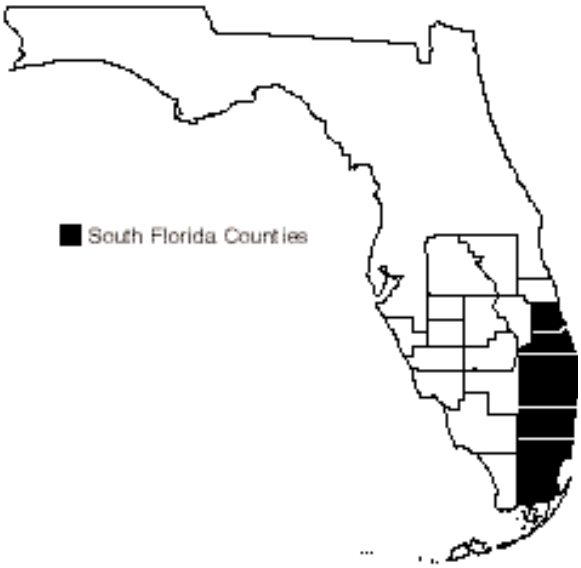
Tiny Polygala

Polygala smallii Smith and Ward

Federal Status:	**Endangered (July 18, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the tiny polygala.



Polygala smallii is in the family Polygalaceae, commonly referred to as the milkworts. It was once thought to be endemic to Miami-Dade and Broward counties, but recent surveys have extended its range to southern St. Lucie County. All 11 known populations are found within 9.7 km of the Atlantic Coast. The tiny polygala or Small's milkwort is a short-lived herb. The only known populations occur in sand pockets of pine rocklands, open sand pine scrub, slash pine, high pine, and well-drained coastal spoil. Within these habitats, it requires high light levels and open sand with little to no organic litter accumulation. The survival and recovery of *Polygala smallii* is threatened by habitat loss from urban development, fire suppression, and exotic plant infestation.

This account represents a revision of the existing recovery plan for the tiny polygala (FWS 1988).

Description

Tiny polygala is an erect short-lived herbaceous species. Most plants germinate and die within one year. It forms a rosette and grows no more than 8 cm tall (Kennedy 1998). It has one to four, short, usually unbranched stems, and a well-developed, scented taproot. Its leaves are oblanceolate to lanceolate, from 1.5 to 5 cm long and 0.2 to 1.4 cm broad and occur in a basal rosette. The inflorescence is a cylindric raceme from 0.4 to 7 cm long and 0.5 to 1.8 cm thick and usually surpassed by the basal leaves (Kennedy 1998) The flowers have both functional stamens and pistils (perfect) and are not radially symmetrical (zygomorphic). The calyx has five sepals. The lateral pair is decurrent, large and petaloid. The corolla is a greenish-yellow color with three petals. The fruit is a thin-walled, two-celled capsule that splits down the center of the compartment. The seed is 1.2 to 1.4 mm long, with sparse rather short, stiff, appressed hairs (strigose). It also has a pair of aril-like outgrowths about half the length of the capsule (Gann and Bradley 1995, Smith and Ward 1976).

Taxonomy

J.K. Small first described tiny polygala as *Polygala arenicola* (Small 1905; type specimen at New York Botanical Garden, Small #1276). The specific epithet was later found to be invalid due to its prior use in 1903 by Gurke in describing another species of *Polygala* from southeast Africa (Smith and Ward 1976). In 1933, Small revived the segregate genus *Pilostaxis* Raf., and renamed tiny polygala *Pilostaxis arenicola* (Small) Small. The genus *Pilostaxis* has since fallen out of use, but represents the series *Decurrentes*, a natural group of seven species of *Polygala* found only in the southeastern U.S. (Smith and Ward 1976). Long and Lakela (1971) considered tiny polygala to be conspecific with *Polygala nana* (Michx.) DC., a species widely distributed in the southeastern U.S., but in 1976, Smith and Ward defended the specific status of tiny polygala, recognizing distinct characters of the seeds, lateral sepals, flower color, and leaves, and proposed *Polygala smallii* Smith and Ward as a nomen novum.

