic matter content (0-15cm horizon only), and higher electrical conductivity, at both horizons. No strong differences were detected among the chemistries of the three types of mined soils, with two major exceptions. First, overburden tended to have higher levels of organic matter than the other types, at both horizons, and sand tailings/overburden tended to have higher levels of organic matter than sand tailings, at the 0-15cm horizon, and second, overburden tended to have higher levels of nitrogen than the other types, at both horizons. None of the types of mined soils were very much like unmined soils in their overall chemistries.

Vegetation

An analysis of life-form coverage (percentage of woody vegetation, wiregrass, etc.) is presented in Figure 7 (individual site data are in Appendix 1). As one might expect, the percentages of the vegetation in the various categories of life form coverage at sandhill sites were different than those at either scrub or scrubby flatwoods sites (Kolmogorov-Smirnov Two-sample Test, $p < 0.10$). [Note that in all subsequent analyses in this section, trends will be identified at a p-value of 0.10, and that the analyses themselves are M-W U-tests, unless otherwise specified.] Mined sites also were different than unmined sites, containing a much smaller percentage of woody vegetation and litter and a much larger percentage of grasses, sedges, and legumes. These differences held for all of the individual kinds of revegetation treatments (see **STUDY SITES AND STUDY SPECIES**) at the mined sites -- topsoil (T), woody (RW), woody/herbaceous (RWRH), and

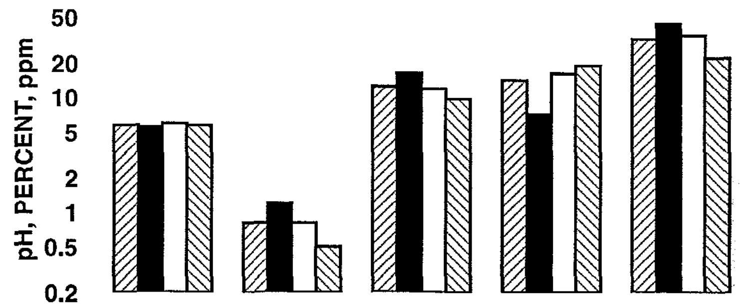
FIGURE 6. Soil chemistry. Means are displayed for the 0-15cm level (upper left) and 15-30cm level (lower left) at unmined sites, and for the 0-15cm level (upper right) and 15-30cm level (lower right) at mined sites. Scaling was used simply to facilitate visual presentation.

UNMINED SITES: 0-15cm LEVEL



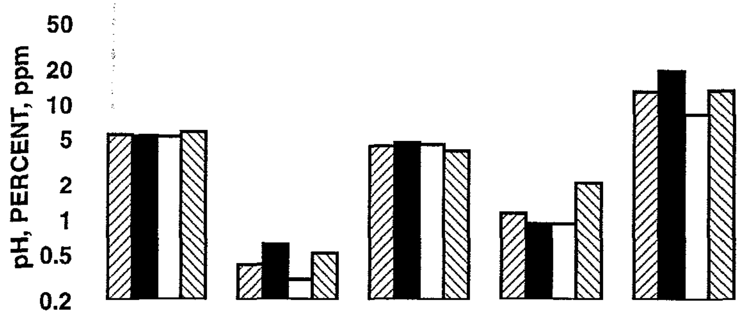
	pH	%ORGANICS	ppmK	ppmP (X100)	ppmN (X 10)
ALL SITES	5.1	1.0	8.7	1.4	32.8
SA SITES	5.0	1.2	9.2	0.3	40.6
SC SITES	5.0	0.9	9.2	1.7	29.3
SF SITES	5.3	0.9	7.7	1.6	31.9

MINED SITES: 0-15cm LEVEL



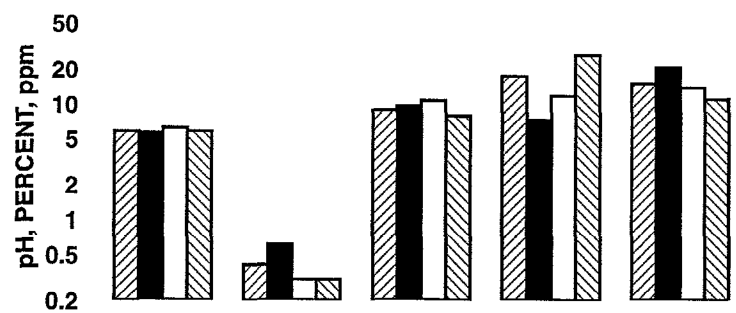
	pH	%ORGANICS	ppmK	ppmP (X100)	ppmN (X10)
ALL SITES	5.7	0.8	12.4	14.0	31.8
OB SITES	5.5	1.2	16.2	7.1	43.6
STOB SITES	5.9	0.8	11.8	16.1	34.3
ST SITES	5.7	0.5	9.6	18.8	21.9

UNMINED SITES: 15-30cm LEVEL



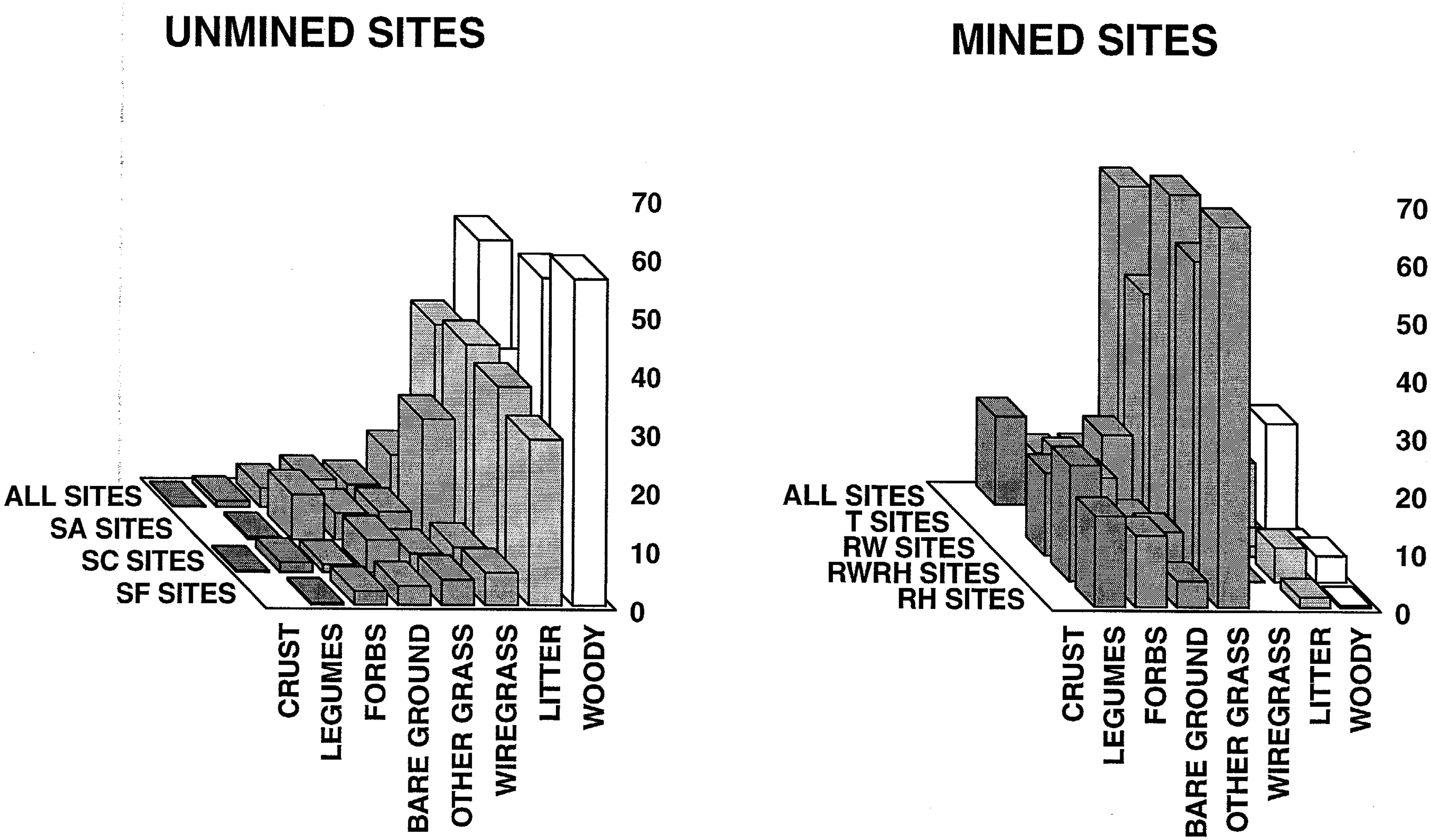
	pH	%ORGANICS	ppmK	ppmP (X100)	ppmN (X10)
ALL SITES	5.3	0.4	4.2	1.1	12.4
SA SITES	5.2	0.6	4.5	0.9	18.8
SC SITES	5.1	0.3	4.3	0.9	7.9
SF SITES	5.6	0.5	3.8	2.0	12.8

MINED SITES: 15-30cm LEVEL



	pH	%ORGANICS	ppmK	ppmP (X100)	ppmN (X10)
ALL SITES	5.7	0.4	8.7	17.0	14.7
OB SITES	5.5	0.6	9.4	7.1	20.2
STOB SITES	6.1	0.3	10.5	11.5	13.6
ST SITES	5.7	0.3	7.7	26.2	10.8

FIGURE 7. Percent coverage of life-form categories. Means are displayed for unmined sites (left) and mined sites (right).



herbaceous (RH) -- as well. [Note that the RW revegetation treatment was used at only two sites, so the power of the statistical analysis is not great.] None of the revegetation treatments could be distinguished from the others. We computed evenness of the distribution of life-form coverage for each unmined and mined site. It was computed as the maximum difference (max-D value) derived from comparing the percentage of the total ground cover in each life-form category with a uniform distribution, using the Kolmogorov-Smirnov One-sample Test. Evenness was lower for mined sites than for unmined sites, indicating that mined sites tended more strongly than unmined sites to be dominated by a few life-form categories.

An analysis of foliage layers (Ground, Gap1 , Shrub, Gap2, etc.) is presented in Figure 8 (individual site data are in Appendix 1). Although sandhill sites could be distinguished strongly from scrub sites, they could not be distinguished very strongly from scrubby flatwoods sites. Mined sites were very different than unmined sites, being much shorter in stature, overall, and lacking a middle canopy. Interestingly, woody revegetation sites could not be distinguished from unmined sites with a high degree of certainty, as could all of the other revegetation treatment sites. We computed evenness of the distribution of foliage among layers for each unmined and mined site. It was computed as the maximum difference (max-D value) derived from comparing the percentage of the total canopy height in each layer with a uniform distribution, using the Kolmogorov-Smirnov One-sample Test. Evenness was lower for mined sites than for unmined sites, indicating that mined sites tended more strongly than unmined sites to be dominated by a few foliage layers. Evenness of foliage distribution among layers is known to influence bird species richness (e.g., MacArthur and MacArthur 1961).

Analyses of horizontal (using a densiometer) and vertical (using a white board) canopy closure are presented in Figure 9 (individual site data are in Appendix 1). Horizontal closure was very similar among the kinds of unmined sites. Vertical closure also was very similar among the three kinds of unmined sites, at heights above 2m. Below 2m, vertical canopy closure was clearly greater for both scrub and scrubby flatwoods sites than for sandhill sites. Mined sites were very different than unmined sites in both kinds of canopy closure, being far more “open.” Not surprisingly, woody and woody/herbaceous revegetation sites tended to have greater horizontal canopy closure, at least at 1m in height, than herbaceous revegetation sites. Below 2m, topsoil and woody revegetation sites tended to have greater vertical canopy closure than the other two revegetation treatment sites. At that height, topsoil sites clearly were most like unmined sites in degree of vertical canopy closure. Above 2m, the differences among the four kinds of revegetation treatment sites lessened substantially, and all four kinds had much less vertical canopy closure than unmined sites.

An analysis of the density of trees, saw palmettos, and snags by height class is presented in Figure 10 (A) (individual site data are in Appendix 1). Relatively-tall trees, greater than 1 m in height, were denser at sandhill and scrub sites than at scrubby flatwoods sites. This pattern was attributable largely to the oaks (*Quercus* spp.). Most height classes of other trees, excluding pines, were denser at sandhill sites than at scrub and scrubby flatwoods

FIGURE 8. Foliage layers. Means are displayed for absolute (upper left) and relative (lower left) measurements at unmined sites, and for absolute (upper right) and relative (lower right) measurements at mined sites. The four layers (Ground, Shrub, Middle-Canopy, Upper-Canopy) are the bands of decreasing intensity, from bottom to top, and the intervening gaps (Gap1, Gap2, Gap3) are the white bands, from bottom to top.

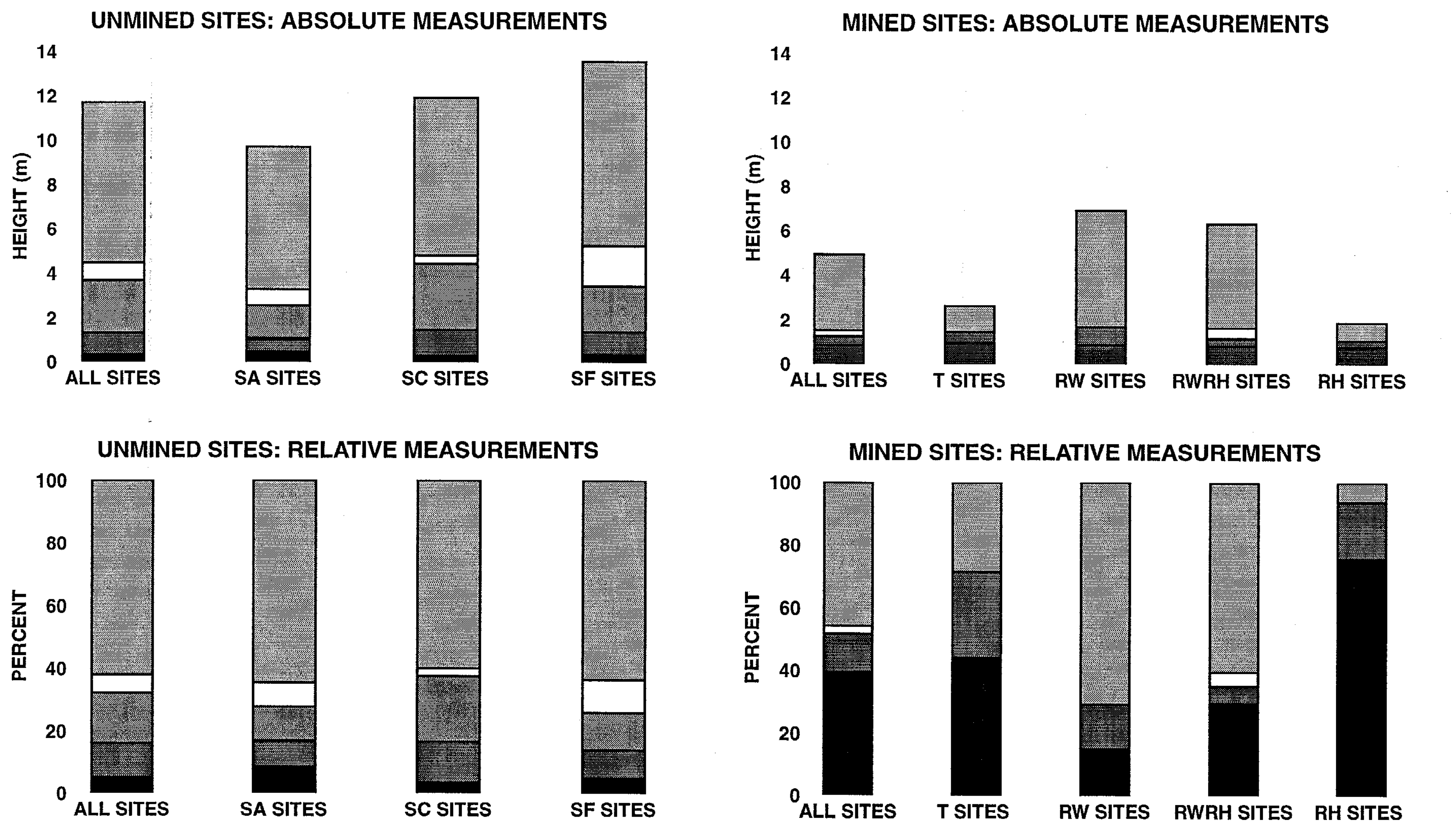


FIGURE 9. Canopy closure. Means are displayed for horizontal (upper left) and vertical (lower left) measurements at unmined sites, and for horizontal (upper right) and vertical (lower right) measurements at mined sites.

