though several of these areas appeared to provide suitable vegetational and moisture requirements, they were all subject to a significant amount of disturbance. Ravines and natural drainage areas, sites often providing the most suitable habitat for the species, were often used as illegal dumping grounds and showed evidence of brush clearing and burning of woody species, and livestock grazing (Espey, Huston & Associates, 1990). Also noted was that the ridgetops in most of the areas surveyed had experienced vegetation clearing for the establishment of deer hunting corridors or for purposes of development (golf courses or houses) (Espey, Huston & Associates, 1990). Brush clearing extended to the edge of the slopes, in many cases. Importantly, at all sites surveyed which contained extant populations, observers (Espey, Huston & Associates, 1990) noted that herbivory appeared to play a major role in reducing the number of S. bracteatus plants that reached the flowering and/or fruiting stage during the 1990 season, thus lending further support to the belief that large numbers of unmanaged white-tailed deer pose a major threat to plants in this area.

The population at Garner State Park in Uvalde County was described by Poole (Poole et al., 1987c) as being a large population of excellent quality. Though much of the habitat was degraded in the recent past, it was described as recovering. Fortunately, the population is found in an area that is not normally used by visitors, and should be relatively easy to defend.

The Mico East and Diversion Lake sites in Medina County were described as large, vigorous populations. As 1990 was a wet year, observers believed plentiful rains may have contributed to both abundance and healthy status of the plants. Plants at both sites, however, are in the right-of-way (although some were seen on adjacent private lands). This proximity to the roadside may render them vulnerable to road maintenance and/or future road-widening activities.

On the surface, it would appear that there still remains much available suitable habitat for this species in other areas of the Texas Hill Country. Past reconnaissance efforts have not, however, been successful in finding new localities. Finally, population dynamics and demographic trends in this species are poorly understood and many gaps exist in our present knowledge of the species. This makes it extremely difficult to tailor effective search and/or management strategies with confidence. Much needs to be learned about this plant. With increased knowledge, further refinement of the habitat profile will be possible, leading to an improved success rate in accurately predicting the whereabouts of the remaining occurrences. Because it will
take time to acquire additional important biological information on this species and to locate additional occurrences, the status of the plant should not be changed.

14. Recommended critical habitat: In order to avoid drawing undue attention to these easily accessible sites, no critical habitat is recommended at this time.

15. Conservation/recovery recommendations

A. General conservation recommendations:

1. Changes in present or anticipated activities: If possible, areas on Cat Mountain harboring Streptanthus bracteatus should be acquired, especially important is the north face of Cat Mountain and the watershed of the drainage at the base of the north slope (McNeal, 1989a). Any management plan for the area should address the problems of herbivory, encroachment of Ashe juniper and/or non-native species, the promotion and maintenance of a better vegetational structure, the securing of water quality and quantity entering sites, restriction of vehicular traffic through easily accessible routes (McNeal, 1989a). Though future residential development of Cat Mountain does not appear imminent, due perhaps to the general slow-down in development resulting from a sluggish Austin economy, it is vitally important to begin to protect these sites now (McNeal, 1989a).

Due to the size of the population and the immediate threat of destruction, the North Cat Mountain site should optimally be acquired as quickly as possible (McNeal, 1989a). This action would also secure the protection of the largest population of Amorpha roemerana, another category 2 species, which is located just below on Bull Creek (McNeal, 1989a). On North Cat Mountain, short-term protection of the species could be assured by halting all forms of home construction around plant locations. Important also is the modification of landscaping practices and elimination of trash and brush dumping that presently prevail on existing residential lots (McNeal, 1989a). Education of present homeowners about the special nature of the habitat of their homesite is also an important step, as enlisting their voluntary help in meeting the management goals is essential to their success (McNeal, 1989a). Other management priorities include
control of browsing animals, maintenance of the present vegetational structure, control of the quantity and quality of water reaching the site, discouragement of foot travel on the steeper slopes, and restricting the encroachment of non-native plant species (McNeal, 1989a).