Synonyms: *Polygala arenicola* Small, non Gurke; *Pilostaxis arenicola* (Small) Small; *Polygala nana* auct., non (Michx.) DC.

Distribution

Prior to 1995 *P. smallii* was thought to be a local endemic of pine rocklands and scrub in Miami-Dade and Broward counties, Florida (Smith and Ward 1976, Austin, *et al*. 1980). Extensive surveys conducted in 1995 by Gann and Bradley expanded the known range of tiny polygala to the north. It is now known to occur on the Atlantic Coastal Ridge of southeast Florida, from the Perrine area of Miami-Dade County north to southeast St. Lucie County (Figure 1). In some populations in Palm Beach and Martin counties, *P. smallii* co-occurs with its closest congener, *P. nana*. *P*olygala *nana* does not occur south of Broward County (S. Kennedy, Florida International University 1999). The historic distribution of tiny polygala to the north is uncertain; it possibly ranged as far north as central Brevard County (derived from E. Palmer, s.n., 1874, labeled “Indian River,” New York Botanical Garden Herbarium).

Habitat

Tiny polygala occurs in four distinct habitats with similar characteristics: pine rockland, scrub, high pine, and open coastal spoil (Gann and Bradley 1995). All of these habitats are pyrogenic-extremely dry and prone to periodic natural fire. Pine rocklands historically burned every 2 to 15 years (Snyder *et al*. 1991). Sand pine scrub and sandhill burn less frequently, possibly every 10 to 50 years.

Miami-Dade County populations of tiny polygala occupy sand deposits within the pine rocklands that are primarily in the southern portion of the county. The depth of the sand deposits ranges from 2 mm to greater than 90 cm (Kennedy 1998). The sand deposits are interspersed throughout the pine rockland’s Opalocka Rock Outcrop soil complex. No plants were found in soil shallower than 2.0 cm. *Polygala smallii* occurs in areas with significantly shallower litter deposits than the surrounding pine rockland habitat. No plants

Tiny polygala.
Original photograph by Deborah Duval.

occurred in litter deeper than 2.5 cm (DERM 1996, Kennedy 1998).

The overstory canopy of the Miami-Dade County population is composed of South Florida slash pine (*Pinus elliottii* var. *densa*), several species of oaks, (*Quercus pumila*, *Q. minima*, *Q. virginiana)*, and tallow-wood (*Ximenia americana).*

The Broward County population occurs in sand pine scrub which regenerated following clearing in the late 1970s. The soils are St. Lucie fine sand, at an elevation of 2.8 m, and have little to no slope. The tree canopy is composed of sand pine (*Pinus clausa*) with a shrub understory of rosemary, scrub live oak (*Quercus geminata*), myrtle oak (*Quercus myrtifolia*), Chapman oak (*Quercus chapmanii*), and dwarf cabbage palm (*Sabal etonia*). Commonly associated herbs and graminoids include: *Paspalum graminifolia, Selaginella arenicola, Rhynchosopora megalocarpa,* and *Licanis michauxii.* Deer moss and soldier moss (*Cladonia* spp. and *Cladina* spp.) are also common groundcover components (Gann and Bradley 1995).

The Palm Beach County population occurs in a scrubby flatwoods association that became established on spoil dredged from the intracoastal waterway prior to 1940. The spoil is relatively well-drained Quartzipsamments, with an elevation of 1.2 m and little to no slope. The tree canopy is dominated by sand live oak (*Quercus geminata*), tallow wood (*Ximenia americana*), sand pine, and slash pine. Other common species include myrtle oak, cocoaplum, saw palmetto, silk grass (*Paspalum graminifolia*), partridge pea (*Chamaecrista fasciculata*), and *Dichanthelium portoricense* (Gann and Bradley 1995).

One Martin County population occurs in turkey oak sandhill with Pomello sand, at an elevation of 1.2 m. The tree canopy is composed of South Florida slash pine and turkey oak with a shrub understory of dwarf live oak, Chapman oak, and myrtle oak. Some of the associated herbs and graminoids are: *P. nana*,

Rhynchospora plumosa, Aristida beyrichiana, Eriocaulon ravenelii, Liatris chapmanii, and *Satureja rigida.* The second Martin County population is on a disturbed north-facing slope of Paola Sand between a sand pine scrub association and a lake. The canopy is composed of a mix of South Florida slash pine and sand pine with no shrub layer. The herb layer is depauperate, composed mostly of silk grass.