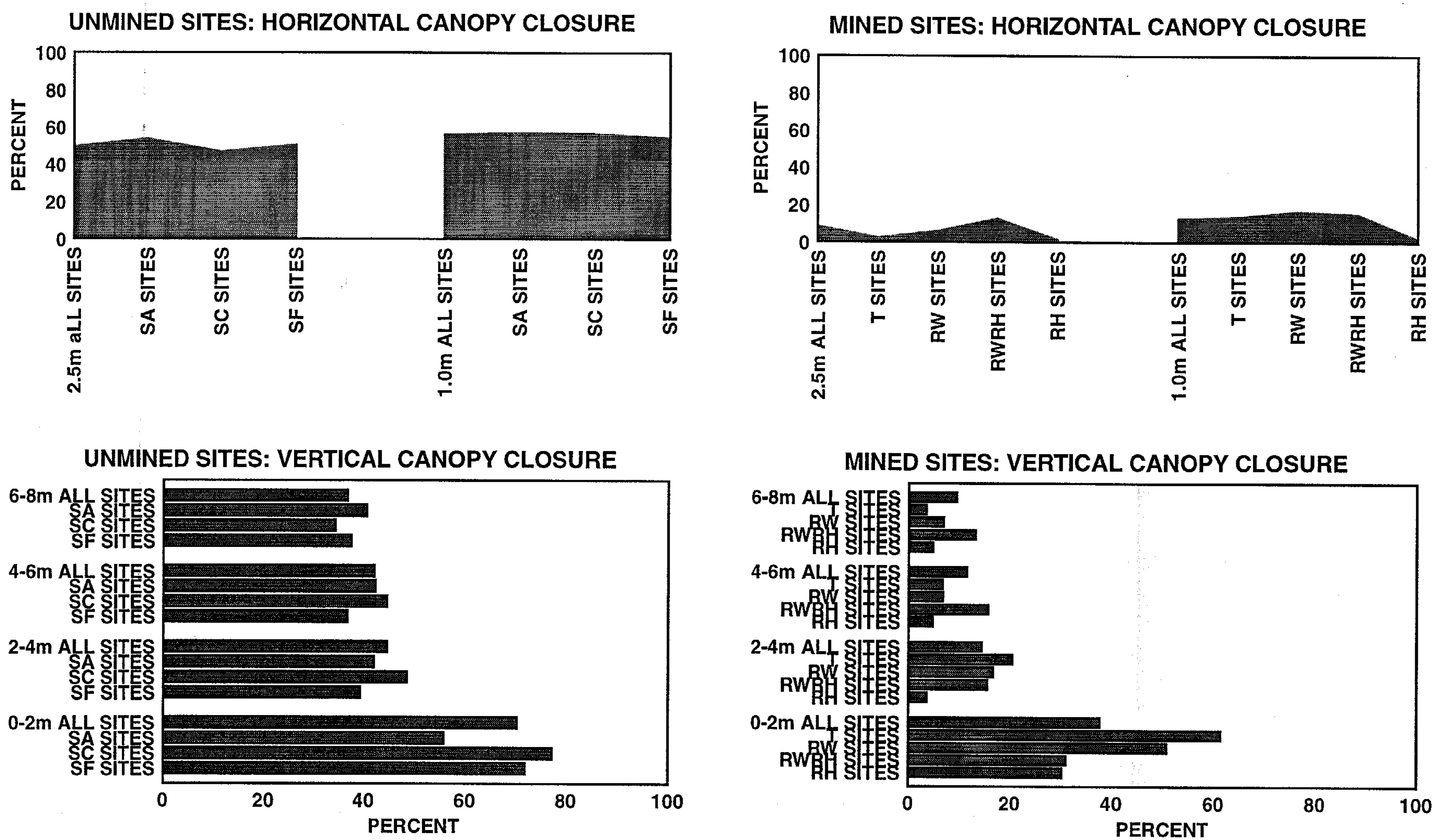
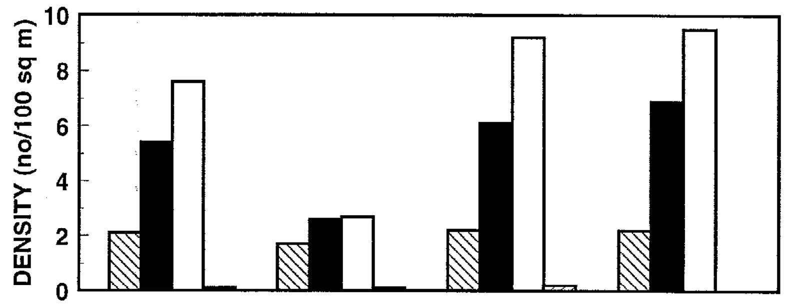


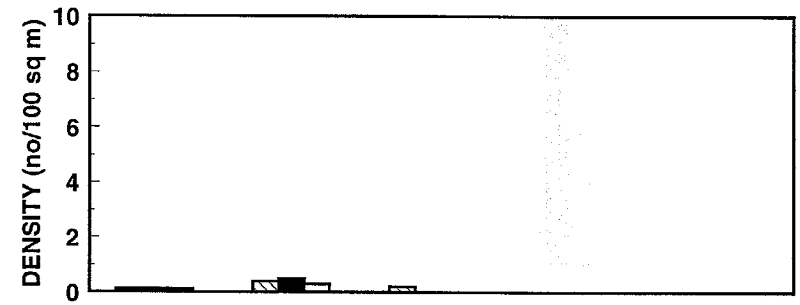
FIGURE 10A. Density of saw palmettos (upper) and snags (lower) of different height classes. Means are displayed for unmined sites (left) and mined sites (right).

UNMINED SITES: SAW PALMETTOS



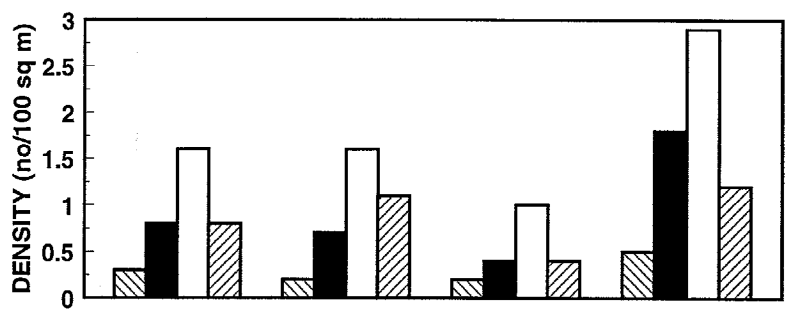
	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	2.1	1.7	2.2	2.2
0.5-1.0m	5.4	2.6	6.1	6.9
1.0-2.0m	7.6	2.7	9.2	9.5
>2.0m	0.1	0.1	0.2	0.0

MINED SITES: SAW PALMETTOS



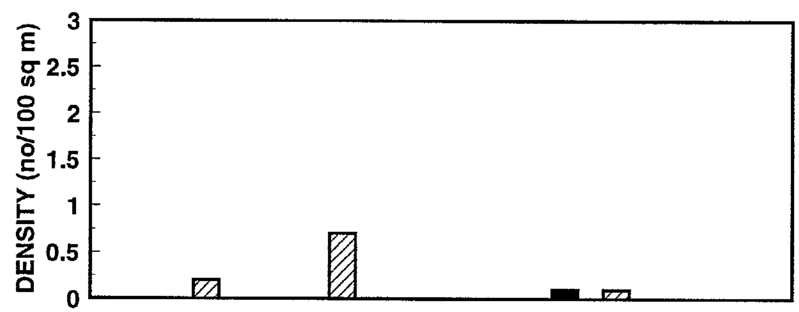
	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	0.1	0.4	0.2	0.0	0.0
0.5-1.0m	0.1	0.5	0.0	0.0	0.0
1.0-2.0m	0.1	0.3	0.0	0.0	0.0
>2.0m	0.0	0.0	0.0	0.0	0.0

UNMINED SITES: SNAGS



	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	0.3	0.2	0.2	0.5
0.5-1.0m	0.8	0.7	0.4	1.8
1.0-2.0m	1.6	1.6	1.0	2.9
>2.0m	0.8	1.1	0.4	1.2

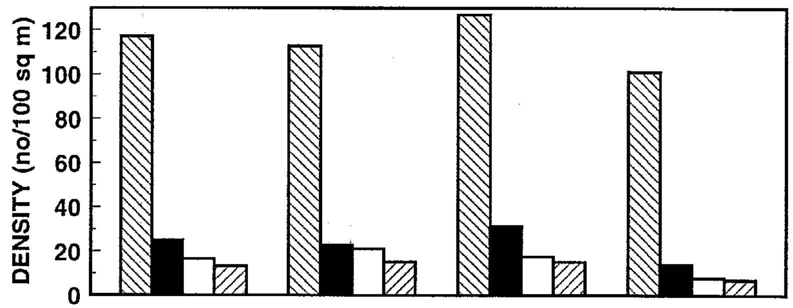
MINED SITES: SNAGS



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	0.0	0.0	0.0	0.0	0.0
0.5-1.0m	0.0	0.0	0.0	0.1	0.0
1.0-2.0m	0.0	0.0	0.0	0.0	0.0
>2.0m	0.2	0.7	0.0	0.1	0.0

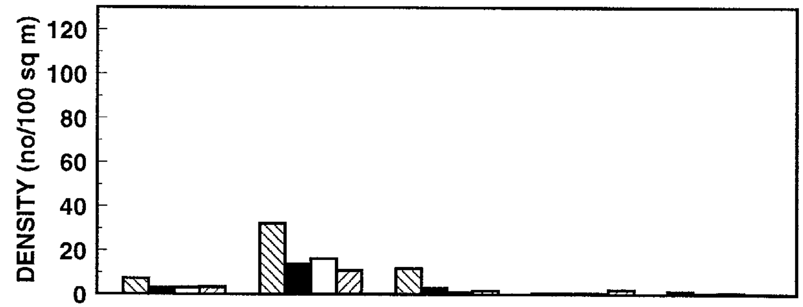
FIGURE 10A (CONTINUED). Density of all trees (upper) and *Pinus* spp. (lower) of different height classes. Means are displayed for unmined sites (left) and mined sites (right).

UNMINED SITES: ALL TREES



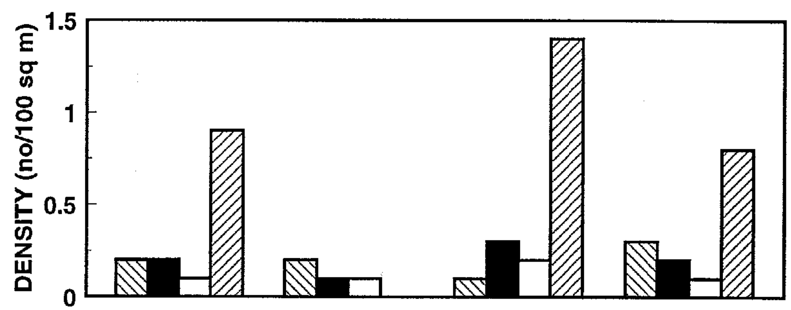
	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	117.2	112.8	126.9	101.3
0.5-1.0m	24.9	22.7	31.1	14.0
1.0-2.0m	16.3	21.1	17.6	7.8
>2.0m	13.2	15.1	15.0	7.0

MINED SITES: ALL TREES



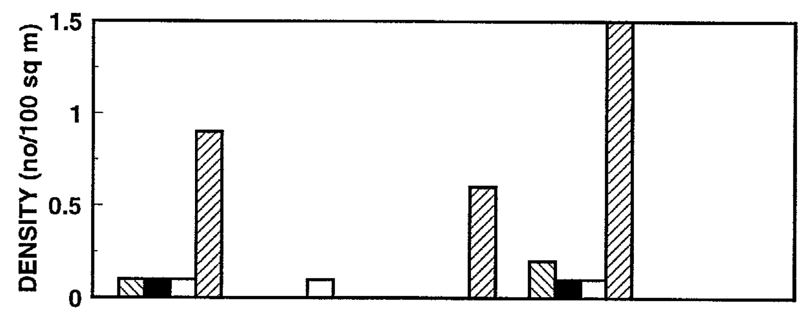
	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	7.2	32.0	11.7	0.6	1.4
0.5-1.0m	3.0	13.8	2.8	0.4	0.4
1.0-2.0m	3.2	16.1	0.9	0.4	0.6
>2.0m	3.3	10.8	1.7	2.1	0.1

UNMINED SITES: PINUS SPP.



	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	0.2	0.2	0.1	0.3
0.5-1.0m	0.2	0.1	0.3	0.2
1.0-2.0m	0.1	0.1	0.2	0.1
>2.0m	0.9	0.0	1.4	0.8

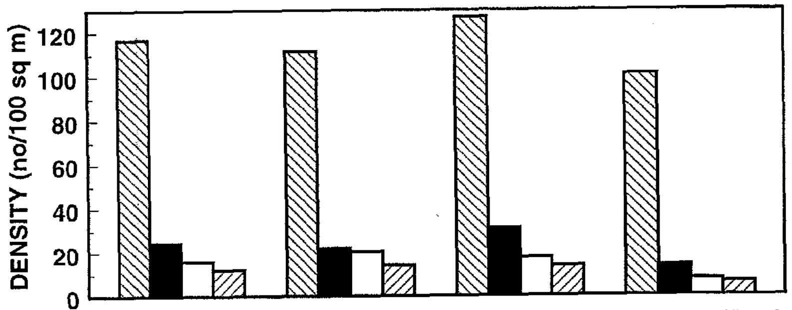
MINED SITES: PINUS SPP.



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	0.1	0.0	0.0	0.2	0.0
0.5-1.0m	0.1	0.0	0.0	0.1	0.0
1.0-2.0m	0.1	0.1	0.0	0.1	0.0
>2.0m	0.9	0.0	0.6	1.5	0.0

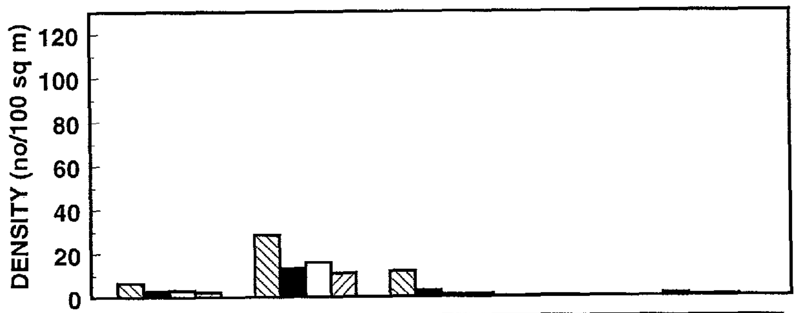
FIGURE 10A (CONTINUED). Density of *Quercus* spp. (upper) and non-runner *Quercus* spp. (lower) of different height classes. Means are displayed for unmined sites (left) and mined sites (right). Note that runner *Quercus* spp. were not found at mined sites.

UNMINED SITES: QUERCUS SPP.



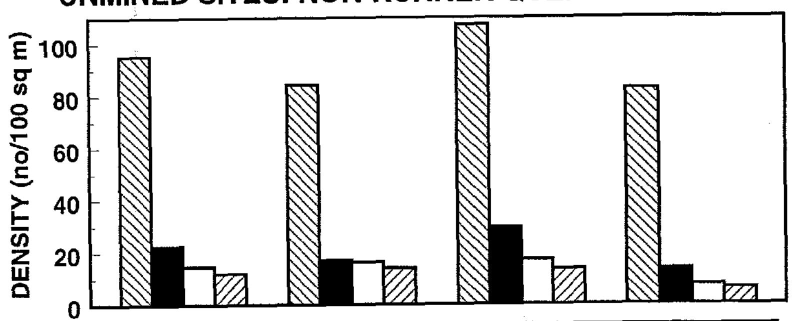
	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	116.7	111.4	126.8	101.0
0.5-1.0m	24.4	21.8	30.8	13.8
1.0-2.0m	15.9	20.2	17.5	7.6
>2.0m	12.0	13.9	13.6	6.2

MINED SITES: QUERCUS SPP.



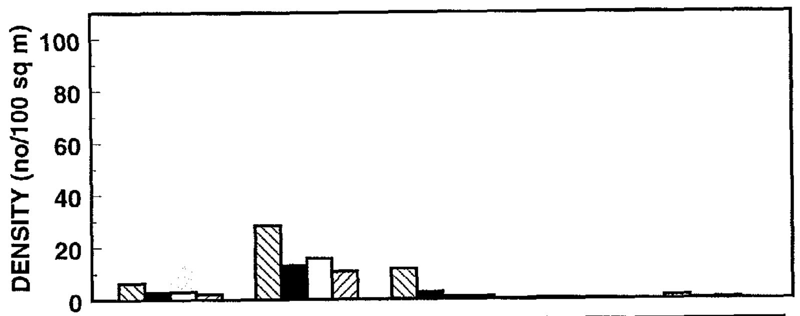
	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	6.4	28.4	11.7	0.4	1.4
0.5-1.0m	2.8	13.2	2.8	0.3	0.4
1.0-2.0m	3.1	15.8	0.9	0.2	0.6
>2.0m	2.2	10.8	1.1	0.2	0.1

UNMINED SITES: NON-RUNNER QUERCUS SPP.



	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	95.3	84.2	107.2	82.6
0.5-1.0m	22.5	17.1	29.5	13.5
1.0-2.0m	14.6	16.2	17.0	7.5
>2.0m	11.9	14.0	13.5	6.2

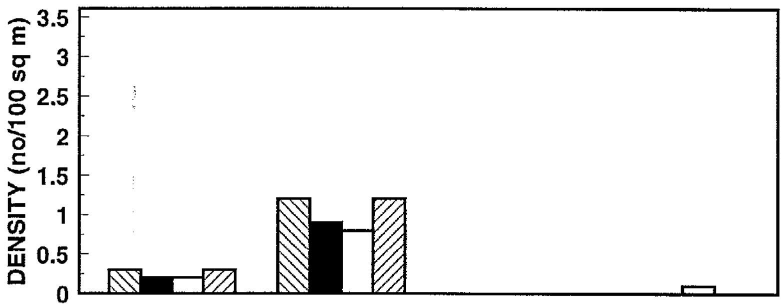
MINED SITES: NON-RUNNER QUERCUS SPP.



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	6.4	28.4	11.7	0.4	1.4
0.5-1.0m	2.8	13.2	2.8	0.3	0.4
1.0-2.0m	3.1	15.8	0.9	0.2	0.6
>2.0m	2.2	10.8	1.1	0.2	0.1

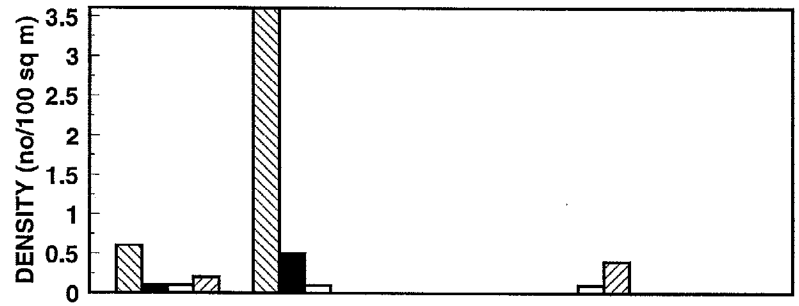
FIGURE 10A (CONTINUED). Density of other tree species of different height classes. Means are displayed for unmined sites (left) and mined sites (right).

UNMINED SITES: OTHER TREE SPECIES



	ALL SITES	SA SITES	SC SITES	SF SITES
<0.5m	0.3	1.2	0.0	0.0
0.5-1.0m	0.2	0.9	0.0	0.0
1.0-2.0m	0.2	0.8	0.0	0.1
>2.0m	0.3	1.2	0.0	0.0

MINED SITES: OTHER TREE SPECIES



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<0.5m	0.6	3.6	0.0	0.0	0.0
0.5-1.0m	0.1	0.5	0.0	0.0	0.0
1.0-2.0m	0.1	0.1	0.0	0.1	0.0
>2.0m	0.2	0.0	0.0	0.4	0.0

sites. Relatively-tall pines (*Pinus* spp.), greater than 2m in height, were denser at both scrub and scrubby flatwoods sites than at sandhill sites, at least in part because of the more intense logging activity at sandhill sites. Saw palmettos between 0.5m and 2m in height were denser at either scrub or scrubby flatwoods sites than at sandhill sites. Saw palmettos grew no taller than 2m at scrubby flatwoods sites. Some tendency existed for relatively-tall snags to be denser at sandhill sites than at scrub and scrubby flatwoods sites, but the tendency was not very strong. All height classes of trees, saw palmettos, and snags were denser at unmined than at mined sites, with two exceptions. The densities of relatively-tall pines, greater than 1 m in height, and of other trees -- oaks excepted -- of any height class, could not be distinguished very strongly between unmined and mined sites. Trees at topsoil and woody revegetation sites tended to be denser, at heights below 1 m, than at woody/herbaceous and herbaceous revegetation sites. Tree densities at topsoil sites clearly were most like densities at unmined sites, at heights above 1m. These patterns also were attributable largely to the oaks. Trees at woody and woody/ herbaceous revegetation sites tended to be denser, at heights above 2m, than at herbaceous revegetation sites. This pattern was attributable largely to the pines. The general rarity of saw palmettos and snags at mined sites makes comparisons of their densities among revegetation treatment sites pointless.