Although the Barton Creek Greenbelt site is in good condition, there are areas where *S. bracteatus* is growing outside the limits of the greenbelt. Optimally, these areas should be acquired, if possible, including the watershed up to Loop 360 (McNeal, 1989a). Again, voluntary cooperation of the adjacent landowners should be enlisted so as to limit potential damage (McNeal, 1989a). Additionally, the City of Austin staff needs to be notified and educated about monitoring the site and implementing future management strategies (McNeal, 1989a). Special attention should be paid to the assessment of threats such as degradation of the vegetational structure, increased deer browsing, and the negative effects of construction activities above the site (McNeal, 1989a). Steps should be taken immediately when threats are detected.

The City of Austin staff is presently managing the Bee Creek Preserve in view of preserving *S. bracteatus* and its habitat. A portion of the area is currently a City of Austin utility right-of-way, however. Optimally, this portion should be relinquished to the Preserve, including a buffer zone (McNeal, 1989a). Additional information and materials on management of the species should be made available to the City preserve management staff (McNeal, 1989a).

Mount Bonnell has the second largest population of *S. bracteatus* in Travis County, and City of Austin Parks and Recreation Department staff should be notified immediately of the presence of the species in the park. Mount Bonnell is a small yet highly popular park in the Austin area. These two factors conspire to create a site subject to a tremendous amount of destruction due to unrestricted foot traffic. Significant also is the destruction of cover vegetation, resulting in severe erosion of the habitat. Location security would be recommendable at this site to ensure the plants' continued existence here. Park personnel should be instructed to carry out routine park operations in a manner that does not jeopardize
the plants (McNeal, 1989a). Stringent park rules should be implemented which would prohibit the collecting of plants and seeds or the picking of flowers (McNeal, 1989a). Signage should be posted in conspicuous areas and rules should be strictly enforced (McNeal, 1989a). High visibility of park officials and police is extremely important in this case. Where severe erosion has been a problem, barriers should be erected to reduce foot traffic (McNeal, 1989a). Should erosion have already occurred, revegetation using plant species native to the park should be initiated (McNeal, 1989a). Because of the vulnerability of this park site, plants should be closely monitored to detect potential threats before they become a problem.

Because *S. bracteatus* is a denizen of City of Austin property, city park planners, park managers, and park workers should be deeply involved in the management and monitoring programs designed for the species (McNeal, 1989a). They are in an excellent position to aid in tailoring practices for each park into their present operational framework (McNeal, 1989a).

The Parks Division of the Texas Parks and Wildlife Department should take the conservation and management of *Streptanthus bracteatus* into consideration during any phase of development of Garner State Park. Posting conspicuous signage prohibiting the collecting or picking of the species might help deter plant poachers. Again, high visibility of park rangers is essential. Fortunately, plants are found in a remote section of the park and visitors to the park rarely penetrate this area.

The Texas State Department of Highways and Public Transportation should be notified as to the presence of *S. bracteatus* along the side of the road to Mico in Medina County in the event future road widening activities are planned. Modification of roadside maintenance operations may also be necessary to protect plants close to the road. Where plants occur beyond the roadsides onto private property, landowners should be contacted and informed as to the presence of the plants on their property.

2. Areas recommended for protection: All occurrences of *Streptanthus bracteatus* which are not currently protected are recommended for protection (i.e.,
management agreements, conservation easements, etc.).

3. Management and recovery recommendations: In view of removing or at least minimizing the major threats to *Streptanthus bracteatus* and its habitat, several habitat management problems need to be addressed. Problems vary somewhat from site to site, though certain generalizations can be made; and to a certain extent each occurrence needs to be considered on an individual basis—some problems are general, some are site specific. At all urban sites where plants are threatened by construction activities, whether actually situated on private land or closely adjacent, efforts must be made to minimize negative impacts resulting from trash and brush dumping, unenlightened landscaping practices, pollution or modification of the quantity of water reaching sites, especially those sites located downslope. If land acquisition is not possible, cooperation with present homeowners may afford the best solution. By appealing to their pride in the natural beauty of their homesite and enlisting their support in the protection of elements of value on their property, some serious damage can be prevented. At most sites, almost without exception, herbivory has been cited as a serious problem. Control and management of white-tailed deer populations is essential. Practices such as feeding deer should be discouraged. Maintaining the integrity of the present vegetational structure, as well as prohibiting foot travel on the steeper slopes will do much to reduce the incidence of erosion. Where thick stands of Ashe juniper appear to be encroaching on plants, threatening to engulf or completely shade them out, judicious thinning or pruning should be carried out. Should non-native species be found on or near plant sites, they should be removed. Heavily eroded sites should be revegetated with plants native to the area. Population sizes and fluctuations should be closely tracked in view of trying to determine critical population levels necessary for this species to survive in the wild. Finally, it is important to monitor the various management measures to track their effectiveness so that improvements or alternate procedures can be devised, if necessary.