The St. Lucie County population occurs on a scrubby flatwoods knoll in Hobe Sand soils. Site elevation is 2.0 to 3.0 m and gently slopes to a mesic flatwoods and marsh area. Canopy trees include sand pine, slash pine, and scrub live oak. Other members of this vegetative community include: saw palmetto, staggerbush, myrtle oak, wiregrass (*Aristida beyrichiana*), silk grass, and wireweed (*Polygonella gracilis*) (Gann and Bradley 1995).

Reproduction

Tiny polygala seedlings can be observed from late October through April, but are most typically seen from December to February (DERM 1996). Populations in Miami-Dade County appear to have two germination periods, a short one in June and a longer one between September and January (Kennedy 1998). Thus, seedlings can be germinating for 6 months out of the year, resulting in plants maturing at different times of the year, and overlapping generations within years. In populations, flowers appear throughour the year with a peak during summer. Also, seeds are produced year-round.

Approximately one year following appearance of seedlings, plants show a marked reduction in condition, apparently allocating resources to flowering instead of growth or self-maintenance. By July, approximately 18 months after the first seedlings are observed, remaining plants senesce and die (DERM 1994).

Pollination in tiny polygala has not been observed in 2.5 years of monitoring (Kennedy 1998), or in 3 years of monthly life history monitoring (DERM 1994). Zomlefer (1991) reports that self-pollination may occur in species of *Polygala* which have a tuft of hairs on the sterile apical lobe of the stigma. These hairs catch pollen when the anthers dehisce, and, as the flower develops, these hairs may touch the receptive lobes of the stigma, transferring pollen. Tiny polygala has these hairs (Smith and Ward 1976) and may be self-pollinating.

Tiny polygala seeds have paired, fleshy outgrowths, a typical adaptation to ant dispersal. Oostermeijer (1989) reports that a similar species *Polygala vulgaris* L. is a specialist in ant dispersal. Also, ants have been observed carrying tiny polygala seeds to their nests on several occasions in Miami-Dade County (K. Bradley, Institute for Regional Conservation, personal communication 1996). The seeds have a bilobed aril attached to the caruncle. This bilobed aril was suggested by some to be an elaisome, a structure that contains lipids that are attractive to ants. Kennedy (1998) reports observing ants going into the flowers and removing and transporting seeds by the arils. After applying Sudan IV stain to the arils, she determined that they do not contain lipids; rather the arils appear to be hollow sacs. It is unclear why the ants are moving the seeds,

Polygala smallii seeds are able to float in water for extended periods (over three weeks) (Kennedy 1998). The hairs on the seed coat appear to provide most of the buoyancy by trapping air. Since many of the sites where tiny polygala occurs are riparian or riverine and the seeds are buoyant, water may be the primary means of dispersal.

After Hurricane Andrew, tiny polygala was found growing in areas where the soil was turned over or disturbed (*ie.* around uprooted fallen trees). A response to soil turnover may indicate a good seed bank. The seed banks probably occur in more habitat types than previously thought.

Relationship to Other Species

Tiny polygala likely has specific relationships to many species. Research on this species has not identified pollinators, or seed dispersers. Although ants have been observed to take seeds of this species back to their hills, the exact nature of the relationship between ants and this small herb is unknown. Hopefully, research needs outlined in this recovery plan will identify the interspecific relationships of this species and other members of this community.

Status and Trends

Until recently, tiny polygala was thought to be endemic to the pine rocklands and scrub of Miami-Dade and Broward counties, Florida (Smith and Ward 1976). However, new populations have been found in recent surveys by Gann and Bradley (1995) that have extended the range to the north about 21 km, and suggest this plant may occur in other vegetative communities.