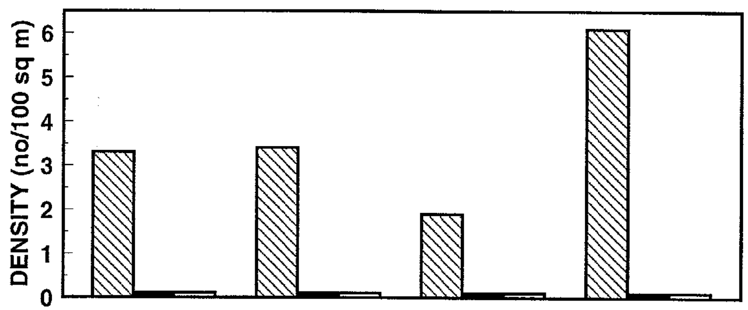
An analysis of the density of trees and snags by DBH class is presented in Figure 10 (B) (individual site data are in Appendix 1). No strong differences among the three kinds of unmined sites could be detected, either for all trees combined or for oaks. Relatively-large pines, greater than 10cm DBH, were denser at both scrub and scrubby flatwoods sites than at sandhill sites, however. Relatively-small trees of other genera, less than 10cm DBH, tended to be denser at sandhill and scrubby flatwoods sites than at scrub sites. All DBH classes of trees and snags were denser at unmined than at mined sites, with three exceptions. The densities of relatively-large pines, greater than 25cm DBH, and of other trees -- oaks excepted -- of any DBH class, could not be distinguished very strongly between unmined and mined sites. As well, the densities of snags 10-25cm DBH could not be distinguished very strongly between unmined and mined sites. While the trends in density based on DBH among the four kinds of revegetation treatments loosely mirrored the trends based on height, the general rarity of large trees and snags at mined sites makes comparisons of their densities among revegetation treatments pointless.

Intercorrelations Among Variables and Data Reduction

We examined the size, isolation, and grazing data for independence (G-test, $p < 0.10$), so that two or more physical variables that essentially measured the same thing were not included in subsequent analyses. Whether a site was grazed or ungrazed at the time it was sampled was independent of distance to seasonal water, for both unmined and mined sites. The same was true for distance to permanent water and size, but not for distance to other upland habitats. Grazed mined sites tended to be near upland habitats with a greater frequency than did ungrazed mined sites. Distances, either to seasonal water or to permanent water, were independent of size and distance to upland habitats; and distance to seasonal water was independent of distance to permanent water. Size, on the

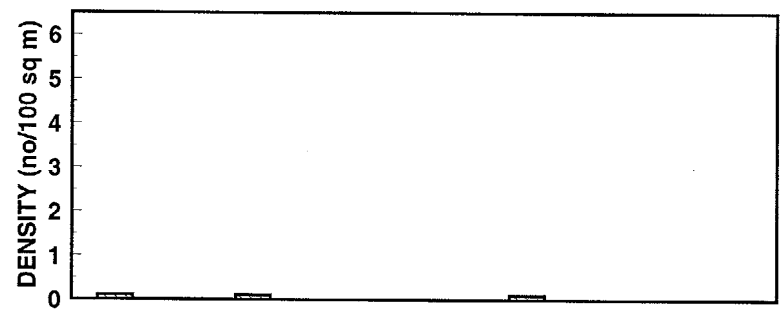
FIGURE 10B. Density of snags (upper) and all trees (lower) of different DBH classes. Means are displayed for unmined sites (left) and mined sites (right).

UNMINED SITES: SNAGS



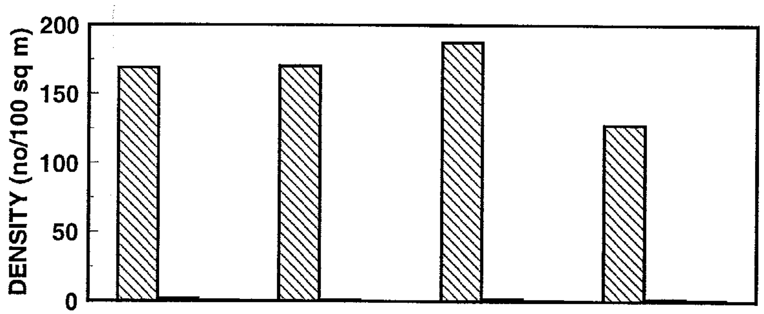
	ALL SITES	SA SITES	SC SITES	SF SITES
<10cm	3.3	3.4	1.9	6.1
10-25cm	0.1	0.1	0.1	0.1
>25cm	0.1	0.1	0.1	0.1

MINED SITES: SNAGS



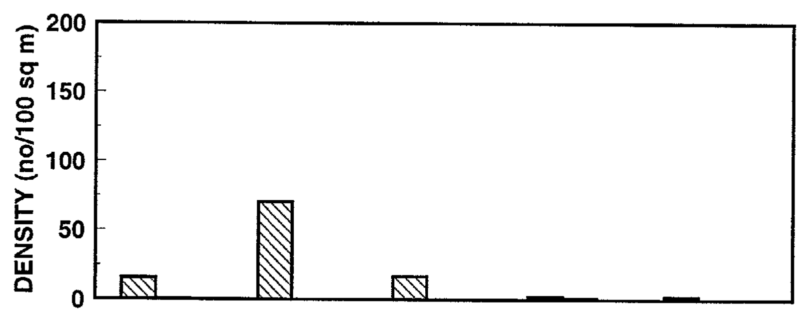
	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<10cm	0.1	0.1	0.0	0.1	0.0
10-25cm	0.0	0.0	0.0	0.0	0.0
>25cm	0.0	0.0	0.0	0.0	0.0

UNMINED SITES: ALL TREES



	ALL SITES	SA SITES	SC SITES	SF SITES
<10cm	168.9	170.1	187.5	127.6
10-25cm	1.7	1.2	1.8	1.9
>25cm	0.6	0.3	0.7	0.8

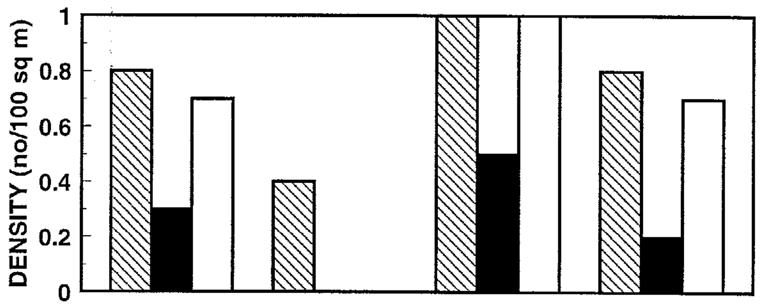
MINED SITES: ALL TREES



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<10cm	15.6	70.5	16.8	2.4	2.4
10-25cm	0.7	0.0	0.2	1.1	0.0
>25cm	0.1	0.0	0.0	0.1	0.1

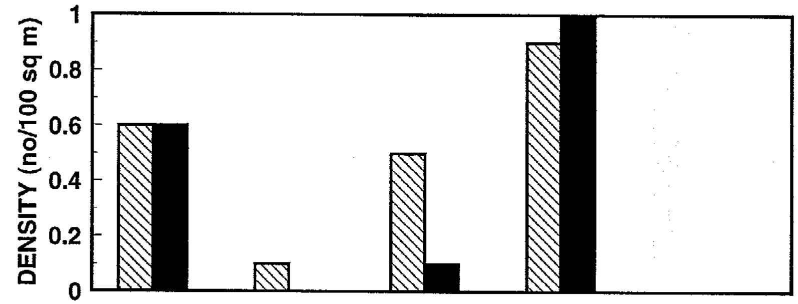
FIGURE 10B (CONTINUED). Density of *Pinus* spp. (upper) and *Quercus* spp. (lower) of different DBH classes. Means are displayed for unmined sites (left) and mined sites (right).

UNMINED SITES: PINUS SPP.



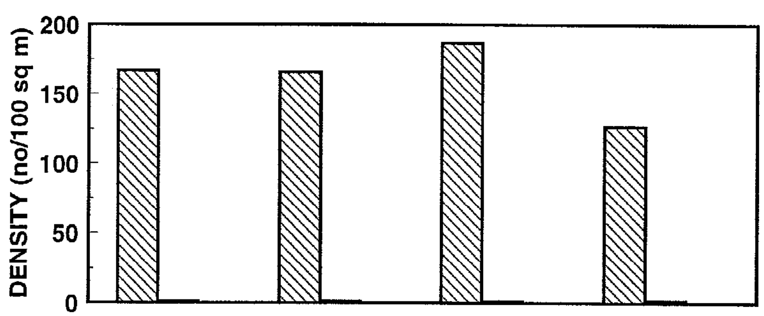
	ALL SITES	SA SITES	SC SITES	SF SITES
<10cm	0.8	0.4	1.0	0.8
10-25cm	0.3	0.0	0.5	0.2
>25cm	0.7	0.0	1.0	0.7

MINED SITES: PINUS SPP.



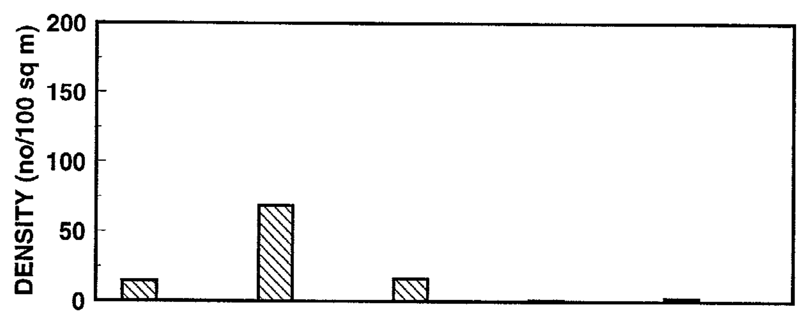
	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<10cm	0.6	0.1	0.5	0.9	0.0
10-25cm	0.6	0.0	0.1	1.0	0.0
>25cm	0.0	0.0	0.0	0.0	0.0

UNMINED SITES: QUERCUS SPP.



	ALL SITES	SA SITES	SC SITES	SF SITES
<10cm	166.9	165.7	186.5	126.5
10-25cm	1.4	1.2	1.3	1.7
>25cm	0.3	0.3	0.2	0.4

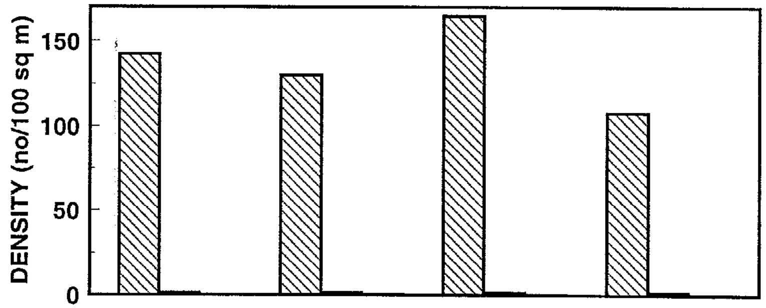
MINED SITES: QUERCUS SPP.



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<10cm	14.4	68.3	16.3	1.2	2.4
10-25cm	0.0	0.0	0.1	0.0	0.0
>25cm	0.0	0.1	0.0	0.0	0.1

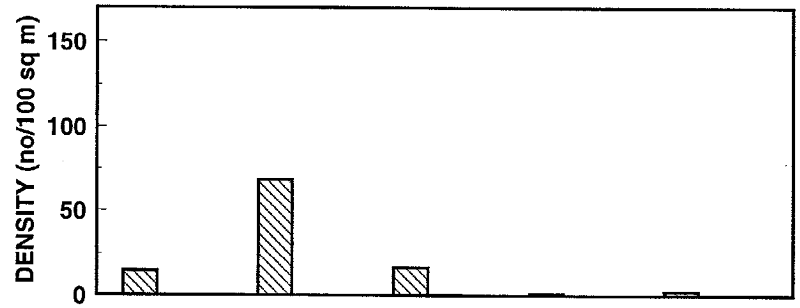
FIGURE 10B (CONTINUED). Density of non-runner *Quercus* spp. (upper) and other tree species (lower) of different DBH classes. Means are displayed for unmined sites (left) and mined sites (right). Note that runner *Quercus* spp. were not found at mined sites.

UNMINED SITES: NON-RUNNER QUERCUS SPP.



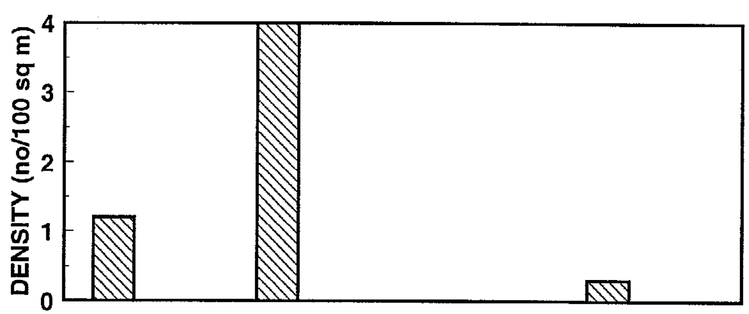
	ALL SITES	SA SITES	SC SITES	SF SITES
<10cm	142.1	129.8	164.6	107.7
10-25cm	1.4	1.2	1.3	1.7
>25cm	0.3	0.3	0.2	0.4

MINED SITES: NON-RUNNER QUERCUS SPP.



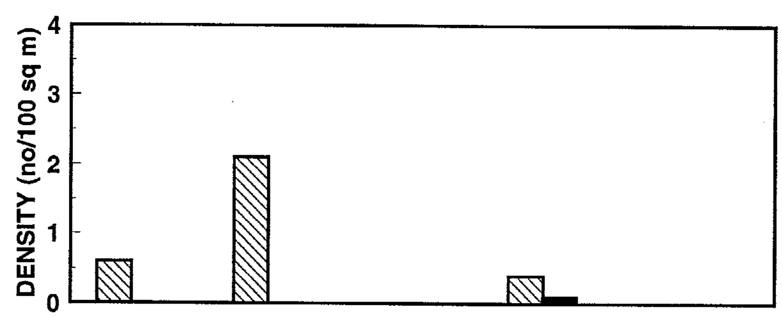
	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<10cm	14.4	68.3	16.3	1.2	2.4
10-25cm	0.0	0.0	0.1	0.0	0.0
>25cm	0.0	0.0	0.0	0.0	0.1

UNMINED SITES: OTHER TREE SPECIES



	ALL SITES	SA SITES	SC SITES	SF SITES
<10cm	1.2	4.0	0.0	0.3
10-25cm	0.0	0.0	0.0	0.0
>25cm	0.0	0.0	0.0	0.0

MINED SITES: OTHER TREE SPECIES



	ALL SITES	T SITES	RW SITES	RWRH SITES	RH SITES
<10cm	0.6	2.1	0.0	0.4	0.0
10-25cm	0.0	0.0	0.0	0.1	0.0
>25cm	0.0	0.0	0.0	0.0	0.0

other hand, was not independent of distance to upland habitats. Small unmined sites tended to be far from other upland habitats with a greater frequency than did large unmined sites.

We examined the vegetation data for intercorrelations (Spearman's Rank Correlation Coefficient, $p < 0.10$), so that two or more vegetation variables that essentially measured the same thing were not included in subsequent analyses. First, we looked for correlations among categories within each kind of vegetation data -- life-form coverage, foliage layers, horizontal and vertical canopy closure, density by height class, density by DBH class -- and then for correlations among the kinds of vegetation data. At each stage, the intercorrelations were used, in conjunction with the vegetation data themselves (Figures 7-10), to reduce the number of variables to be employed in subsequent explanations for vertebrate distributions and abundances.

Eight categories were identified for the first kind of vegetation data, life-form coverage (Figure 7). The intercorrelations among these categories, for unmined and for mined sites, are presented in Table 5. For unmined sites, woody vegetation and litter generally account for about 77% of coverage (Figure 7), and these two life-form categories are negatively correlated with others, with the exception of crust -- for woody vegetation and for litter. Woody vegetation and litter are themselves strongly negatively correlated. Wiregrass, other grasses, legumes, forbs, and bare ground, with one exception, are all positively correlated with one-another. These results indicate the following.

- The ground cover of unmined sites tends to be comprised largely of woody vegetation and litter, and that where either of these two life-form categories occur, other categories do not.

- The ground cover of unmined sites tends to be comprised here-and-there of several herbaceous life-form categories and bare ground, which tend to co-occur.

For mined sites, grasses other than wiregrass and legumes account for about 70% of coverage (Figure 7), and these two life-form categories are negatively correlated with the others, with the exception of wiregrass -- for legumes. Grasses other than wiregrass and legumes are themselves negatively correlated. Forbs, bare ground, litter, and crust, with one exception, are all positively correlated with one-another. These results indicate the following.

- The ground cover of mined sites tends to be comprised largely of grasses and legumes, and that where either of these two life-form categories occur, other categories do not.

- The ground cover of mined sites tends to be comprised here-and-there of several life-form categories other than grasses and legumes, which tend to co-occur.

TABLE 5. Intercorrelations (Spearman's Rank Correlation Coefficient) of vegetation variables measuring life-form coverage (see text). WD = woody, MY = fungi, PT = ferns, MO = mosses, LR = litter, WG = wiregrass, OG = other grasses, LG = legumes, FB = forbs, BG = bare ground. Minuses indicate negative correlations, pluses indicate positive correlations, and asterisks indicate $p < 0.05$.

UNMINED SITES

	MY	PT	MO	LR	WG	OG	LG	FB	BG
WD	-		+	-*	-*	-	-	-*	-
MY			-	+	-*	-	+	-*	+
PT									
MO				-	-	-	+	-	-
LR					-	-*	-	-	-
WG						+*	+	+	+
OG							+	+*	+
LG								+	-
FB									+

MINED SITES

	MY	PT	MO	LR	WG	OG	LG	FB	BG
WD	+*			+*	-	-	-*	+	+
MY				+	-	-	-	-	+
PT									
MO									
LR					+	-*	-*	+	+*
WG						-	+	+	+
OG							-	-	-*
LG								-	-
FB									+

Based on all of these results, we reduced the number of categories of life-form coverage from eight to five: grasses other than wiregrass (= grasses, from now on), woody vegetation, litter, legumes, and bare ground.

Seven categories were identified for the second kind of vegetation data, foliage layers (Figure 8). The intercorrelations among these seven categories, for unmined and for mined sites, are presented in Table 6. Note (cf. Figure 8) that at unmined sites, the Gap1 category was missing, indicating that the ground and shrub layers were contiguous, and that at mined sites, the Gap2 and Middle-Canopy categories were missing, indicating that the intermediate foliage layer was absent. For unmined sites, development of a ground layer was negatively correlated with development of a shrub layer, while for mined sites, the correlation was positive. Likewise, for unmined sites, the size of Gap3 was negatively correlated with development of the Upper-Canopy, while for mined sites, the correlation was positive. These results indicate the following.

- The presence of a well-developed Shrub layer tends to be associated with the absence of a well-developed Ground layer at unmined sites, and that the opposite is true at mined sites.

- The Upper-Canopy tends to be contiguous with the Middle-Canopy at unmined sites, but well-separated from the other foliage layers at mined sites.

Based on these results, we retained all seven foliage layers.