4. Publicity sensitivity: Relatively high. *Streptanthus bracteatus* has enormous aesthetic
appeal and would make a delightful accent plant in any garden. As the plant becomes more widely known, it may attract the attention of horticultural enthusiasts intent on commercializing on its beauty. Cultivated stock must be made available for commercial development before too much publicity about the plant ignites a flurry of clandestine overcollecting activities in the wild.

5. Other recommendations: Because of the potential threat from wildflower horticultural enthusiasts, it is recommended to set up one or more repositories for seed and cultivated plants with responsible individuals or recognized botanical gardens. This would help insure against catastrophic loss of the species, on the one hand, and would lay the foundation for augmentation management activities, should the need arise, on the other. Refining cultivation and propagation techniques is good insurance against chance extirpation and provides suitable stock for reintroduction into the wild.

B. Monitoring and further research activities:

1. Further searches for Streptanthus bracteatus should be initiated, as much seemingly suitable habitat exists in the Texas Hill Country. Exploring open juniper/oak woodlands, mesic slopes and river drainages in Williamson, Travis, Hays, Burnet Blanco, Gillespie, Kerr, Real, Uvalde, Bandera, Kendall, Bexar and Comal counties presenting similar soils, geology and habitat profiles needs to continue. Perhaps field surveys by boat or canoe up major river systems of the area might prove cost effective by covering greater areas of potential habitat more easily. Areas such as limestone gravel bars along streams could be searched, while steep, rocky, mesic limestone slopes and ravines could be marked on the map. Where roads intersect with the rivers, an easy access strategy could be planned. Curiously, despite searching by botanists from several agencies and universities, S. bracteatus has remained frustratingly elusive for the amount of time and effort put in. This may suggest that botanists need to be ever alert and willing to revise old ways of thinking and be ready to substitute alternate search strategies should new evidence be found to that effect.
2. Known populations in Travis, Medina and Uvalde counties should be visited at least annually to evaluate any demographic changes. Wide fluctuations in population numbers should be closely monitored. Data concerning the population biology should be recorded and information about overall reproductive success should be noted. Details as to size, population density and distribution on the site should be carefully recorded. Evidence of herbivory and insect infestation should be noted. Accurate tracking of the weather should be made with special attention being paid to the onset of spring and fall rains, length of drought periods (especially in the spring and fall), excessive summer heat, timing of first frost, changing soil temperatures, and episodes of flooding.

3. In-depth studies on the life history, demography, reproductive biology, and population ecology of Streptanthus bracteatus are crucial to our understanding of this species, as so little is known about the dynamics of its distribution. If resources permit, sites should be inventoried quantitatively several times during the growing season. Sites should be visited in early fall to establish timing of rosette initiation. Precise details of all aspects of phenology should be recorded. Tantamount to our understanding of the plant and what a viable population structure might be is the ability to begin to answer questions about why population sizes fluctuate so widely from year to year and from site to site. Some populations have even been observed as much as 450 feet from the location of the previous year (McNeal, 1989a). Such movement needs to be investigated further to determine if it is attributable to a mechanism of seed dispersal or to the storage of seed in the soil and/or random germination patterns (McNeal, 1989a). Care must be taken to insure that fluctuations observed are not merely an artifact of differences in observational techniques or size of area surveyed. Standardized modalities should be respected. If possible, seed bank samples should be taken from plots harboring plants and from plots of equal size nearby with similar habitat that are devoid of plants. Seed bank dynamics may be an important key to understanding this species. Finally, further refinement of the habitat profile must be done so that a more accurate prediction of "probable" habitat can be made, thus facilitating
the location of remaining occurrences (McNeal, 1989a).