The first known collection of *P. smallii* was made by Edward Palmer in 1874 (Herbarium of the New York Botanical Garden). The herbarium label reads "East Florida. Indian River." The Indian River extends from central Brevard County south to central Martin County. This collection was originally determined to be *P. nana* and later identified as *P. smallii* by C. Nauman. The next collections of *P. smallii* were made by A.P. Garber from "Miami" in 1877 (New York Botanical Garden and University of Florida herbaria). Additional collections in the Miami area were not made until 1903 (J.K. Small in Miami-Dade County "Between Coconut Grove and Cutler"). In November of 1903, Small collected tiny polygala in Broward County (New York Botanical Garden). Small made one more collection, from Miami-Dade County (New York Botanical Garden).

These collections show that Miami-Dade County populations once occurred from at least Arch Creek to the Cutler Ridge area. Assessment of the historical status of tiny polygala outside of Miami-Dade County is very difficult, since it was collected only two times before 1973, once in Fort Lauderdale and once at "Indian River." Upland habitats throughout its range along the Atlantic coast of peninsular Florida have been destroyed over such a large area, only a few scattered populations of this species remain.

Tiny polygala is currently known from 11 populations. Seven of these populations are on public land and are protected. Population sizes of tiny polygala can exhibit annual fluctuations as much as several hundred percent (season to season) (Gann and Bradley 1995, DERM 1994). Miami-Dade County DERM has

been monitoring six populations in Miami-Dade County for 3 years and has not found any clear population trends.

Although effects of burning on *P. smallii* have not been thoroughly investigated, pine rockland habitat must be burned periodically to maintain an open, sunlit environment and to reduce organic litter accumulations. Fire suppression allows hardwood succession and litter accumulation that will eventually overshade and eliminate shade-intolerant herbaceous species. Exotic plant invasion will also out-compete scrub community species, and will eventually eliminate the tiny polygala. In Miami-Dade County pine rocklands, Burma reed (*Neyraudia reynaudiana*) is the greatest threat. This grass is now present in almost every pine rockland fragment and is expanding rapidly. Burma reed is seriously threatening at least two of the Miami-Dade County populations. Other species, including Brazilian-pepper (*Schinus terebinthifolius*), earleaf acacia (*Acacia auriculaeformis*), and natal grass (*Rhynchelytrum repens*) are problems in upland habitats throughout the range of tiny polygala.

The publicly owned populations seem to be significantly threatened by direct human impacts, primarily due to heavy foot and bicycle traffic.

Management

Of the 11 tiny polygala populations, seven occur on public sites with active management. The four other populations occur on private property. Two of these four populations are being managed as preserves; one is designated for acquisition and development by the DOT, and one is designated for acquisition by the St. Lucie County land acquisition program.

The Palm Beach County population of the tiny polygala is protected in the 108 ha Jupiter Ridge Natural Area. This site is owned by the State of Florida (former CARL project) and leased to Palm Beach County for management. The management plan addresses the needs of the tiny polygala.

The Miami-Dade County Parks and Recreation Department is managing exotic plant infestations at two tiny polygala sites, including the removal of Burma reed and Brazilian pepper; however, a fire management program has not been fully implemented. A management plan is currently being developed for the third publicly-owned Miami-Dade County site. This management plan will include provisions for fire management and exotic plant removal.

One of the Martin County sandhill populations is being burned regularly and exotic plants are not threatening this population. The second Martin County population is not being managed, although the Florida Park Service is developing a management plan for this site.

The fire ecology of *P. smallii* is not well understood. Since it is a short-lived plant with a shallow root system, fire kills it, and it must return from the seed bank. Field observations at a site in Martin County found *P. smallii* seedlings germinating a few months after a wildfire. The storm surge of Hurricane Andrew in August 1992 washed over one population of tiny polygala in Miami-Dade County on the eastern edge of the Miami Rock Ridge very close to Biscayne Bay. This population increased from about three plants before the storm to a dozen the next year (DERM 1994).