The two measures of horizontal canopy closure were very strongly positively correlated, for both unmined and mined sites. Vertical canopy closure measurements taken at adjacent heights were all positively correlated, usually strongly, for both unmined and mined sites. Closure near the ground, at heights of 0-2m, was not a very good predictor of closure of the canopy, at heights greater than 4m, especially at unmined sites. These results indicate the following.

- The horizontal measurements tend to be similar, regardless of the heights at which they are taken.

- The vertical measurements tend to be similar, when taken either relatively near the ground or relatively far from it.

Based on these results, we reduced the number of categories of horizontal canopy closure from two to one: height of 1m; and the number of categories of vertical canopy closure from four to two: heights of 0-2m and 4-6m.

Densities of saw palmettos and snags were so low at mined sites that correlations among height or DBH categories essentially would be analyses of presence/absence data; therefore, we did not attempt such correlations. Densities of saw palmettos and snags at

TABLE 6. Intercorrelations (Spearman's Rank Correlation Coefficient) of vegetation variables measuring foliage strata (see text). GRD = ground layer, SHB = shrub layer, MID = Middle-Canopy, UPR = Upper-Canopy. Minuses indicate negative correlations, pluses indicate positive correlations, and asterisks indicate $p < 0.05$.

UNMINED SITES

	GAP1	SHB	GAP2	MID	GAP3	UPR
GRD		-*	+	-*	+	-
GAP1						
SHB			-	+*	-	+
GAP2				+	+	-
MID					-	+*
CAP3						-

MINED SITES

	GAP1	SHB	GAP2	MID	GAP3	UPR
GRD	-	+			+	-
GAP1		+			+*	+
SHB					-	+
GAP2						
MID						
CAP3						+*

unmined sites generally were positively correlated for height and DBH categories. Densities of all trees were positively correlated for all height categories, with one exception, at both unmined and mined sites. Densities of *Quercus* spp. alone were positively correlated for all height categories, at both unmined and mined sites. Densities of large *Quercus* spp. -- >10cm DBH -- were so low that we did not attempt correlations among DBH categories. Densities of *Pinus* spp. and other tree species, with a few exceptions, were positively correlated for all height and DBH categories, at both unmined and mined sites. For both *Pinus* spp. and for other trees, these correlations were much stronger at unmined sites than at mined sites, probably because of the rarity of both groups at mined sites. These results indicate the following.

- The relative densities of trees, saw palmettos, and snags all tend to be similar among the unmined and mined sites at which they occur in reasonable numbers, regardless of the sizes of individuals considered.

Based on these results, we eliminated all height and DBH categories, and used total densities of all trees, saw palmettos, snags, *Quercus* spp., *Pinus* spp., and other tree species for further analyses.

Correlations among the kinds of vegetation data were performed for unmined and for mined sites separately. Horizontal canopy closure and vertical canopy closure at 4-6m were strongly positively correlated -- that is, both measurements essentially provided the same information -- for both unmined and mined sites, so we eliminated the measure of horizontal canopy closure. We note for the future, however, that horizontal canopy closure is much easier to measure, and, therefore, perhaps is to be preferred over vertical canopy closure. Vertical canopy closure at 0-2m is most strongly correlated, positively, with the density of saw palmettos, both at unmined and mined sites; at 4-6m, it is most strongly correlated, positively, with the density of *Pinus* spp. at mined sites and with the densities of *Pinus* spp. and other tree species at unmined sites. These results indicate the following.

- The vertical canopy closure serves as a general assessment of density.

Based on these results, we eliminated the two measures of vertical canopy closure, as well as total density of all trees -- retaining total densities of saw palmettos, snags, *Quercus* spp., *Pinus* spp., and other tree species for further analyses, because we decided that individual species' densities provide more information.

Few strong positive correlations existed between the measures of foliage layers and measures of density; the only one that was present both at unmined and mined sites was between Upper-Canopy and density of *Pinus* spp. -- that is, *Pinus* spp. tends to contribute substantially to the formation of Upper-Canopy at both unmined and mined sites. Likewise, few strong positive correlations existed between the measures of life-form coverage and the measures of foliage layers, especially at mined sites; none was present both at unmined and mined sites. On the other hand, relationships between the measures of life-form coverage and the measures of density were clear and different between unmined and mined sites (Table 7). Based on these results, we decided that it was necessary to retain all measures of life-form coverage, foliage layers, and density.

Interrelationships between physical variables and vegetation variables were determined with Mann-Whitney U-tests ($p < 0.10$). No interrelationships were found between grazing and the five categories of life-form coverage that we retained. We did note that percent-cover of wiregrass was greater at ungrazed unmined sites than at grazed mined sites, however. Percent of total height represented by Gap1 was greater at grazed mined sites than ungrazed mined sites, and the density of *Quercus* spp. was greater at ungrazed unmined sites than at grazed unmined sites. These results indicate the following.

- Grazing has some effect on the vegetation, which, in turn, may have some effect on the resident fauna.

Our analyses were not specifically designed to detect the effects of grazing, however, and additional research in this area would seem warranted. No interrelationships were found between distance to seasonal water and either life-form coverage, foliage layers, or total density. These results indicate the following.

- Distance to seasonal water seems to have little effect on the vegetation.

Percent-cover of woody vegetation, percent of total height represented by Middle-Canopy, and the density of saw palmetto all were greater at unmined sites that were distant from permanent water than at unmined sites that were near. The density of *Quercus* spp. was greater at near unmined sites than at distant unmined sites, however. The density of tree species other than *Quercus* spp. and *Pinus* spp. was greater at distant mined sites than at near mined sites. These results are problematic.

- Distance to permanent water may have some effect on the vegetation, but we can offer no ready interpretation for our particular results.

No interrelationships between distance to upland habitats and life-form coverage were found. Percent of total height represented by the Shrub layer and the density of *Quercus* spp. were greater at mined sites that were near upland habitats than at mined sites that were distant from them. The density of tree species other than *Quercus* spp. and *Pinus* spp. was greater at distant unmined sites than at near unmined sites. These results also are problematic.

- Distance to upland habitats may have some effect on the vegetation, but we can offer no ready interpretation for our particular results.

Percent-cover of woody vegetation was greater at small mined sites than at large mined sites. Although it is not one of the five categories we retained, we also noted that percent-cover of forbs was greater at small unmined sites than large unmined sites. Percent of total height represented by the Ground layer and by Upper-Canopy, and the density of

TABLE 7. Correlations (Spearman's Rank Correlation Coefficient) of vegetation variables measuring life-form coverage and density (see text). Life forms are: WD = woody, OG = other (than wiregrass) grasses, LG = legumes, BG = bare ground, LR = litter. Density are: SP = saw palmettos, SN = snags, QS = *Quercus* spp., PS = *Pinus* spp., OS = other tree species. Minuses indicate negative correlations, pluses indicate positive correlations, and asterisks indicate p < 0.05.

UNMINED SITES

	WD	OG	LG	BG	LR
SP	+*	-*	-	+	+
SN	-	-*	-	-*	+*
QS	-	-	-	-	+
PS	+	-*	-	-*	+*
OS	-*	-	+	-*	+*

MINED SITES

	WD	OG	LG	BG	LR
SP	+*	-*	+	+*	+*
SN	+*	-	+	+	+
QS	+*	-	+	+	+*
PS	+	-	+	+	+
OS	+	-	+	-	+

snags were greater at small unmined sites than at large unmined sites. The density of *Pinus* spp. was greater at large unmined sites than at small unmined sites. These results indicate the following.

- Size has some effect on the vegetation, which, in turn, may have some effect on the resident fauna.

One interpretation of the results for mined sites is that reclamation efforts incorporating tree plantings have been focused on smaller, more manageable, areas; and for unmined sites is that absence of fires on smaller areas has allowed them to become overgrown.

At mined sites, we examined the effect of time since initial reclamation on vegetation structure. We found that older reclaimed sites tended to have proportionately less representation of wiregrass, forbs, and bare ground than younger reclaimed sites (r_s, p's < 0.10). We also found that older reclaimed sites tended to have relatively larger Upper-Canopy layers than younger reclaimed sites. Finally, we found that older reclaimed sites have a moderate tendency to have lower densities of *Quercus* spp. (r_s, $p = 0.13$).

Vertebrates: Resident Species Captured or Observed

The list of resident species (Appendix 2) includes 10 amphibians, 35 reptiles, 26 mammals (of which 7 are trappable in our arrays), and 69 birds. We note that the method of identifying resident species that we used provided satisfactory discrimination, in our opinion, with the possible exception of the exclusion of *Geothlypis trichas* (common yellowthroat) from the list of residents. This bird species was observed breeding at a relatively-large number of unmined sites. The species actually captured (amphibians, reptiles, mammals) or observed (birds) during this study (Table 8) include 9 resident amphibian species (90% of all resident amphibian species), 24 resident reptile species (69% of all resident reptile species), 7 resident mammal species (100% of all trappable resident mammal species), and 39 resident bird species (57% of all resident bird species). This group of 79 species (65% of all resident species) is the group from which focal species are selected. Note that DRI's indicate that another 25 or so resident species were captured or observed at/near our sites in the past, but we have no way of judging the reliability of these records.

Vertebrates: Habitat Distributions

The resident species that we captured or observed potentially could have been recorded from seven habitat/time combinations: (1) unmined land during a previous DRI, (2) reclaimed land during a DRI, (3) sandhill during the present study, (4) scrub during the present study, (5) scrubby flatwoods during the present study, (6) pre-1975 reclaimed land during the present study, and (7) post-1975 reclaimed land during the present study. The 79 species are ranked, by the number of combinations recorded for each; the rankings are done separately for amphibians, reptiles, and mammals (Table 9) and for birds (Table 10). The species are placed into five categories of distribution for heuristic purposes; one of the

TABLE 8. Numbers of resident species in different habitats. Quadrupeds = amphibian + reptilian + (trappable) mammalian species.

HABITAT	QUADRUPEDS	BIRDS
A. Our Sandhill Data	33	30
B. Our Scrub Data	30	31
C. Our Scrubby Flatwoods Data	28	28
TOTAL (A + B + C)	38	37
D. Our Pre-1975 Reclamation Data	19	19
E. Our Post-1975 Reclamation Data	21	21
TOTAL (D + E)	26	22
TOTAL (A + B + C + D + E)	40	39
F. DRI Unmined Sites Data	43	43
G. DRI Reclaimed Sites Data	14	30
TOTAL (F + G)	45	45
TOTAL (All habitats)	52	52

TABLE 9. Resident quadrupeds ranked by breadth of distribution. Records are from our own data (SA = sandhill, SC = scrub, SF = scrubby flatwoods, PR = pre-1975 reclamation, PT = post-1975 reclamation) and from DRI's (UN = unmined sites, RE = reclaimed sites). Y = recorded from at least one site, N = not recorded. Letters are possible categories of distribution (i.e., number of habitat/time combinations): A = recorded in all seven, B = recorded in five or six, C = recorded in three or four and absent at mined sites, D = recorded in three or four and present at mined sites, E = recorded in one or two.

SPECIES	SA	SC	SF	PR	PT	UN	RE	
Bufo terrestris	Y	Y	Y	Y	Y	Y	Y	A
Gastrophryne c. carolinensis	Y	Y	Y	Y	Y	Y	Y	A
Cnemidophorus s. sexlineatus	Y	Y	Y	Y	Y	Y	Y	A
Coluber constrictor priapus	Y	Y	Y	Y	Y	Y	Y	A
Gopherus polyphemus	Y	Y	Y	Y	Y	Y	Y	A
Blarina brevicauda	Y	Y	Y	Y	Y	Y	Y	A
Cryptotis parva	Y	Y	Y	Y	Y	Y	Y	A
Peromyscus polionotus	Y	Y	Y	Y	Y	Y	Y	A
Sigmodon hispidus	Y	N	Y	Y	Y	Y	Y	A
Scaphiopus h. holbrooki	Y	Y	Y	Y	Y	Y	N	B
Eleutherodactylus p. planirostris	Y	Y	Y	Y	Y	Y	N	B
Bufo quercicus	Y	Y	Y	N	Y	Y	Y	B
Eumeces inexpectatus	Y	Y	Y	Y	Y	Y	N	B
Scincella laterale	Y	Y	Y	Y	Y	Y	N	B
Cemophora c. coccinea	Y	Y	Y	Y	Y	Y	N	B
Masticophis f. flagellum	Y	Y	Y	Y	Y	N	N	B
Elaphe g. guttata	N	Y	N	Y	Y	Y	Y	B
Peromyscus gossypinus	Y	Y	Y	Y	Y	Y	N	B
Hyla femoralis	Y	Y	Y	N	N	Y	N	C
Rana capito aesopus	N	Y	Y	N	N	Y	N	C
Anolis c. carolinensis	Y	Y	Y	N	Y	Y	N	C
Sceloporus u. undulatus	Y	Y	Y	N	Y	Y	N	C
Tantilla relicta neilli	Y	Y	Y	Y	N	Y	N	C
Drymarchon corais couperi	Y	Y	Y	N	N	Y	N	C
Podomys floridanus	Y	Y	Y	N	Y	Y	N	C
Ochrotomys nuttalli	N	Y	Y	N	N	Y	N	C
Tantilla r. relicta	Y	N	Y	N	N	Y	N	C
Hyla squirrela	Y	Y	N	N	N	N	Y	D
Diadophis p. punctatus	N	Y	Y	N	Y	N	N	D
Opheodrys aestivus	N	Y	N	Y	N	Y	N	D
Pituophis melanoleucus mugitus	N	N	N	Y	Y	Y	N	D
Pseudacris nigrita verrucosa	Y	N	N	N	N	N	N	E
Eumeces egregius onocrepis	Y	Y	N	N	N	N	N	E
Ophisaurus ventralis	Y	N	N	N	N	Y	N	E
Ophisaurus attenuatus longicaudus	Y	N	N	N	N	N	N	E
Micrurus f. fulvius	Y	Y	N	N	N	N	N	E
Lampropeltis getulus floridana	N	N	N	N	Y	N	Y	E
Elaphe obsoleta quadrivittata	Y	N	N	N	N	N	N	E
Heterodon platyrhinos	Y	N	N	N	N	N	N	E
Rhadinaea flavilata	Y	N	N	N	N	N	N	E

TABLE 10. Resident birds ranked by breadth of distribution. Records are from our own data (SA = sandhill, SC = scrub, SF = scrubby flatwoods, PR = pre-1975 reclamation, PT = post-1975 reclamation) and from DRI's (UN = unmined sites, RE = reclaimed sites). Y = recorded from at least one site, N = not recorded. Letters are possible categories of distribution (i.e., number of habitat/time combinations): A = recorded in all seven, B = recorded in five or six, C = recorded in three or four and absent at mined sites, D = recorded in three or four and present at mined sites, E = recorded in one or two.

SPECIES	SA	SC	SF	PR	PT	UN	RE	
Cardinalis cardinalis	Y	Y	Y	Y	Y	Y	Y	A
Columbina passerina	Y	Y	Y	Y	Y	Y	Y	A
Cyanocitta cristata	Y	Y	Y	Y	Y	Y	Y	A
Dendroica palmarum	Y	Y	Y	Y	Y	Y	Y	A
Mimus polyglottos	Y	Y	Y	Y	Y	Y	Y	A
Picoides pubescens	Y	Y	Y	Y	Y	Y	Y	A
Pipilo erythrophthalmus	Y	Y	Y	Y	Y	Y	Y	A
Polioptila caerulea	Y	Y	Y	Y	Y	Y	Y	A
Sayornis phoebe	Y	Y	Y	Y	Y	Y	Y	A
Toxostoma rufum	Y	Y	Y	Y	Y	Y	Y	A
Zenaida macroura	Y	Y	Y	Y	Y	Y	Y	A
Melanerpes carolinus	Y	Y	Y	Y	Y	Y	N	B
Chordeiles minor	Y	Y	Y	Y	N	Y	Y	B
Colinus virginianus	Y	Y	N	Y	Y	Y	Y	B
Lanius ludovicianus	Y	N	Y	Y	Y	Y	Y	B
Colaptes auratus	Y	Y	N	Y	Y	Y	N	B
Dendroica coronata	Y	N	Y	Y	Y	Y	N	B
Caprimulgus carolinensis	Y	Y	Y	N	N	Y	Y	B
Thryothorus ludovicianus	Y	Y	Y	N	N	Y	Y	B
Vireo griseus	Y	Y	Y	N	N	Y	Y	B
Buteo jamaicensis	N	N	Y	Y	Y	Y	Y	B
Myiarchus crinitus	Y	Y	Y	N	N	Y	N	C
Parus bicolor	Y	Y	Y	N	N	Y	N	C
Aphelocoma coerulescens	Y	Y	N	N	N	Y	N	C
Regulus calendula	Y	Y	N	N	N	Y	N	C
Dendroica pinus	Y	Y	Y	N	N	N	N	C
Parula americana	Y	Y	Y	N	N	N	N	C
Setophaga ruticilla	Y	Y	Y	N	N	N	N	C
Troglodytes aedon	Y	Y	N	Y	Y	N	N	D
Dryocopus pileatus	N	Y	Y	N	Y	Y	N	D
Dumetella carolinensis	Y	Y	N	N	N	Y	Y	D
Cathartes aura	N	Y	N	N	N	Y	Y	D
Falco sparverius	N	N	N	N	Y	Y	Y	D
Vireo solitarius	N	Y	Y	N	N	N	N	D
Dendroica dominica	N	Y	N	N	N	Y	N	E
Mniotilta varia	Y	N	N	N	N	Y	N	E
Strix varia	N	N	Y	N	N	Y	N	E
Melanerpes erythrocephalus	N	N	Y	N	N	N	N	E
Spizella passerina	N	N	N	N	Y	N	N	E

categories emphasizes species that appear to be avoiding reclaimed land (Tables 9, 10).

Vertebrates: Numbers of Sites Occupied

The resident species that we captured or observed potentially could have been recorded from 30 unmined sites and 30 mined sites. The 79 species are ranked by the number of unmined sites at which each was recorded; the rankings are done separately for amphibians, reptiles, and mammals (Table 11) and for birds (Table 12). After the species had been ranked by site distribution, we compared the resulting orderings (Tables 11, 12) with the orderings based on habitat distribution (Tables 9, 10), using Spearman's Rank Correlation Coefficient. The correlations are strongly positive for all groups ($r_s = 0.92$, $p < 0.05$ (amphibians); $r_s = 0.97$, $p < 0.05$ (lizards/turtles); $r_s = 0.69$, $p < 0.05$ (snakes), $r_s = 0.73$, $p < 0.05$ (birds)), with the exception of mammals ($r_s = 0.38$, $p < 0.40$). These strong positive correlations indicate that, for all groups but mammals, those species that are widely distributed among habitats also tend to be found at a relatively large number of unmined sites.

Among amphibians ($r_s = 0.95$, $p < 0.05$) and lizards/turtles ($r_s = 0.90$, $p < 0.05$), those species found at a relatively large number of unmined sites also tend strongly to be found at a relatively large number of mined sites, but the same is not true among snakes ($r_s = 0.36$, $p < 0.20$) or mammals ($r_s = 0.58$, $p < 0.20$). A strong correlation between number of unmined sites occupied and number of mined sites occupied is found among birds -- that is, species of birds that occur at relatively-large numbers of unmined sites tend also to occur at relatively-large numbers of mined sites, and vice-versa -- but the correlation coefficient is small ($r_s = 0.36$, $p < 0.05$).

Vertebrates: Numbers of Individuals

The 79 species also are ranked by the median number of individuals captured (amphibians, reptiles, mammals) or median number of times individuals were observed at unmined sites (birds); the rankings are done separately for amphibians, reptiles, and mammals (Table 13) and for birds (Table 14). After the species had been ranked by number of individuals or number of observations, we compared the resulting orderings (Tables 13, 14) with the orderings based on habitat distribution (Tables 9, 10) and on site distribution (Tables 11, 12), using Spearman's Rank Correlation Coefficient. Correlations with habitat distribution are strongly positive for amphibians ($r_s = 0.71$, $p < 0.05$) and snakes ($r_s = 0.80$, $p < 0.05$), but not for lizards/turtles ($r_s = 0.58$, $p < 0.20$) or mammals ($r_s = 0.52$, $p < 0.05$). A strong correlation between habitat distribution and number of individuals is found among birds, but the correlation coefficient is small ($r_s = 0.32$, $p < 0.05$). Correlations with site distribution are strongly positive for amphibians ($r_s = 0.76$, $p < 0.05$), snakes ($r_s = 0.76$, $p < 0.05$), and mammals ($r_s = 0.79$, $p < 0.05$), but not for lizards/turtles ($r_s = 0.58$, $p < 0.20$). A strong correlation between site distribution and number of individuals is found among birds, but the correlation coefficient, once again, is small ($r_s = 0.49$, $p < 0.05$). These relationships, combined with the unmined:mined sites comparison from the previous section, indicate the following.

TABLE 11. Number of sites at which resident quadruped species were captured, ranked by combined numbers in sandhill, scrub, and scrubby flatwoods. Column designation and letters indicating possible categories are the same as in Table 9.

SPECIES	SA	SC	SF	PR	PT	
Cnemidophorus s. sexlineatus	8	15	7	12	8	A
Gopherus polyphemus *	7**	14	7	8 (3)	4 (2)	A
Gastrophryne c. carolinensis	8	13	6	11	15	A
Coluber constrictor priapus	7	12	7	8	9	A
Bufo terrestris	5	13	6	5	9	A
Eumeces inexpectatus	7	12	5	1	3	B
Scincella laterale	6	8	7	3	3	B
Eleutherodactylus p. planirostris	4	10	5	1	4	B
Scaphiopus h. holbrooki	5	7	5	1	4	B
Cemophora c. coccinea	3	7	6	3	2	B
Blarina brevicauda	4	7	5	5	5	A
Cryptotis parva	4	6	6	11	13	A
Anolis c. carolinensis	4	6	5	0	5	C
Sceloporus u. undulatus	2	9	3	0	1	C
Peromyscus gossypinus	2	10	2	2	4	B
Podomys floridanus	1	8	3	0	2	C
Bufo quercicus	3	6	2	0	2	B
Masticophis f. flagellum	2	8	1	1	6	B
Peromyscus polionotus	3	6	1	4	7	A
Tantilla relicta neilli	2	6	1	1	0	C
Sigmodon hispidus	3	2	4	2	7	A
Hyla squirrela	2	5	0	0	0	D
Hyla femoralis	1	1	2	0	0	C
Eumeces egregius onocrepis	1	3	0	0	0	E
Drymarchon corais couperi	1	2	1	0	0	C
Micrurus f. fulvius	2	1	0	0	0	E
Rhadinaea flavilata	3	0	0	0	0	E
Ochrotomys nuttalli	0	2	1	0	0	C
Rana capito aesopus	0	1	1	0	0	C
Ophisaurus ventralis	2	0	0	0	0	E
Elaphe g. guttata	1	1	0	2	3	B
Diadophis p. punctatus	0	1	1	0	2	D
Tantilla r. relicta	1	0	1	0	0	C
Pseudacris nigrita verrucosa	1	0	0	0	0	E
Ophisaurus attenuatus longicaudus	1	0	0	0	0	E
Opheodrys aestivus	0	1	0	1	0	D
Elaphe obsoleta quadrivittata	1	0	0	0	0	E
Heterodon platyrhinos	1	0	0	0	0	E
Pituophis melanoleucus mugitus	0	0	0	1	1	D
Lampropeltis getulus floridana	0	0	0	0	1	E

* = numbers in parentheses are sites without known relocations, ** = one site mined before survey could be made

TABLE 12. Number of sites at which resident bird species were observed, ranked by combined numbers in sandhill, scrub, and scrubby flatwoods. Column designation and letters indicating possible categories are the same as in Table 10. The last column is the number of unmined (first number) and mined (second number) sites at which signs of breeding were observed.

SPECIES	SA	SC	SF	PR	PT		
Pipilo erythrophthalmus	7	15	7	5	5	A	28-8
Cyanocitta cristata	6	14	7	8	4	A	2-1
Cardinalis cardinalis	7	12	5	2	4	A	21-3
Thryothorus ludovicianus	5	15	4	0	0	B	23-0
Vireo griseus	6	13	5	0	0	B	22-0
Dendroica palmarum	7	9	5	9	13	A	0-0
Zenaida macroura	6	10	2	5	3	A	2-0
Parus bicolor	3	10	3	0	0	C	11-0
Melanerpes carolinus	3	6	4	2	1	B	1-0
Polioptila caerulea	4	6	3	1	1	A	0-0
Picoides pubescens	4	6	2	2	2	A	1-0
Mimus polyglottos	3	5	3	6	9	A	8-13
Myiarchus crinitus	4	6	1	0	0	C	8-0
Toxostoma rufum	3	5	1	5	2	A	6-1
Caprimulgus carolinensis	2	5	2	0	0	B	5-0
Parula americana	3	4	1	0	0	C	8-0
Setophaga ruticilla	1	5	1	0	0	C	0-0
Columbina passerina	1	4	1	3	3	A	1-0
Chordeiles minor	3	2	1	3	0	B	3-0
Dendroica pinus	2	2	2	0	0	C	0-0
Dryocopus pileatus	0	5	1	0	2	D	0-0
Sayornis phoebe	3	1	1	4	2	A	0-0
Dendroica coronata	3	0	2	2	4	B	0-0
Colinus virginianus	2	2	0	4	6	B	4-8
Lanius ludovicianus	3	0	1	9	5	B	1-2
Aphelocoma coerulescens	1	3	0	0	0	C	1-0
Colaptes auratus	1	2	0	3	1	B	0-1
Regulus calendula	1	2	0	0	0	C	0-0
Troglodytes aedon	2	1	0	2	1	D	0-0
Vireo solitarius	0	2	1	0	0	D	0-0
Dumetella carolinensis	1	1	0	0	0	D	2-0
Buteo jamaicensis	0	0	1	1	1	B	0-2
Cathartes aura	0	1	0	0	0	D	0-0
Dendroica dominica	0	1	0	0	0	E	0-0
Melanerpes erythrocephalus	0	0	1	0	0	E	0-0
Mniotilta varia	1	0	0	0	0	E	0-0
Strix varia	0	0	1	0	0	E	0-0
Falco sparverius	0	0	0	0	1	D	0-0
Spizella passerina	0	0	0	0	1	E	0-0

TABLE 13. Median number of individuals at sites at which resident quadrupeds were captured, ranked by combined numbers in sandhill, scrub, and scrubby flatwoods. Column designation and letters indicating possible categories are the same as in Table 9; numbers following letters are ranks of species from Table 11. Data are from marked individuals, except where indicated.

SPECIES	SA	SC	SF	PR	PS		
Cnemidophorus s. sexlineatus	11.0	14.0	7.5	10.0	5.5	A	1
Sceloporus u. undulatus	21.0	2.5	7.0	0.0	3.0	C	14.5
Gastrophryne c. carolinensis	4.5	4.0	4.5	3.0	6.0	A	3
Scaphiopus h. holbrooki	4.0	5.0	1.5	1.0	2.0	B	9
Bufo quercicus	2.0	4.0	3.5	0.0	1.0	B	17.5
Gopherus polyphemus *	3.5	3.0	2.0	2.0	1.0	A	2
Eumeces inexpectatus	3.0	2.5	3.0	1.0	1.0	B	5.5
Bufo terrestris	2.0	4.0	2.5	1.0	3.5	A	5.5
Cryptotis parva **	2.5	1.0	3.0	2.0	5.0	A	11
Coluber constrictor priapus	2.0	2.0	3.0	1.0	1.0	A	4
Cemophora c. coccinea	2.0	2.0	3.0	2.0	1.5	B	11
Blarina brevicauda **	2.0	1.0	2.0	1.0	2.0	A	11
Masticophis f. flagellum	2.0	1.0	2.0	1.0	1.0	B	17.5
Hyla squirrela	3.0	1.0	0.0	0.0	0.0	D	22
Ophisaurus ventralis	2.0	0.0	0.0	0.0	0.0	E	31
Tantilla relicta neilli	5.0	1.5	1.0	2.0	0.0	C	20.5
Eleutherodactylus p. planirostris	1.5	1.5	2.0	2.0	1.0	B	8
Elaphe g. guttata	1.0	2.0	0.0	1.0	1.0	B	31
Tantilla r. relicta	1.0	0.0	2.0	0.0	0.0	C	31
Diadophis p. punctatus	0.0	2.0	1.0	0.0	1.5	D	31
Peromyscus gossypinus	1.0	1.0	2.5	1.0	1.0	B	14.5
Podomys floridanus	1.0	1.5	1.0	0.0	1.0	C	16
Peromyscus polionotus	1.0	1.5	1.0	1.5	1.0	A	20.5
Sigmodon hispidus	1.0	2.0	1.0	1.5	1.5	A	20.5
Hyla femoralis	2.0	1.0	1.0	0.0	0.0	C	24
Drymarchon corais couperi	1.0	1.0	2.0	0.0	0.0	C	24
Scincella laterale	1.5	1.0	1.0	1.0	2.0	B	7
Anolis c. carolinensis	1.5	1.0	1.0	0.0	1.0	C	13
Eumeces egregius onocrepis	1.0	1.0	0.0	0.0	0.0	E	24
Ochrotomys nuttalli	0.0	1.0	1.0	0.0	0.0	C	27
Micrurus f. fulvius	1.0	1.0	0.0	0.0	0.0	E	27
Rana capito aesopus	0.0	1.0	1.0	0.0	0.0	C	31
Rhadinaea flavilata	1.0	0.0	0.0	0.0	0.0	E	27
Opheodrys aestivus	0.0	1.0	0.0	1.0	0.0	D	36
Pseudacris nigrita verrucosa	1.0	0.0	0.0	0.0	0.0	E	36
Ophisaurus attenuatus longicaudus	1.0	0.0	0.0	0.0	0.0	E	36
Elaphe obsoleta quadrivittata	1.0	0.0	0.0	0.0	0.0	E	36
Heterodon platyrhinos	1.0	0.0	0.0	0.0	0.0	E	36
Pituophis melanoleucus mugitus	0.0	0.0	0.0	1.0	1.0	D	39.5
Lampropeltis getulus floridana	0.0	0.0	0.0	0.0	1.0	E	39.5

* = data are number of active burrows, so are not comparable, ** = data not from marked individuals

TABLE 14. Median number of observations at sites at which resident birds were observed, ranked by combined numbers in sandhill, scrub, and scrubby flatwoods. Column designation and letters indicating possible categories are the same as in Table 10; numbers following letters are ranks of species from Table 12.

SPECIES	SA	SC	SF	PR	PS		
Pipilo erythrophthalmus	3.5	5.0	4.0	1.0	3.0	A	1
Aphelocoma coerulescens	5.0	2.0	0.0	0.0	0.0	C	25
Vireo griseus	3.0	3.5	2.0	0.0	0.0	B	4
Cardinalis cardinalis	3.0	3.0	2.0	1.0	1.0	A	4
Thryothorus ludovicianus	2.0	3.0	3.0	0.0	0.0	B	4
Lanius ludovicianus	1.0	0.0	5.0	1.0	1.0	B	25
Parus bicolor	4.0	1.0	2.0	0.0	0.0	C	8
Cyanocitta cristata	1.0	2.0	2.0	1.0	1.0	A	2
Dendroica palmarum	2.0	1.0	2.0	2.0	2.0	A	6
Colaptes auratus	2.0	2.0	0.0	1.0	3.0	B	28.5
Regulus calendula	2.0	1.5	0.0	0.0	0.0	C	28.5
Dendroica pinus	1.0	2.5	1.5	0.0	0.0	C	19.5
Zenaida macroura	1.5	1.5	1.5	1.0	2.0	A	7
Mimus polyglottos	3.0	1.0	1.0	1.0	2.0	A	12.5
Parula americana	3.0	1.0	1.0	0.0	0.0	C	16
Picoides pubescens	1.0	1.0	2.5	1.5	1.5	A	11
Polioptila caerulea	1.0	1.0	2.0	1.0	1.0	A	9.5
Melanerpes carolinus	1.0	1.0	2.0	2.0	1.0	B	9.5
Toxostoma rufum	1.0	2.0	1.0	1.0	1.0	A	14.5
Columbina passerina	1.0	1.0	2.0	1.0	2.0	A	19.5
Sayornis phoebe	1.0	2.0	1.0	1.0	1.5	A	22.5
Caprimulgus carolinensis	1.0	1.0	1.5	0.0	0.0	B	14.5
Myiarchus crinitus	1.0	1.0	1.0	0.0	0.0	C	12.5
Chordeiles minor	1.0	1.0	1.0	1.0	0.0	B	19.5
Setophaga ruticilla	1.0	1.0	1.0	0.0	0.0	C	19.5
Dryocopus pileatus	0.0	1.0	1.0	0.0	1.5	D	19.5
Dendroica coronata	1.0	0.0	1.0	1.0	1.0	B	22.5
Colinus virginianus	1.0	1.0	0.0	1.0	1.5	B	25
Troglodytes aedon	1.0	1.0	0.0	1.0	1.0	D	28.5
Vireo solitarius	0.0	1.0	1.0	0.0	0.0	D	28.5
Dumetella carolinensis	1.0	1.0	0.0	0.0	0.0	D	31
Buteo jamaicensis	0.0	0.0	1.0	1.0	1.0	B	34.5
Cathartes aura	0.0	1.0	0.0	0.0	0.0	D	34.5
Dendroica dominica	0.0	1.0	0.0	0.0	0.0	E	34.5
Melanerpes erythrocephalus	0.0	0.0	1.0	0.0	0.0	E	34.5
Mniotilta varia	1.0	0.0	0.0	0.0	0.0	E	34.5
Strix varia	0.0	0.0	1.0	0.0	0.0	E	34.5
Falco sparverius	0.0	0.0	0.0	0.0	1.0	D	38.5
Spizella passerina	0.0	0.0	0.0	0.0	1.0	E	38.5

- Among amphibians and snakes, those species that are widely distributed among habitats and/or found at a relatively large number of unmined sites also tend to be found in relatively large populations sizes there.

- Among lizards/turtles, those species that are widely distributed among habitats and/or found at a relatively large number of unmined sites do not tend very strongly to be found in relatively large population sizes there.

- Among mammals, those species that are widely distributed among habitats do not tend very strongly either to be found at a relatively large number of sites or to be found in relatively large population sizes, but those species that are found at a relatively large number of sites do tend also to be found in relatively large population sizes there.

- The pattern for birds is much the same as those for amphibians and snakes, but the correlation coefficients (i.e., explanatory abilities) are small.

For amphibians ($r_s = 0.78$, $p < 0.05$), lizards/turtles ($r_s = 0.63$, $p < 0.05$), and mammals ($r_s = 0.75$, $p < 0.05$), those species found in relatively large population sizes at unmined sites also tend strongly to be found in relatively large population sizes at mined sites, but the same is not true among snakes ($r_s = 0.52$, $p < 0.20$) or birds ($r_s = 0.06$, $p > 0.50$). These relationships, combined with the unmined:mined sites comparison from the previous section, indicate the following.

- Among amphibians and lizards/turtles, those species that are found at a relatively large number of unmined sites and/or in relatively large population sizes there tend strongly to be relatively common at mined sites.

- Among snakes, neither number of unmined sites occupied nor population sizes there tend very strongly to identify those species that are relatively common at mined sites.

- Among mammals, those species that have relatively large population sizes at unmined sites tend strongly to be relatively common at mined sites, but the same is not true for those species that occupy a relatively large number of unmined sites.

- Among birds, those species that occupy a relatively large number of unmined sites tend strongly -- but the correlation coefficient is low -- to be common at mined sites, but the same is not true for those species that have relatively large population sizes there.

Vertebrates: Focal Species

Focal species are those species which are found much more commonly -- locally -- on unmined lands than on mined lands. These focal species, therefore, serve as targets for reclamation efforts aimed at making the vertebrate compositions of mined sites more representative of those of upland habitats. The list of focal species (Table 15) includes 5 amphibians< 5 lizards/turtles, 3 snakes, 1 mammal, and 15 birds. One of the bird species, *Lanius ludovicianus* (loggerhead shrike), actually was demonstrably more common at mined than unmined sites, and is not included in subsequent analyses. The preference of this bird for open areas is well known, and it may be declining in many parts of its range because these preferred areas are disappearing (Prescott and Collister 1993). The remaining group of 28 species is the group that will be used to document differences between the vertebrate compositions of unmined and mined lands. We are satisfied with this group of focal species, with the possible exception of *Setophaga ruticilla* (American redstart), which, despite its common occurrence at several unmined sites, is a transient species (Robertson and Woolfenden 1992), and *Elutherodactylus p. planirostris* (greenhouse frog), which is an exotic species (Ashton and Ashton 1988). We note that four of the listed (Wood 1991) resident species -- *Gopherus polyphemus* (gopher tortoise), *Aphelocoma coerulescens* (scrub jay), *Drymarchon corais couperi* (eastern indigo snake), *Podomys floridanus* (Florida mouse) -- are in the group of focal species, but three -- *Rana capito aesopus* (Florida gopher frog), *Pituophis melanoleucus mugitus* (Florida pine snake), *Falco sparverius* (American kestrel) -- are not. The three excluded taxa simply occur at too few sites to determine if any difference in their distributions exists between unmined and mined lands.

Vertebrates: Distributions Among Sites

Numbers of resident species captured/observed (Table 16) at the 60 sites, and their relative abundances there (Table 17) are presented. Sites also are ranked by their representation of focal species; separate rankings are presented for quadrupeds (= amphibians + reptiles + mammals) (Table 18) and birds (Table 19). These rankings of sites are used in all subsequent analyses. Among all 60 sites, rank based on number of resident quadruped species is strongly positively correlated with rank based on number of resident bird species ($r_s = 0.69$, $p < 0.05$). Likewise rank based on representation of focal quadruped species is strongly positively correlated with rank based on representation of focal bird species ($r_s = 0.79$, $p < 0.05$). Among the 30 unmined sites alone, the correlations are not as strong, either for numbers of resident species ($r_s = 0.23$, $p < 0.20$) or for representation of focal species ($r_s = 0.36$, $p < 0.10$). Among the 30 mined sites alone, the correlations are intermediate, both for numbers of resident species ($r_s = 0.45$, $p < 0.05$) and for representation of focal species ($r_s = 0.49$, $p < 0.05$). These relationships indicate the following.