The seed bank of *P. smalii* may be the key to survival for this species. It

has a very long-lived seed band; persistent seeds take over 1 year to germinate. Kennedy (1998) discovered that seeds buried in the soil within a natural population had an average viability rate of 80 percent after 2 years. Thus, the viability rate was nearly the same as the mean viability of fresh seeds. Because viability declined little in 2 years, *P. smallii* may remain viable for decades if buried under the soil surface.

P. smallii exhibits two kinds of dormancy in seeds: innate dormancy and conditional dormancy. Innate dormancy is the inability of fresh seeds to germinate within a few days. In *P. smallii*, it takes freshly produced seeds at least 2 to 3 weeks to overcome innate dormancy and then germinate, regardless of temperature. Seeds that become buried 1 cm or deeper become nondormant when primary dormancy is overcome after rippening. Then, during the winter, some of the buried seeds become conditionally dormant, meaning that they are viable, but will not germinate. In other species that have cycles of conditional dormancy/nondormancy, conditional dormancy prevents germination during unfavorable periods, and allows germination throughout the growing season. Seeds on the soil surface never express conditional dormancy; most germinate during September through January. Those surface seeds that fail to germinate during that period subsequently become inviable. Hopefully, the findings of Kennedy (1998) will encourage more research on seed biology studies and studies on how to stimulate seed bank recruitment in extirpated populations.

Because of the limited amount of habitat remaining for tiny polygala, continued management of the populations in public ownership will be necessary. Monitoring of all populations of tiny polygala is a necessary part of recovery and will tell us the effectiveness of the management practices. However, the natural fluctuations in population size from season to season will make it difficult to interpret the effect of management actions. Monitoring for tiny polygala should focus on the habitat, including the responses of other species to management actions, and the structural and compositional characteristics of other scrub-dependent species. Information collected from ongoing studies on the life history of tiny polygala will refine monitoring and management techniques.

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Recovery for the Tiny Polygala

Polygala smallii Smith and Ward

Recovery Objective: **PREVENT** extinction, then stabilize.

Recovery Criteria

Polygala smallii will, most likely, never reach a level at which reclassification could be possible. The objective of this recovery plan should be to increase existing populations and prevent extinction. *Polygala smallii* may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain pine rocklands and scrub flatwoods to support *P. smallii*. Monitoring programs should demonstrate that populations of *P. smallii* on these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Genetic information is of particular importance to the recovery of *P. smallii*, especially considering the recently identified populations in Martin and St. Lucie counties. Reclassification criteria may be developed if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. **Conduct surveys to determine distribution and status of *Polygala smallii*.** Pine rocklands have been thoroughly surveyed in Miami-Dade County. Additional surveys in the historic range of this plant should be performed in the scrub, sandhill, and open coastal spoil of Broward, Palm Beach, Martin, and St. Lucie counties. Fire eliminates litter concealing species, it may kill seeds in the litter or soil surface, or it may enable seeds in the seed bank to germinate. For that reason, suitable habitats which did not contain listed species when unmanaged should be resurveyed after fire events.

S2. **Protect and enhance existing populations.** It is imperative for the recovery of this species that populations not be lost.

S2.1. **Augment natural populations of *P. smallii*, where appropriate.** The known populations of *P. smallii* are in a precarious situation; therefore, *ex situ* collections of *P. smallii* should be established, if possible. These collections should be used to cultivate plants and augment sparse populations in protected areas. These experiments with reintroductions will be useful in the future, and could be essential

for the recovery of this species. Kennedy (1998) was able to germinate *P. smallii* seeds with high germination rates, and grow them through their entire life cycle *ex situ* at Fairchild Tropical Garden.

S2.1.1. Continue work with *ex situ* propagation and seed banks. Seeds should be banked for tiny polygala and should be identified precisely as to collection location.

S2.1.2. Continue to identify potential reintroduction sites and reintroduce plants, where appropriate. Sites identified as suitable for reintroduction, within the known historic range of this species should be surveyed and prepared to receive plants. Federal lands under proper management regimes may be good recipient sites. These sites should receive reintroduction stock.

S2.2. Enforce available protective legislation. State, Federal, and local regulations should be used to protect the pine rockland ecosystem and listed plants.