- Unmined and mined sites differ dramatically in any of the criteria employed (see Tables 16-19).

TABLE 15. Focal species. The first column includes both unmined (first number) and mined (second number) sites. The sites scores are the binomial test scores, reflecting the strengths of the differences of the real site distributions (unmined:mined) and equal distributions (see text). Only species for which the significance (p-value) of the binomial test score is < 0.10 are included. Factors are indications of relative differences in abundance, with 1 indicating no difference (see text). The factor scores are (sites scores X factors), and are the scores used to rank species. Note that no species is included solely on the basis of relative differences in abundance.

SPECIES	SITES	SITES SCORE	FACTOR	ADJUSTED SITES SCORE
Thryothorus ludovicianus	24- 0	20.72	4	82.88
Vireo griseus	24- 0	20.72	4	82.88
Parus bicolor	16- 0	13.82	3	41.46
Eumeces inexpectatus	24- 4	8.54	3	25.62
Gopherus polyphemus	28- 5	10.29	2	20.58
Myiarchus crinitus	11- 0	9.46	2	18.92
Cardinalis cardinalis	24- 6	6.08	3	18.24
Hyla squirrela	7- 0	6.06	3	18.18
Sceloporus u. undulatus	14- 1	7.64	2.3	17.57
Aphelocoma c. coerulescens	4- 0	3.46	4.5	15.57
Caprimulgus carolinensis	9- 0	7.76	2	15.52
Parula americana	8- 0	6.88	2	13.76
Dendroica pinus	6- 0	5.16	2.5	12.90
Bufo quercicus	11- 2	3.68	3.5	12.88
Setophaga ruticilla	7- 0	6.06	2	12.12
Pipilo erythrophthalmus	29-10	4.98	2	9.96
Scaphiopus h. holbrooki	17- 5	3.58	2.7	9.67
Hyla femoralis	4- 0	3.46	2	6.92
Drymarchon corais couperi	4- 0	3.46	2	6.92
Cyanocitta cristata	27-12	3.04	2	6.08
Polioptila caerulea	13- 2	4.88	1	4.88
Scincella laterale	21- 6	4.60	1	4.60
Eleutherodactylus p. planirostris	19- 5	4.58	1	4.58
Podomys floridanus	12- 2	4.28	1	4.28
Tantilla relicta neilli	9- 1	4.06	1	4.06
Melanerpes carolinus	13- 3	3.56	1	3.56
Cemophora c. coccinea	16- 5	3.16	1.1	3.48
Anolis c. carolinensis	15- 5	2.72	1	2.72
Lanius ludovicianus	4-14	3.08	1	3.08

TABLE 16. Number of resident amphibian (AM), reptile (RL = lizards/turtles, RS = snakes), (trappable) mammal (MA), and total quadruped (QA) species captured, and number of bird (BI) species observed, at the 60 study sites. Sites are arranged by habitat and ranked by combined numbers of all taxa within geographical clusters (see text). Medians are provided for unmined and mined sites, habitats, and counties.

SITE	NUMBER OF SPECIES					
	AM	RL	RS	MA	QA	BI
SA03H	5	3	4	6	18	14
SA02H	4	4	2	2	12	12
SA05H	4	5	2	1	12	15
SA04H	5	5	4	0	14	9
SA07P	3	4	7	4	18	9
SA08P	3	5	4	1	13	11
SA06P	3	3	3	1	10	16
SA01P	2	2	0	2	6	15
SC04H	4	4	4	3	15	19
SC03H	4	5	4	3	16	16
SC02H	5	4	3	6	18	12
SC05H	3	4	3	4	14	14
SC14M	4	4	2	3	13	14
SC13M	4	5	3	3	15	10
SC10M	4	4	3	2	13	9
SC11M	3	3	4	3	13	9
SC12M	5	2	3	3	13	7
SC06H	4	4	4	2	14	12
SC07H	3	3	2	3	11	13
SC01P	4	2	1	2	9	12
SC15H	3	4	1	1	9	11
SC09H	2	4	2	2	10	9
SC08H	3	1	0	1	5	10
SF06H	5	4	4	5	18	14
SF05H	6	4	2	5	17	12
SF07H	4	4	3	4	15	12
SF01H	3	4	3	2	12	11
SF04H	5	3	3	2	13	6
SF02H	2	4	2	2	10	7
SF03H	2	4	2	2	10	5
PR04P	1	1	3	2	7	10
PR05P	2	1	4	1	8	9
PR01P	1	2	1	1	5	7
PR10P	1	0	1	2	4	4
PR06P	0	1	1	0	2	4
PR09P	2	2	1	1	6	8
PR08P	1	2	1	0	4	4
PR13H	1	1	0	4	6	7
PR14H	2	1	0	3	6	4
PR07H	2	1	2	2	7	3

TABLE 16 (CONTINUED).

SITE	NUMBER OF SPECIES					
	AM	RL	RS	MA	QA	BI
PR03H	1	2	2	2	7	0
PR02H	2	0	1	1	4	0
PR12P	2	1	0	2	5	8
PR11P	0	1	0	3	4	7
PT08P	2	3	4	4	13	13
PT09P	1	1	0	2	4	1
PT12H	3	4	2	3	12	7
PT13H	4	2	2	4	12	7
PT11H	3	0	2	1	6	5
PT14H	2	0	2	3	7	6
PT04P	4	2	3	3	12	5
PT06P	2	1	0	3	6	8
PT03P	2	2	2	2	8	3
PT02P	2	1	2	2	7	2
PT01P	2	1	0	2	5	2
PT05P	2	0	1	1	4	3
PT10P	1	1	2	3	7	5
PT16P	2	0	2	2	6	1
PT15P	1	0	0	1	2	1
PT07P	1	2	0	1	4	1
SITES MEDIANS						
Unmined	4	4	3	2	13	12
Mined	2	1	1	2	6	4.5
HABITAT MEDIANS						
Sandhill	3.5	4	3.5	1.5	12.5	13
Scrub	4	4	3	3	13	12
Scrubby Flatwoods	4	4	3	2	13	11
Pre-1975 Reclamation	1	1	1	2	5.5	4
Post-1975 Reclamation	2	1	2	2	6.5	4
COUNTY MEDIANS						
Hillsborough (Unmined)	4	4	3	2.5	13	12
Hillsborough (Mined)	2	1	1.5	3	7	5
Manatee (Unmined)	4	4	3	3	13	9
Polk (Unmined)	3	3	3	2	10	12
Polk (Mined)	1.5	1	1	2	5	4

TABLE 17. Relative number of resident amphibian (AM), reptile (RL = lizards and turtles, RS = snakes), (trappable) mammal (MA), and total quadruped (QA) individuals captured, and number of observations of resident bird (BI) species, at the 60 study sites. Sites are arranged by habitat and ranked by combined numbers of individuals within geographical clusters (see text). Relative numbers were calculated for each site by dividing the number of individuals of each species by the median number of individuals in that species over all sites, summing the resulting values, and dividing by the total number of taxa at the site (= mean) (see text). Medians are provided for quadrupeds and birds, unmined and mined sites, habitats, and counties.

SITE	INDIVIDUALS/OBSERVATIONS					
	AM	RL	RS	MA	QA (median)	BI (median)
SA02H	4.55	2.12	2.20	0.78	2.72 (1.18)	0.86 (0.64)
SA03H	6.32	1.22	1.34	1.34	2.70 (0.96)	0.94 (0.82)
SA04H	1.57	1.76	1.00	----	1.47 (1.06)	1.19 (1.00)
SA05H	1.00	1.70	1.20	0.33	1.27 (1.20)	1.04 (1.00)
SA06P	1.11	1.63	0.85	0.66	1.15 (1.12)	0.97 (0.84)
SA07P	0.69	0.70	1.17	1.56	1.07 (1.00)	1.00 (1.00)
SA08P	0.40	1.16	1.52	0.72	1.06 (0.94)	0.65 (0.68)
SA01P	0.78	0.84	----	0.76	0.80 (0.82)	1.25 (1.30)
SC03H	3.72	2.29	1.40	1.89	2.35 (1.82)	1.18 (1.04)
SC04H	2.76	2.48	1.58	1.07	2.03 (1.65)	1.50 (1.37)
SC02H	1.11	0.71	1.00	0.84	0.91 (0.84)	1.26 (1.20)
SC15H	4.31	2.00	0.85	0.33	2.23 (0.89)	1.39 (1.12)
SC01P	2.10	1.14	1.28	1.24	1.60 (0.90)	1.30 (1.15)
SC10M	1.72	1.46	1.29	0.80	1.40 (0.87)	0.88 (0.79)
SC13M	2.12	1.06	0.88	0.64	1.22 (0.81)	1.10 (1.04)
SC11M	1.86	1.42	0.82	0.82	1.20 (0.87)	0.68 (0.65)
SC12M	1.04	0.68	1.18	1.79	1.19 (0.97)	0.69 (0.72)
SC14M	1.11	1.17	0.70	0.75	0.98 (0.82)	1.21 (1.06)
SC05H	0.95	1.01	0.62	1.55	1.07 (0.77)	0.88 (0.86)
SC06H	1.19	1.19	0.73	0.60	0.97 (0.86)	0.97 (0.84)
SC07H	0.36	0.59	1.42	0.82	0.74 (0.87)	0.99 (0.83)
SC09H	0.72	1.12	1.30	0.52	0.96 (0.81)	1.09 (1.00)
SC08H	0.65	1.07	----	1.55	0.91 (0.67)	1.13 (0.92)
SF06H	2.69	2.29	0.67	0.91	1.68 (0.94)	1.43 (1.17)
SF05H	1.16	0.90	0.99	0.69	0.94 (0.85)	1.18 (1.07)
SF02H	0.78	0.93	1.48	2.14	1.25 (0.90)	0.97 (1.00)
SF03H	0.48	0.80	1.70	1.84	1.12 (0.86)	0.84 (0.82)
SF07H	1.08	0.92	1.18	1.76	1.24 (1.23)	0.92 (0.92)
SF01H	1.15	0.80	1.98	0.89	1.20 (0.81)	1.15 (1.06)
SF04H	1.01	1.24	1.52	1.03	1.19 (1.28)	1.65 (1.20)
PR12P	2.21	1.07	----	0.69	1.37 (1.07)	0.98 (0.80)
PR11P	----	0.78	----	1.36	1.21 (1.23)	1.12 (0.85)
PR07H	0.49	2.53	2.13	0.60	1.28 (0.87)	0.64 (0.68)
PR14H	1.40	1.36	----	1.11	1.24 (1.18)	0.98 (0.79)
PR13H	0.34	0.87	----	0.77	0.72 (0.78)	0.99 (0.82)
PR08P	0.89	1.34	1.13	----	1.17 (0.98)	0.83 (0.78)

TABLE 17 (CONTINUED).

SITE	INDIVIDUALS/OBSERVATIONS					
	AM	RL	RS	MA	QA (median)	BI (median)
PR09P	0.28	1.09	1.69	0.81	0.87 (0.82)	1.29 (1.26)
PR06P	----	1.36	0.85	----	1.10 (1.10)	0.82 (0.79)
PR05P	1.06	0.39	1.00	0.33	0.85 (0.92)	1.11 (1.12)
PR04P	1.34	0.87	0.74	0.52	0.78 (0.87)	0.85 (0.81)
PR01P	0.45	0.70	0.56	0.66	0.61 (0.57)	0.73 (0.83)
PR10P	0.45	----	0.56	0.69	0.60 (0.61)	0.88 (0.84)
PR03H	0.67	0.30	0.70	1.78	0.89 (0.66)	----
PR02H	1.06	----	0.56	0.66	0.84 (0.61)	----
PT11H	1.77	----	2.68	4.30	2.50 (2.20)	0.93 (0.82)
PT13H	1.41	0.88	1.56	1.91	1.51 (1.32)	1.03 (1.00)
PT12H	0.94	0.64	0.70	1.51	0.89 (0.82)	1.06 (1.00)
PT15P	1.78	----	----	2.42	2.10 (2.10)	1.12 (1.12)
PT16P	1.62	----	0.72	0.74	1.02 (0.74)	0.56 (0.56)
PT10P	2.67	1.64	0.72	1.75	1.57 (1.47)	0.73 (0.79)
PT03P	2.40	0.84	0.85	2.04	1.54 (1.28)	1.11 (1.27)
PT01P	1.01	0.10	----	1.90	1.18 (0.74)	1.31 (1.31)
PT04P	1.37	0.90	0.95	0.77	1.04 (0.84)	1.62 (1.32)
PT02P	0.78	0.49	0.92	1.53	0.87 (0.92)	0.60 (0.60)
PT05P	0.73	----	0.56	0.33	0.59 (0.50)	0.74 (0.76)
PT06P	0.72	0.10	----	0.65	0.58 (0.80)	1.04 (0.92)
PT09P	2.23	0.91	----	1.17	1.37 (1.19)	0.56 (0.56)
PT08P	0.61	1.91	0.66	2.00	1.35 (0.91)	1.27 (1.00)
PT14H	0.48	----	0.94	1.37	0.99 (0.72)	1.03 (0.94)
PT07P	0.22	0.96	----	0.81	0.74 (0.52)	1.00 (1.00)
SITES MEDIANS						
Unmined	1.11	1.16	1.19	0.86	1.20	1.06
Mined	1.01	0.91	0.85	0.96	1.03	0.98
HABITAT MEDIANS						
Sandhill	1.06	1.42	1.20	0.76	1.21	0.98
Scrub	1.19	1.14	1.09	0.82	1.19	1.10
Scrubby Flatwoods	1.08	0.92	1.48	1.03	1.20	1.15
Pre-1975 Reclamation	0.78	0.97	0.80	0.69	0.88	0.93
Post-1975 Reclamation	1.19	0.88	0.85	1.52	1.11	1.03
COUNTY MEDIANS						
Hillsborough (Unmined)	1.13	1.16	1.24	0.91	1.22	1.11
Hillsborough (Mined)	0.94	0.88	0.94	1.37	0.99	0.99
Manatee (Unmined)	1.72	1.17	0.88	0.82	1.20	0.88
Polk (Unmined)	0.78	1.14	1.22	0.76	1.07	1.00
Polk (Mined)	1.01	0.91	0.80	0.81	1.04	0.98

TABLE 18. Sites ranked by representation of quadruped focal species. The score is computed from the presences of focal species; the factor is the mean abundance of resident species, relative to their abundances elsewhere; and adjusted sites score is (sites score X factor), if factor < 1, or (sites score), otherwise). Maximum possible adjusted sites score = 121.48. Open spaces indicate sites at which no focal species were recorded. Asterisks indicate either unmined sites that are not among the first 30 sites or mined sites that are.

SITE	SITES SCORE	FACTOR	ADJUSTED SITES SCORE
SC02H	101.44	0.84	85.21
SF06H	86.74	0.94	81.54
SA05H	81.12	1.20	81.12
SC13M	93.53	0.81	75.76
SC03H	73.10	1.82	73.10
SC04H	71.68	1.06	71.68
SC10M	82.31	0.87	71.61
SA03H	74.08	0.96	71.12
SF07H	69.80	1.23	69.80
SA04H	68.50	1.65	68.50
SC12M	69.02	0.97	66.95
SC14M	77.15	0.82	63.26
SA06P	60.94	1.12	60.94
SC06H	67.84	0.86	58.34
SA02H	55.70	1.18	55.70
SC07H	57.14	0.87	49.71
PT08P	53.99	0.91	49.13*
SA07P	48.53	1.00	48.53
SF04H	44.85	1.28	44.85
PT13H	44.15	1.32	44.15*
SC05H	56.43	0.77	43.45
SF03H	50.37	0.86	43.32
SC11M	49.68	0.87	43.22
SF05H	49.54	0.85	42.11
SA08P	43.95	0.94	41.31
PT04P	47.36	0.84	39.78*
SC09H	48.50	0.81	39.29
SF01H	47.19	0.81	38.22
SF02H	36.42	0.90	32.78
SC15H	34.80	0.89	30.97
PT12H	34.56	0.82	28.34
PR03H	29.10	0.66	19.21
PT11H	14.25	2.20	14.25

TABLE 18 (CONTINUED).

SITE	SITES SCORE	FACTOR	ADJUSTED SITES SCORE
SC08H	18.53	0.67	12.42*
PT14H	14.25	0.72	10.26
SC01P	10.80	0.90	9.72*
PR07H	9.67	0.87	8.41
PR04P	7.54	0.87	6.56
PT03P	6.20	1.28	6.20
PT10P	4.60	1.47	4.60
PR12P	4.58	1.07	4.58
PR08P	4.60	0.98	4.51
PR09P	4.60	0.82	3.77
PR05P	3.48	0.92	3.20
PT09P	2.72	1.19	2.72
PR01P	4.60	0.57	2.62
PT07P	2.72	0.52	1.41
PT15P		2.10	
PR11P		1.23	
PR14H		1.18	
PR06P		1.10	
PT02P		0.92	
SA01P		0.82	*
PT06P		0.80	
PR13H		0.78	
PT01P		0.74	
PT16P		0.74	
PR02H		0.61	
PR10P		0.61	
PT05P		0.50	

TABLE 19. Sites ranked by representation of bird focal species. The score is computed from the presences of focal species; the factor is the mean abundance of resident species, relative to their abundances elsewhere; and adjusted sites score is (sites score X factor), if factor < 1, or (sites score), otherwise. Maximum possible adjusted sites score = 338.73. Open spaces indicate sites at which no focal species were recorded. Asterisks indicate either unmined sites that are not among the first 30 sites or mined sites that are.

SITE	SITES SCORE	FACTOR	ADJUSTED SITES SCORE
SC04H	323.16	1.37	323.16
SF06H	306.16	1.17	306.16
SA05H	301.19	1.00	301.19
SC14M	295.52	1.06	295.52
SC03H	294.74	1.04	294.74
SF05H	265.46	1.07	265.46
SC13M	263.98	1.04	263.98
SC02H	261.90	1.20	261.90
SC05H	291.62	0.86	250.79
SC01P	220.44	1.15	220.44
SC07H	261.90	0.83	217.38
SF01H	217.04	1.06	217.04
SC06H	241.50	0.84	202.86
SC08H	217.04	0.92	199.68
SC15P	191.46	1.12	191.46
SA06P	224.00	0.84	188.16
SA02H	280.28	0.64	179.38
SA03H	217.18	0.82	178.09
SC10M	223.26	0.79	176.38
SF03H	200.04	0.82	164.03
SC12M	191.29	0.72	137.73
SA01P	137.61	1.30	137.61
SC09H	129.28	1.00	129.28
SC11M	197.37	0.65	128.29
SA07P	117.16	1.00	117.16
SA04H	100.82	1.00	100.82
SA08P	122.04	0.68	83.01
SF07H	65.94	0.92	60.66
SF02H	49.80	1.00	49.80
PT08P	33.08	1.00	33.08*
SF04H	32.50	1.20	32.50*
PT06P	28.88	0.92	26.57
PR12P	29.88	0.80	23.90
PT11H	24.32	0.82	19.94

TABLE 19 (CONTINUED).

SITE	SITES SCORE	FACTOR	ADJUSTED SITES SCORE
PT13H	18.24	1.00	18.24
PT04P	16.04	1.32	16.04
PR05P	16.04	1.12	16.04
PT12H	16.04	1.00	16.04
PR04P	19.60	0.81	15.88
PR11P	16.04	0.85	13.63
PR01P	16.04	0.83	13.31
PR13H	16.04	0.82	13.15
PR07H	18.24	0.68	12.40
PR09P	9.64	1.26	9.64
PT10P	9.96	0.79	7.87
PT14H	6.08	0.94	5.72
PR10P	6.08	0.84	5.11
PR14H	6.08	0.79	4.80
PT01P		1.31	
PT03P		1.27	
PT15P		1.12	
PT07P		1.00	
PR06P		0.79	
PR08P		0.78	
PT05P		0.76	
PT02P		0.60	
PT09P		0.56	
PT16P		0.56	
PR02H			
PR03H			

- Quadrupeds and birds are found at substantially different suites of unmined sites, perhaps because the suites differ in size, isolation, vegetation structure, or other ways, that may be differentially important to the two groups of species.

- Quadrupeds and birds are found at more similar suites of mined sites than unmined sites, perhaps because they differ in fewer important ways than to unmined sites.

interestingly, regardless of which of the three groups of sites -- unmined, mined, unmined and mined combined -- are employed, correlations between numbers of resident species and representation of focal species, both for quadrupeds and birds, are very strongly positively correlated (r_S's = 0.67-0.89, p's < 0.05) -- that is, representation of focal species, either quadrupeds or birds, at a site gives a strong indication of the relative species richness at that site. In this particular case, therefore, two of the potential ways of judging the success of rehabilitation efforts -- representativness and species diversity -- lead to virtually the same conclusions.

If any tendency exists for species to be particularly common or uncommon in a county or habitat, then this tendency could account for some of the differences found between mined and unmined sites, because our unmined and mined sites are not uniformly distributed among counties. To determine if any such tendency exists, we created a matrix with the focal species as rows and the three counties -- Hillsborough, Manatee, Polk -- and three habitats -- sandhill, scrub, scrubby flatwoods -- as columns. We then calculated the percentage of sites in each county and habitat where a species was captured/observed, and noted when the percentage was zero or when it was "low" (defined as < 50%, if at least one county/habitat was > 50%). Finally, we counted the number of species for which a zero or a "low" was noted, for each county and each habitat, and found that Hillsborough County = 6, Manatee County = 10, Polk County = 15; sandhill = 6, scrub = 6, scrubby flatwoods = 6. Mann-Whitney U-tests showed, on the other hand, that unmined sites in Manatee County tended to have higher ranks in representation of quadrupedal focal species than unmined sites in either Hillsborough County or Polk County, and that unmined sites in Hillsborough County tended to have higher ranks in representation of quadrupedal focal species than unmined sites in Polk County. A moderate tendency (M-W U, p = 0.11) also existed for mined sites in Hillsborough County to have higher ranks in representation of quadrupedal focal species than mined sites in Polk County. These results could indicate that focal species generally are less common in Manatee County and, especially, Polk County than in Hillsborough County, and that sites in Manatee County tend preferentially to harbor high ranking quadrupedal focal species. One might conclude that regional differences exist in the availability of a pool of species to recolonize mined sites. These results also could reflect differences in trapping effort among counties, however, because the number of unmined sites were Hillsborough = 20, Manatee = 5, Polk = 5.

Vertebrates: Nestedness and Species' Associations

We determined if the distributions of quadrupeds and birds among sites were nested. The Sites X Species matrices (Tables 20-21) indicate that some nestedness exists. These results suggest that the species compositions of less-rich sites tend, at least in part, to include more widely distributed species preferentially. Because the distributions of species among sites are nested, we also determined the associations of species that tended to occur at the sites. Variance Ratio Tests indicated that associations among species were indeed present, as was to be expected from the nestedness analyses. For all focal species, $W = 74.87$ ($p < 0.05$) at unmined sites and $W = 39.50$ ($p < 0.05$) at mined sites. For quadrupeds alone, $W = 41.52$ ($p < 0.10$) and for birds alone, $W = 76.68$ ($p < 0.05$), at unmined sites. We then used simple monothetic divisive cluster analysis to identify associations (Table 22). Among unmined sites, the presence of *Parus bicolor* (tufted titmouse) tended very strongly to group the sites with the greatest representation of focal species. We are not prepared to suggest, however, that this species be used as an "indicator." Among mined sites, no particular tendency for sites with the greatest representation of focal species to group could be detected. The results of the cluster analysis reinforce the point made earlier, that the distribution of sites in space may influence the comparison of unmined and mined sites. It can be noted (Table 22) that geographical clustering of "good" sites exists. For example, nine sites within but two clusters in Hillsborough County comprise more than 1/3 of all of unmined and mined sites having the ten largest complements of focal species.

TABLE 20. Sites X Species matrix for focal quadrupeds. Sites are arranged from most (top) to least species rich and species are arranged from most (left) to least widespread among sites. Species numbers are ranks from Table 15.

SITE	SPECIES													
	5	4	22	23	17	27	28	9	24	14	25	8	18	19
SF06H	X	X	X	X	X	X		X	X	X	X			
SC02H	X	X	X	X	X			X	X	X	X	X		
SA05H	X	X	X	X	X	X	X	X		X				
SC03H	X	X	X	X	X		X	X	X		X			
SC13M	X	X	X			X		X	X	X		X		X
SF04H	X		X	X	X	X	X			X			X	X
SF07H	X	X	X	X	X	X		X	X					
SA04H	X	X	X	X	X		X	X					X	
SC14M	X	X	X		X	X	X			X		X		
SC04H	X	X		X	X		X	X	X		X			
SA03H	X	X				X	X		X	X		X		X
SF05H	X		X	X	X	X	X	X					X	
SC09H	X	X	X	X			X				X		X	
SF03H	X	X	X		X	X	X		X					
SC10M	X	X	X			X		X		X		X		
SC06H	X	X		X	X	X		X						X
SC12M	X	X		X		X			X	X		X		
SC11M	X					X	X	X	X	X	X			
SF01H	X	X	X	X	X		X							
SA07P	X	X	X	X	X						X			
SA02H	X	X	X	X			X					X		
SC05H	X	X	X	X				X			X			
SA06P	X	X	X		X	X				X				
SA08P	X	X	X		X						X			
SF02H	X	X	X			X	X							
SC07H	X	X			X			X	X					
PT08P		X	X			X	X			X				
SC08H	X			X	X				X					
SC01P	X			X		X	X							
PT13H		X		X	X				X					
PT04P		X		X					X	X				
PT12H			X		X		X	X						
PT11H	X			X	X									
PR04P	X					X					X			
SC15H		X	X	X										
PR01P	X		X											
PR07H	X				X									
PR03H		X				X								
PT14H				X	X									
PT03P						X	X							
PT02P	X													
PR08P			X											
PR09P			X											
PT10P			X											
PR12P				X										
PR05P						X								
PT07P							X							
PT09P							X							
SA01P														
PR02H														
PR06P														
PR10P														
PR11P														
PR13H														
PR14H														
PT01P														
PT05P														
PT06P														
PT15P														
PT16P														

TABLE 21. Sites X Species matrix for focal birds. Sites are arranged from most (top) to least species rich and species are arranged from most (left) to least widespread among sites. Species numbers are ranks from Table 15.

SITE	SPECIES													
	16	20	7	1	2	3	26	21	6	11	12	15	13	10
SC04H	X	X	X	X	X	X	X	X	X	X	X	X	X	
SC03H	X	X	X	X	X	X	X	X	X		X	X		
SC14M	X	X	X	X	X	X	X	X	X		X		X	
SF06H	X	X	X	X	X	X	X		X	X	X		X	
SC05H	X	X	X	X	X	X	X		X	X		X		
SA05H	X	X	X	X	X	X			X	X	X	X		
SF05H	X	X	X	X	X	X	X	X		X				
SC13M	X	X	X	X	X	X	X		X					
SC07H	X	X	X	X	X	X		X		X				
SC02H	X	X	X	X	X	X			X	X				
SA06P	X	X	X	X	X		X	X		X				
SC15H	X	X	X	X		X	X			X	X			
SA02H	X		X	X	X	X			X		X		X	
SC08H	X	X	X	X	X			X				X		
SF01H	X	X	X	X	X			X				X		
SC01P	X	X	X	X	X			X						X
SA03H	X	X		X	X		X		X				X	
SC06H	X	X	X	X	X	X								
SA01P	X	X	X		X			X						X
SA04H		X			X	X	X	X		X				
SF03H	X	X	X	X	X									
SF07H	X	X			X	X	X	X						
SC09H	X	X	X	X								X		
SA08P	X	X	X		X			X						
SC10M	X	X		X	X	X								
SC11M	X	X		X	X									X
SA07P	X	X	X	X										
SF04H	X	X					X						X	
SC12M	X			X	X									X
SF02H	X	X	X											
PR04P	X	X					X							
PT08P	X		X					X						
PR12P		X	X					X						
PR01P	X	X												
PR05P	X	X												
PR11P	X	X												
PR13H	X	X												
PT04P	X	X												
PT12H	X	X												
PT06P	X		X											
PT11H		X	X											
PR09P		X					X							
PT10P	X													
PR10P		X												
PT14H		X												
PR07H			X											
PT13H			X											
PR02H														
PR03H														
PR06P														
PR08P														
PR14H														
PT01P														
PT02P														
PT03P														
PT05P														
PT07P														
PT09P														
PT15P														
PT16P														

TABLE 22. Groupings of sites derived from monothetic divisive cluster analysis. The species which provided the basis for clustering are listed, and numbered in the order in which clusters were derived (e.g., the presence/absence of *Parus bicolor* provided the first two clusters of unmined sites, I and II). The asterisks in the first column after the sites designate those sites with the ten largest representations of focal species (one asterisk for quadrupeds or birds, two asterisks for both groups). The letters refer to the geographical clusters in which the sites occur, and the asterisks in the column after the letters designate those sites for which other sites in the same geographical cluster are found in other groupings (number of asterisks, one to three, indicates "distance" between groupings (e.g., SF05H in group IA is farther away from site SF06H in group IB than site SC09H in group IIA1 is from site SC08H in group IIA2). Mined sites PR06P (geographical cluster C), PT01P (D), PT05P (D), PT06P (D), PR02H (M), PR14H (P), PT15P (O), and PT16P (O) had no focal species.

UNMINED SITES

IA	SA04H	*	E	
	SA05H	**	E	
	SF07H	*	E	
	SC02H	**	H	
	SC03H	**	H	
	SC04H	**	H	
	SC06H		L	
	SC07H		L	
	SF05H	*	M	**
	SC14M	*	U	
(2) *Scaphiopus h. holbrooki*				
IB	SC15H		B	
	SC05H	*	K	
	SF06H	**	M	**
	SA02H		R	***
	SC10M	*	T	***
	SC13M	**	T	***
(1) *Parus bicolor*				
IIA1	SA06P		A	
	SA07P		C	
	SA08P		C	
	SC09H		J	*
	SF01H		N	
	SF02H		S	
	SF03H		S	
(3) *Eumeces inexpectatus*				
IIA2	SA01P		D	
	SC01P	*	D	
	SC08H		J	*
(2) *Cardinalis cardinalis*				
IIB	SA03H	*	R	***
	SF04H		R	***
	SC11M		T	***
	SC12M		T	***

MINED SITES

I	PT04P	**	D	**
	PT13H	**	H	**
	PR03H	*	M	
	PT08P	**	Q	**
(1) *Eumeces inexpectatus*				
IIA	PR12P	*	G	*
(2) *Polioptila caerulea*				
IIB	PR08P		A	
	PR09P		A	
	PR07H	*	B	
	PR01P		C	
	PR04P	**	C	
	PRO5P	*	C	
	PR10P		C	
	PT02P		D	**
	PT03P	*	D	**
	PT06P	*	D	**
	PT10P		F	
	PR11P	*	G	*
	PT11H	**	H	**
	PT12H	**	H	**
	PT07P		I	
	PT14H	*	N	
	PR13H		P	
	PT09P		Q	**

EXPLANATIONS

Insights from Vertebrate Natural History

For amphibians, reptiles, and mammals, and for birds, we asked what aspects of their natural histories might distinguish focal from non-focal resident species. Realize that this question is not appropriate for those resident species which occurred at too few unmined sites to be recognized mathematically as focal species, and we have, therefore, not included them in the analysis. Among amphibians, reptiles, and mammals, we found that preferences for breeding sites -- for amphibians -- and for substrate or vegetation structures could distinguish nearly all focal from non-focal species (Table 23). The one focal species not included in Table 23, *Gopherus polyphemus* (gopher tortoise), probably has not been able to recolonize most of the mined sites because of their isolation. We assume that other focal species may be relatively-poor colonizers, as well, but we have no direct evidence to support this assumption. One non-focal resident species, *Peromyscus gossypinus* (cotton mouse), also was not included in Table 23, because it is a forest resident, and, therefore, is like some of the focal species in habitat preference. Interestingly, this species occupied 14 unmined sites and 6 mined sites, a larger discrepancy than any other non-focal amphibian, reptile, or mammal; but the discrepancy was not large enough to recognize it as a focal species, according to the criterion we employed.

Among birds, we found that vegetation structure alone could distinguish nearly all focal from non-focal resident species (Table 23). The focal species all prefer wooded areas -- some favoring areas with extensive tree canopy and others favoring areas with shrubs or low canopy -- while the non-focal resident species almost all prefer open areas that are conducive to ground foraging. These non-focal resident species may also favor areas with nearby trees, however. Two of the non-focal resident species included in Table 23, *Dryocopus pileatus* (pileated woodpecker) and *Zenaida macroura* (mourning dove), and one species not included -- because it did not fit any of the categories -- *Picoides pubescens* (downy woodpecker), had a much greater discrepancy between the number of unmined and mined sites occupied than other non-focal birds, but the discrepancy was not large enough to recognize them as focal species, according to the criterion we employed. Three other non-focal resident species, *Chordeiles minor* (common nighthawk), *Sayornis phoebe* (eastern phoebe), and *Troglodytes aedon* (house wren), also were not included in Table 23 -- because they did not fit any of the categories. The first species has a very large foraging territory and hawks insects in the air, over both wooded and open areas, and the other two species have no particular preference for open areas. None of these three species demonstrates any particular preference for wooded areas, in contrast to all of the focal species.

Two interesting observations reinforce the importance of habitat structure in distinguishing focal from non-focal resident birds. The first observation concerns the distribution of these species in native Florida habitats. We thought that the native habitat most similar to

TABLE 23. Differences in habitat selection by focal and non-focal resident species. The few species that did not fit these categories are discussed in text.

FOCAL SPECIES	NON-FOCAL SPECIES
I BREEDING SITE	
Temporary Ponds	Permanent Bodies of Water
Bufo quercicus	*Bufo terrestris*
Eleutherodactylus p. planirostris	*Gastrophryne carolinensis*
Hyla femoralis	
Hyla squirella	
Scaphiopus h. holbrooki	
II BURROWING SUBSTRATE	
Sand with Litter	None
Cemophora c. coccinea	*Coluber constrictor*
Drymarchon corais couperi	*Masticophis flagellum*
Tantilla relicta neilli	
III VEGETATION COVER	
Canopy/Understory/Litter	Open
Anolis carolinensis	*Cnemidophorus sexlineatus*
Eumeces inexpectatus	*Blarina brevicauda*
Sceloporus undulatus	*Cryptotis parva*
Scincella laterale	*Peromyscus polionotus*
Apheloco}a coerulescens	*Sigmodon hispidus*
Caprimulgus carolinensis	*Colaptes auratus*
Cardinalis cardinalis	*Colinus virginianus*
Cyanocitta cristata	*Columbina passerina*
Dendroica pinus	*Dendroica coronata*
Melanerpes carolinus	*Dendroica palmarum*
Myiarchus crinitus	*Dryocopus pileatus*
Parula americana	*Mimus polyglottos*
Parus bicolor	*Toxostoma rufum*
Pipilo erythrophthalmus	*Zenaida macroura*
Polioptila caerulea	
Setophaga ruticilla	
Thryothorus ludovicianus	
Vireo griseus	
IV OTHER HABITAT ELEMENTS:	
(Gopher Tortoise) Burrows	
*Podomys floridanus**	

* This species was found at two mined sites and both sites had tortoise burrows

reclaimed mined sites was dry prairie, and we looked at records of the distribution of the bird species we observed at our unmined and mined sites in this habitat (Kale and Maehr 1990; also see Layne et al. 1977). We found that 17 of the non-focal resident species are residents of dry prairie, but none of the focal species are. The second observation concerns the distribution of bird species in other manipulated habitats. A previous study (Humphrey et al. 1985) documented differences in the relative abundances of birds in a biological preserve and in a nearby abandoned orange grove. The rank order of species based on difference in abundance between preserve and grove in this previous study is correlated strongly with the rank order of species based on difference in representation between unmined and mined sites in our study, for the 18 species held in common ($r_s = 0.62$, $p < 0.05$). Bird species that seem to be affected most strongly by habitat simplification from agricultural development also seem to be affected most strongly by habitat simplification from mining. Apparently, habitat simplification of many kinds can elicit similar responses from resident birds.

The Importance of Habitat Structure

We compared the rankings of the representation of focal species for each site with five physical variables associated with each site, size, distance to seasonal water, distance to permanent water, distance to upland habitats, and presence/absence of cattle grazing. We made the comparisons separately for quadrupeds and birds, and for unmined and mined sites. [Note that correlations could obtain for either the sites score, which takes only presence/absence into account, or the adjusted sites score, which takes relative abundance into account, or for both.] Large unmined sites tended to rank higher than small unmined sites, both for quadrupeds and birds (M-W U-test, $p < 0.10$). Small mined sites tended to rank higher than large mined sites, but only for quadrupeds. No relationships were found for distance from seasonal water or for distance from permanent water. We note, however, that a moderate tendency was found for unmined sites near permanent water to rank higher than unmined sites far from permanent water, for quadrupeds (M-W U, $p = 0.12$). Unmined sites near other upland habitats tended to rank higher than unmined sites far from other upland habitats, both for quadrupeds and birds. Ungrazed unmined sites tended to rank higher than grazed unmined sites, for birds. Explanations for these relationships are reasonably clear, and most were to be expected from previous ecological research. Unmined sites generally had higher ranks in representation of focal species if they were large and/or near sources of potential colonists (see, for example, McCoy and Mushinsky 1994). Because size and distance to other upland habitats were not independent for the set of unmined sites that we employed, the individual effects of these two variables cannot be distinguished. Unmined sites also generally had higher ranks -- albeit, only moderately so -- in representation of quadrupedal focal species if they were near permanent water (see, for example McCoy and Mushinsky 1994). Finally, unmined sites had higher ranks in representation of focal bird species if they were ungrazed. This result apparently reinforces our previous conclusion that grazing is able to affect the resident fauna, either directly or indirectly, through alteration of the vegetation structure.

tailings (ST) or overburden (OB) alone. For birds, sites with woody revegetation (RW) tended to rank higher than sites with herbaceous revegetation (RH). That substrate should be particularly important to quadrupeds and canopy vegetation particularly important to birds was to be expected from our previous analysis of natural histories (Table 23) and correlations with vegetation variables.