S2.2.1. Initiate section 7 consultation when applicable. Section 7 of the ESA applies to Federal activities which might impact listed species, especially on Federal lands.

S2.2.2. Encourage implementation of management plans. Federal agencies are obligated under section 7(a)(1) of the ESA to perform positive conservation programs for the benefit of listed species. Implementation of the Miami-Dade County's Richmond Pine Rocklands Management Plan (DERM 1994) constitutes such a positive conservation program. The Jupiter Ridge Natural Area Management Plan, prepared by Palm Beach County DERM, is another positive conservation program for this species (S. Farnsworth, Palm Beach County DERM, personal communication 1998). The FWS is available to meet with these agencies to discuss and assist in developing management plans for areas not under current management programs.

S2.2.3. Continue to enforce take prohibitions. *P. smallii* is protected by take and trade restrictions of the ESA and the Preservation of Native Flora Act.

S3. Collect biological information important to species recovery. Additional information on the ecology and life history of *P. smallii* plants needs to be collected.

S3.1. Determine population size and viability of all populations. Known populations of *P. smallii* should continue to be evaluated. Population viability needs to be investigated and determined for this species. This work has been initiated by Fairchild Tropical Garden for 2 populations in Miami-Dade County.

S3.2. Investigate the genetic relationship of distinct Polygala populations. Populations of *P. smallii* have been identified outside of Miami-Dade County. However, some researchers question the genetic relationship between these populations, since morphological characters alone were used to identify the populations. It is essential to identify their relationship since the plants appear to occur under somewhat similar habitat (dry, well-drained sites), although with different soil types.

S4. Develop standardized monitoring. Standardized monitoring needs to be developed for scrub

species in order to determine the effect of management actions on these species.

S4.1. **Collect existing and historical data, and place in a central location.** Contact former researchers for historical data, gather information from herbaria and museums, and contact all present researchers to compile data and place in GIS database in the South Florida Ecosystem Office. This location will allow all researchers access to both historic and current data and provide the FWS with a means to monitor the success of recovery tasks.

S4.2. **Convene a meeting of all researchers.** A meeting of current researchers and land managers would enable the FWS to locate information sources and begin the process of compiling those data. The meeting would also afford cooperators an opportunity to discuss monitoring and management procedures and set realistic species-level goals.

S4.3. **Monitor status and success of all populations**; **change management practices if so indicated.** Because of the varying vegetation conditions and fire histories, different management may be required at different scrub sites. Different prescribed burn intervals may be necessary for best results. Intervals should be adjusted over the years to promote pine re-establishment and hardwood reduction.

S4.4. **Monitor reintroduction success and modify procedures as necessary.** Plant reintroductions should be monitored to determine the success of the procedure. The goal of reintroduction should be to establish a viable population. Management of the reintroduction sites should be modified as necessary to improve results.

S5. **Continue to provide public information about scrub, sandhill, and open coastal spoil habitat and its unique flora.** Public support will increase the chances of recovery for these species. Informational and educational materials have been produced. DERM and Miami-Dade County Parks and Recreation Department's Natural Areas Management have developed flyers, displays, newsletters, and press releases for pine rockland habitats, and have held workshops with the general public. Organizations best able to carry out information and education programs include: Metropolitan Miami-Dade County Parks and Recreation Department, the Florida Native Plant Society, Everglades National Park, Miami-Dade County DERM, and Palm Beach County DERM Support of local press coverage should continue.

Habitat-level Recovery Actions

H1. **Continue to protect existing pine rockland, scrub, sandhill, and open coastal spoil plant habitats.** The decline of the five federally listed pine rockland plants in Miami-Dade County is due to the almost complete elimination or alteration of pine rocklands in South Florida. The coastal scrub, sandhill and open spoil habitats in Palm Beach, Martin, and St. Lucie counties are also undergoing extensive development. Without protection and proper management, the remaining scrub habitat will be developed or will deteriorate.