We asked the question: If we chose only the "best" unmined or mined sites, as indicated by representation of focal species, what physical and vegetation variables then would correlate most strongly with rankings of representation? In other words, this procedure should reveal reasons for a second level of habitat choice by the focal species, a level nested within the group of sites already chosen by them for other reasons. We again used Spearman's Rank Correlation Coefficient, with $p < 0.10$ for significance, to compare rankings. We selected the set of "best" unmined sites as the smallest set of sites, beginning with the highest ranking site in terms of representation of focal species, that cumulatively contained the entire collection of focal species. We selected the set of "best" mined sites as the set of sites that each contained at least one focal species. We made these choices independently for quadrupeds and for birds.

Among quadrupeds, ranking of representation of focal vertebrates at the "best" unmined sites ($n = 7$) was related positively to the relative amount of legume ground cover and relative representation of Shrub layer, and related negatively to total density of snags and total density of trees. We note that representation of focal quadrupeds at the "best" unmined sites also was related positively to vertical canopy closure, at a height of 0-2m. Based on our previous analyses of vegetation variables, these relationships indicate the following.

- **Presence of cover at a height relevant to ground-dwelling focal quadrupeds promotes their representation at the best unmined sites, and such cover is less abundant in the presence of relatively-high densities of trees.**

Among quadrupeds, ranking of representation of focal vertebrates at the "best" mined sites ($n = 19$) was related positively to the relative amount of woody ground cover, total density of snags, and total density of trees; and related negatively to the relative amount of legume cover. We note that representation of focal quadrupeds at the "best" mined sites also was related positively to vertical canopy closure, at a height of 0-4m. These relationships, which parallel those for unmined sites, indicate the following

- Presence of cover at a height relevant to ground-dwelling focal quadrupeds promotes their representation at the best mined sites, and such cover is more abundant in the presence of relatively extensive woody growth at all heights.

At mined sites, it is unlikely that trees will be dense enough to shade out ground cover, as they can be at unmined sites. The relationship between representation of focal quadrupeds and density of saw palmetto near the ground strongly reinforces this last suggestion. At the “best” unmined sites, saw palmetto at a height of 0-2m is related negatively to representation of focal quadrupeds, but at the “best” mined sites, it is related positively. Among birds, ranking of representation of focal vertebrates at the “best” unmined sites (n = 15) was related positively to density of *Pinus* spp. -- especially those 0-2m high. We note that representation of focal birds at the “best” unmined sites also was related positively to the relative amount of wiregrass ground cover, and related negatively to the density of moderately-tall saw palmetto and *Quercus* spp. Among birds, ranking of representation of focal birds at the “best” mined sites (n = 17) was related positively to the relative representation of ground layer, the density of saw palmetto, and the density of non-runner Quercus spp.; and negatively related to representation of Gap3. We note that representation of focal birds at the “best” mined sites also was related positively to vertical canopy closure, at a height of 0-2m, and the total density of trees, at a height of 0-2m. Finally, we note that, while representation of focal birds was not related strongly to represention of Upper-Canopy, it was related to the absolute size of Upper-Canopy. Based on our previous analyses of vegetation variables, all of these relationships suggest the following.

- Presence of cover at a height relevant to vegetation dwelling focal birds promotes their representation at the best unmined sites, but such cover may become too dense, reducing the numbers of individuals of focal bird species or even eliminating them.

- Presence of cover at a height relevant to vegetation dwelling focal birds promotes their representation at the best mined sites, and such cover is rarely -- or never -- too dense, and focal bird species generally respond positively to increased cover.

Our conclusion about the differential importance of cover at the best unmined and mined sites is reinforced by the fact that ranking of representation of focal birds at the best mined sites was related negatively to time since initial reclamation. Our previous findings indicated that older reclaimed sites tended to have increased representation of Upper-Canopy, and that such sites tended to have relatively-poor representations of other, lower, layers.

Quality of Sites as Indicated by Individual Focal Species

We used the site score, which takes only presence/absence into account, and the adjusted sites score, which takes relative abundance into account, for each focal species (Table 15) to examine habitat choice more closely. We did this by comparing the physical and vegetation variables of sites where a particular species occurred with those variables at sites where it did not, for each of the 28 focal species. The results are listed in four tables, one concerning the physical variables, one concerning the vegetation variables relating to life-form coverage, one concerning the vegetation variables relating to foliage layers, and one concerning the vegetation variables relating to density.

The results for the physical variables (Table 24) show that large size of unmined sites is important for several species, but that small size of mined sites is important for several other species. The second relationship probably is spurious, however, indicating once again that it is the smaller mined sites that have undergone the reclamation procedures most relevant to the focal species. The results also show that nearness to other populations on uplands is important for several species. Finally, the results show that grazing is important for several species, in a positive way for quadrupeds and a negative way for birds, at unmined sites. Strangely, grazing seems to be important in a positive way for a few species of birds, at mined sites. Clearly, as we have noted previously, the effects of grazing need to be examined much more carefully. No other physical variables were related very generally to habitat choice.

The results for life-form coverage (Table 25) show that relatively-large amounts of woody vegetation is important for many species, especially at mined sites. The results also show that relative amounts of bare ground and litter are important, but sometimes in a positive way and sometimes in a negative way. Unmined sites relatively-rich in a category of life-form coverage not included in the table, forbs, apparently were avoided by many species. We suggest, based on our field observations, that this category is a “disturbance indicator,” and that sites relatively-rich in forbs may have been grazed, or logged, or otherwise disturbed.

The results for foliage layers (Table 26) and density (Table 27) are complex, but they clearly show the general value of a relatively well-developed and multi-layered canopy. The additional comments -- based mostly on canopy density measurements -- that we have included in Table 26 reinforce this conclusion.

TABLE 24. Individual focal species' responses to physical variables. SZ = size, SW = distance to seasonal water, PW = distance to permanent water, UP = distance to upland, GR = grazing. S = small, L = large, N = near, F = far, G = grazed, NG = not grazed. Entries refer to unmined sites, unless otherwise specified.

SPECIES	PHYSICAL VARIABLE				
	SZ	SW	PW	UP	GR
Eumeces inexpectatus					
MINED	*S*				
Gopherus polyphemus					
MINED				*N*	
Hyla squirella					G
Sceloporus u. undulatus	L			N	
Bufo quercicus					G
Scaphiopus h. holbrooki					
MINED					
Hyla femoralis					
Drymarchon corais couperi					
Scincella laterale					
MINED		*F*			
Eleutherodactylus p. planirostris		F			
MINED	*S*				
Podomys floridanus	L			N	
Tantilla relicta neilli					
Cemophora c. coccinea		N			
MINED	*S*				
Anolis c. carolinensis					
Thryothorus ludovicianus					
Vireo griseus				N	
Parus bicolor	L			N	
Myiarchus crinitus			N	N	
Cardinalis cardinalis					NG
MINED	*S*		*F*		
Aphelocoma coerulescens					
Caprimulgus carolinensis					NG
Parula americana					
Dendroica pinus			N		
Setophaga ruticilla					
Pipilo erythrophthalmus					
MINED					*G*
Cyanocitta cristata					NG
MINED					*G*
Polioptila caerulea					
MINED					*G*
Melanerpes carolinus					

TABLE 25. Individual focal species' responses to life-form categories. OG = grasses, WD = woody vegetation, LE = legumes, LT = litter, BG = bare ground. H = prefers high values, L = prefers low values. Entries refer to unmined sites, unless otherwise specified.

SPECIES	LIFE-FORM CATEGORY				
	OG	WD	LE	LT	BG
Eumeces inexpectatus					H
MINED		*H*			
Gopherus polyphemus					
Hyla squirella					H
Sceloporus u. undulatus					
Bufo quercicus					
MINED		*H*			
Scaphiopus h. holbrooki					L
MINED	*H*				
Hyla femoralis					
Drymarchon corais couperi					
Scincella laterale				H	L
Eleutherodactylus p. planirostris					
MINED		*H*			
Podomys floridanus					L
MINED		*H*			
Tantilla relicta neilli					
Cemophora c. coccinea					
Anolis c. carolinensis					
Thryothorus ludovicianus					
Vireo griseus					
Parus bicolor					
Myiarchus crinitus			H		
Cardinalis cardinalis				H	L
MINED		*H*			
Aphelocoma coerulescens			L	L	H
Caprimulgus carolinensis					
Parula americana			H		
Dendroica pinus	H		H	L	
Setophaga ruticilla	L				
Pipilo erythrophthalmus					
MINED		*H*			
Cyanocitta cristata		H			
Polioptila caerulea					
MINED		*H*			
Melanerpes carolinus	H				

TABLE 26. Individual focal species' responses to foliage layers. Categories are the same as in Table 10. H = prefers high values, L = prefers low values. Entries refer to unmined sites, unless otherwise specified. Comments reflect mostly canopy density measurements.

SPECIES	FOLIAGE LAYER							COMMENT(S)
	GRD	GAP1	SHB	GAP2	MID	GAP3	UPR	
Eumeces inexpectatus			L					1
MINED			*L*					*2*
Gopherus polyphemus								
Hyla squirella						L		3
Sceloporus u. undulatus	L				H		L	4
Bufo quercicus	H							
MINED						*H*		
Scaphiopus h. holbrooki								
MINED		*H*						
Hyla femoralis				H				
Drymarchon corais couperi						L		
Scincella laterale	L							1
MINED						*H*		
Eleutherodactylus p. planirostris								5
MINED	*L*	*H*					*H*	*6*
Podomys floridanus								7
Tantilla relicta neilli								
Cemophora c. coccinea								
MINED							*L*	
Anolis c. carolinensis						L		
MINED							*L*	
Thryothorus ludovicianus	L				H	L		
Vireo griseus	L							
Parus bicolor	L		L		H			
Myiarchus crinitus				H				
Cardinalis cardinalis	L						H	8
MINED							*H*	*8*
Aphelocoma c. coerulescens	H		H			L		9
Caprimulgus carolinensis								10
Parula americana			L	L				11
Dendroica pinus								12, 13
Setophaga ruticilla	L				H			
Pipilo erythrophthalmus				L		H		5
Cyanocitta cristata				L				
MINED	*L*						*H*	*6*
Polioptila caerulea								
MINED						*H*		
Melanerpes carolinus								10, 4
MINED						*H*		*1*

1 = Dense upper canopy
2 = Trees, in general
3 = Sparse low vegetation
4 = Dense middle canopy
5 = Dense low vegetation
6 = Dense middle-upper canopy
7 = Sparse middle canopy
8 = Dense vegetation, in general
9 = Sparse canopy
10 = Large upper canopy layer
11 = Large middle-upper canopy layers
12 = Large ground layer
13 = Small middle canopy layer

TABLE 27. Individual focal species' responses to density of trees, saw palmetto, and snags. SP = saw palmetto, SN = snags, PI = *Pinus* spp., QU = *Quercus* spp., OT = other trees. H = prefers high values, L = prefers low values. Entries refer to unmined sites, unless otherwise specified. Comments refer to the catgories with asterisks, and delimit them.

SPECIES	DENSITY					COMMENTS
	SP	SN	PI	QU	OT	
Eumeces inexpectatus				H*		tall QU
Gopherus polyphemus				L		
MINED				H*		med QU
Hyla squirella	L*			L		tall SP
Sceloporus u. undulatus			H			
Bufo quercicus		L		L		
MINED	H*			H*	H	sht SP, tall QU
Scaphiopus h. holbrooki	L*	H*		L*	L	med-tall SP, med QU, tall SN
MINED		H	H*	L*		tall PI, med QU
Hyla femoralis		H*			H*	tall SN, tall OT
Drymarchon corais couperi		L*			L*	tall SN, sht oaks
Scincella laterale	H*	H*		L*		med SP, tall SN, sht QU
Eleutherodactylus p. planirostris		H				
MINED	H*	H	H	H/L*		tall SP, H tall QU, L sht QU
Podomys floridanus	L*	H	H*	L*	L	sht SP, tall QU, tall PI
MINED	H*	H	H*	H*		sht SP, med PI, sht QU
Tantilla relicta neilli				H*		sht QU
Cemophora c. coccinea	H	H		L		
MINED			L	L	H	
Anolis c. carolinensis				L*		sht QU
MINED	H*				H	sht SP
Thryothorus ludovicianus			H			
Vireo griseus						
Parus bicolor			H			
Myiarchus crinitus			H*	L*		sht PI, tall QU
Cardinalis cardinalis				H		
MINED	H*	H				tall SP
Aphelocoma coerulescens	H*	L		H*		tall SP, med QU
Caprimulgus carolinensis		H*	H	H*		tall SN, sht QU
Parula americana		H*	H*			tall SN, sht PI
Dendroica pinus				L*		tall QU
Setophaga ruticilla	H*	H	H*	H		med-tall SP, med PI
Pipilo erythrophthalmus				L		
MINED	H		L	H		
Cyanocitta cristata	H		H*	H		tall PI
MINED			H*	H/L*		tall PI, H sht QU, L tall QU
Polioptila caerulea				H	H	
MINED	H*			H/L*	H	tall SP, H sht QU, L tall QU
Melanerpes carolinus		H*		L*		tall SN, tall QU
MINED				H*		med QU

RECOMMENDATIONS

The recommendations are divided into two sections. The recommendations in the first section are the most important, in our estimation; the remaining ones may well be irrelevant to the rehabilitation process if the first five are not followed. The recommendations in the second section focus on necessary attributes of the habitat structure of rehabilitated lands. A third section address issues that, while important, were not salient components of our research, and, therefore, they are couched as speculations.

SECTION 1: Key Recommendations

- Rehabilitated habitat patches should be large. Large habitat patches support a greater representation of vertebrate species than smaller patches. Large patches also may facilitate the incorporation and management of relatively-large scale habitat heterogeneity, so that a variety of vertebrate species, with different habitat requirements may be accommodated. [Although we separated large from small patches at 25ha in our study, based on our prior experience with upland habitats and the availability of study sites, we have no empirical data to suggest that 25ha is large enough to support a viable population of any of the resident vertebrate species.]

- Rehabilitated habitat patches should not be isolated. Habitat patches relatively-near upland habitats support a greater representation of vertebrate species than patches relatively-far from upland habitats. [We separated near from far patches at 300m, again based on our prior experience with upland habitats and the availability of study sites, but, although we believe that a distance of 300m between patches is enough to isolate populations of many resident vertebrate species, the degree of isolation depends greatly on the types of habitats between patches, the condition of the substrate between patches, and many other factors.]

- Rehabilitation efforts should be coordinated with existing conservation and management plans. Coordination will help to increase the effective size of the rehabilitated habitat patches and to decrease their isolation.

- Within parts of central Florida, especially in Polk County, a broad, regional approach to rehabilitation and conservation should be undertaken. A regional approach will promote restoration and subsequent maintenance of a regional vertebrate species pool that is adequate for recolonization of rehabilitated habitat patches.

- The various groups actively involved in rehabilitation of previously-mined lands should share information, to ensure that successes are repeated and failures are not. The data gathered during each project should be reported in some standard way and stored in some readily-accessible central location (e.g, the library of The Florida Institute of Phosphate Research).

SECTION 2: Secondary Recommendations

- Rehabilitated habitat patches should have woody vegetation near ground level and a well-developed litter layer. Patches with these structural features support a greater representation of vertebrate species than patches without them.

- Rehabilitated habitat patches should have relatively-tall vegetation, overall, with a well-developed Middle-Canopy layer. Patches with these structural features also support a greater representation of vertebrate species than patches without them.

- Rehabilitated habitat patches should have a heterogeneous ground cover. Patches that have a variety of ground structures support a greater representation of vertebrate species than patches that do not.

- Rehabilitated habitat patches should have a relatively-even distribution of foliage among all canopy layers, from ground level to upper canopy. A variety of foliage layers, like a variety of ground structures, is beneficial for vertebrate species.

- Rehabilitated habitat patches should have a diversity of plants. Vertebrate species do not respond in the same way to all tree species or to size classes within species.

- Rehabilitated habitat patches should not be used for intense pasturing of cattle. Although we did not study its effects directly, grazing -- at its current intensity -- does not appear to be beneficial to the vegetation or to many species of vertebrates. The goal of habitat rehabilitation may not accommodate the joint goal of profitable leasing for cattle pasturing, especially if the intensity of grazing is not regulated carefully.

SECTION 3: Speculations

- Habitat rehabilitation may be improved by paying closer attention to the importance of soil texture, compaction, and chemistry in influencing the vegetation, and, in turn, the vertebrates. Although we did not draw a direct connection between soils and vegetation, soils replaced after mining are so different than the original soils that we infer that such an effect exists. If the soil in a rehabilitated habitat patch cannot support the breadth of plant species found in upland habitats, then most certainly, not very many of the vertebrates resident in those habitats will recolonize the patch.

- Habitat rehabilitation also may be improved by paying closer attention to the importance of soil microflora and microfauna in influencing the vegetation. Topsoiling could provide an immediate inoculum of these organisms at rehabilitated sites, and its value as a rehabilitation technique should be explored further.

- Habitat rehabilitation may be improved by a better understanding of the process of succession -- replacement of plant and animal species at a site over time -- in upland habitats. The important structural elements that we have described may develop gradually over time, but such development may require well-planned initial revegetation and well-informed subsequent management practices. Use of "indicator species" -- perhaps key invertebrates, like ants and springtails -- potentially could be used to track and adjust the course of succession. Comparison of the development of plant assemblages on mined lands with upland habitats that have been cleared, but not mined, potentially could suggest whether or not the mining process itself affects the course of succession.

- Habitat rehabilitation that ultimately will mimic upland habitats in terms of both plants and animals will probably take decades, at least. The regional vertebrate species pool of central Florida is unlikely to be intact by then. Initial plantings of fast-growing shrubs and trees may be used to "rescue" the vertebrate fauna until slow-growing sandhill, scrub, and scrubby flatwoods plants can be established. These plantings could employ native plants, such as slash pine, live oak, wax myrtle, and saltbush, or perhaps even non-native, but non-invasive, plants. Not all vertebrate species are likely to respond positively to unusual groupings of plants, however. Our results indicate that some species do not respond in the same way to all tree species or to size classes within species, for example. Habitat rehabilitation may be improved by a better understanding of the habitat requirements of individual vertebrate species.

In the **INTRODUCTION,** we listed the problems, solutions, and products of the research project. We have provided the two products that we promised: (1) lists of the relative abundances of vertebrate species at our study sites and (2) lists of the physical variables correlated with the presence/absence of focal species at our study sites. In addition, we have provided much additional information about the vertebrates and their habitats. We suggest that it is now important to establish cause-and-effect relationships between physical variables and the responses of vertebrates, through a set of well-conceived, manipulative experiments. The goal of these experiments should be to help the industry demonstrate successful rehabilitation of previously-mined lands for focal vertebrate species, by providing it with the tools necessary to establish these species on rehabilitated lands.

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