H1.1. **Protect pine rockland habitat.** Acquisition of remaining private sites may be the only effective way to protect or conserve pine rockland habitat. Miami-Dade County's Environmentally Endangered Lands program and the State of Florida's CARL program have acquired over 180 ha of pine rocklands in Miami-Dade County since 1990. The State of Florida's CARL program has also purchased sensitive scrub habitat in Palm Beach, Martin, and St. Lucie counties. It should be noted that public

lands may still be subject to development for recreational, maintenance, or other purposes. Such disturbances, unless carefully planned, may directly destroy preserved habitats and may secondarily result in exotic plant infestations as well as destructive human uses.

H1.2. Protect or acquire privately owned sites. Less-than-fee-simple acquisition should be used, where appropriate, as an alternative means of protecting scrub, sandhill, and open coastal spoil habitat. Covenants, as provided for under Miami-Dade County regulations, provide tax incentives for private landowners to protect pine rockland sites. A site owned by Florida Power and Light Company may be maintained through cooperation with that utility. Similar programs are being developed for Broward, Palm Beach, Martin, and St. Lucie counties.

H2. Restore areas to suitable habitat.

H2.1. Eliminate physical degradation of habitat and restore to optimal conditions. Physical degradation of scrub, sandhill, and open coastal spoil continues to occur. Hurricane Andrew in 1992 killed most of the adult pines in southern Miami-Dade County, excluding pine stands at Long Pine Key in Everglades NP. The continued degradation of these areas should be curtailed and restoration of uneven-aged pine stands undertaken. Tubelings, or direct seeding experiments may be used to accomplish this task. In order to use direct seeding techniques, collection of local pine seeds must continue.

H2.2. Develop best management practices for scrub, sandhill, and open coastal spoil. This would include development of fire management strategies that would benefit scrub, sandhill, and open coastal spoil species.

H2.2.1. Implement necessary management. Without active fire and exotic plant management, scrub, sandhill, and open coastal spoil will continue to disappear or degrade. Because of the highly fragmented and restricted nature of the remaining scrub, sandhill, and open coastal spoil, intensive management may be necessary at many of the remaining sites.

H2.2.2. Continue to conduct prescribed burns. Fire should be conducted at appropriate times of year to lower fuel loads, although growing season burns should be employed most often after fuel levels are under control. Due to the highly urbanized lands surrounding many of the remaining scrub, sandhill, and open coastal spoil sites, burning involves risks of smoke damage and annoyance, or worse, losing control of the fire. The Florida Division of Forestry has expertise in carrying out controlled burns in these habitats and can assist with burns. Fire management is necessary for all Federal and County scrub lands. Burning sites with *P. smallii* will take extra preparation and monitoring.

H.2.3. Implement additional management to meet habitat needs.

H2.3.1. Eliminate human-caused degradation. Preventing trash dumping or other destructive human activities in scrub, sandhill, and open coastal spoil habitats is important. In order to accomplish this task, fencing and access restrictions may be necessary.

H2.3.2. Control invasive plant species, particularly exotics. Burma reed,

Cogon grass (*Imperata cylindrica*) and persistent hardwoods need to be controlled and may require special techniques, including herbicide, fire, mechanical, and hand clearing at most sites. Other management needs indicated by ongoing research should also be implemented.

H3. Research additional habitat relationships.

H3.1. Continue to investigate and refine the habitat needs of P. smallii. The habitat needs of scrub species have been studied, but are still not completely understood. The pollination, germination, or other requirements of *P. smallii* have not been fully investigated. Research should address how light levels affect survival and how fire management affects light levels, reproduction, and regeneration of these species.

H3.2. Investigate fire history and incorporate into management strategies. Look at fire history for pine rocklands and scrub, sandhill, and open coastal spoil sites in Miami-Dade, Broward, Palm Beach, Martin, and St.Lucie counties, incorporate into GIS database and analyze relative to healthy populations. This exercise will provide adequate information on fire history and intervals in urbanized and non-urbanized settings and enable assessment of the appropriateness of proposed management regimes in each of the counties.

H4. Monitor sites with pine restoration programs to determine success. A monitoring protocol should be developed and implemented at these sites.

H5. Continue implementation of the fire education program and modify as necessary, any fire management education program that has been developed. Future modifications to this program may include tri-lingual distribution (Spanish, English, and Haitian Creole).