Additional questions to be answered that might be of relevance to this species include:

a. Are the habitat requirements of S. bracteatus as we presently conceive them to be or has some crucial element been overlooked? What habitat does the plant prefer under optimal conditions? Is it heliophytic, preferring open woodlands where the ground is relatively free of dense shrubby vegetation, as suggested by Kral (pers. comm., 1990)? Does it find refuge from intense herbivory by growing under the protective cloak of overtopping shrubs, as suggested by McNeal (1989a)? What is its seral nature? Is it a colonizer of disturbance areas, petering out with the restoration of climax vegetation (Kral, pers. comm., 1990)? Is the species an example of a relict flora persisting with difficulty in changing moisture and temperature regimes, holding on in areas where moisture levels are slightly higher and excessive levels of heat are modified by mitigating microclimatic parameters?

b. What is the actual impact of grazing and browsing pressure on this species? Are rodents, rabbits, exotic game animals, goats or cattle implicated? Do increases in the white-tailed deer population and consequent rise in rates of herbivory on foliage, stems, infructescences and seeds compromise the plant's ability to produce enough seed for future survival? Are there other major sources of seed loss attributable to insect damage (Kral, pers. comm., 1990; Dieringer, 1989), inviability of seed due to inbreeding (Dieringer, 1989), improper timing and sequence of suitable triggering events such as onset of rains after critical soil temperatures are reached (McNeal, pers. comm., 1990)?
c. What other insects besides those observed during Dieringer's (1989) report, pollinate S. bracteatus? According to Dieringer (1989) some insects are more effective than others in pollinating the plant. What are the identities of the good versus bad pollinators? Are there any nectar robbers? Are known effective pollinators subject to adverse impacts (excessive predation, habitat alteration, etc.) which would effect their population numbers?

d. With respect to reproductive biology, although evidence suggests that S. bracteatus is primarily an outcrossing species, evidence of autogamy and self-compatibility were noted (Dieringer, 1989). How extensively are these alternate methods of reproduction resorted to? How much inbreeding goes on?

e. Practically nothing is known about seed dispersal, seed germination, seed viability and viable population structure, and these factors should be studied.

f. What is the importance of soil moisture levels, litter content, and climatic vicissitudes on establishment and early growth cycle of seedlings (McNeal, 1989a)?

g. What are the various impacts on Streptanthus bracteatus of adjacent residential development and construction activities, as well as other land-use practices such as brush clearing, trash dumping, diversion and pollution of water, etc.?

4. Studies should be implemented in population ecology.

a. It would be instructive to determine which species of insects feed on Streptanthus bracteatus or use it as a larval host plant, besides sulphur butterflies (Kral, pers. comm., 1990) and whether these constitute negative
interactions or not. What impact do aphids have on this plant (Dieringer, 1989) in other populations?

b. Are there any as yet undetected incidences of interspecific competition between S. bracteatus and other native or non-native plant species which share the same habitat?

16. Interested parties

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Division of Endangered Species
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Washington, D. C. 20240

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III. INFORMATION SOURCES

17. Sources of Information

A. Publications

1. References cited in report: See appended list.

2. Other pertinent publications: None known.

B. Museum collections:

1. The following herbaria were surveyed for specimens by Texas Natural Heritage Program personnel in 1984 (asterisks indicate herbaria where specimens were found):

   Texas A & M University, Tracy Herbarium (TAES)
   Texas A & M University, Department of Biology (TAMU)
   University of Texas at El Paso (UTEP)
   Howard Payne University, Brownwood (HPC)
   Pan American University, Edinburg (PAUH)
   San Angelo State University (SAT)
   Stephen F. Austin St. University (ASTC)
   *Southern Methodist University (SMU)
   South Plains College, Levelland (SPCT)
   Sul Ross State University (SRSU)
   Texas Southmost College, Brownsville
   *University of Texas at Austin (TEX, LL)

C. Fieldwork:

1. Dr. Robert Kral (Vanderbilt University) searched all sites indicated on specimens he received from various herbaria. However, he did not give site names and dates (Kral, pers. comm., 1990).

2. Site visits by Jackie M. Poole (Texas Natural Heritage Program):

   Texas, Travis Co.
   Cat Mountain: April 30, 1986; May 12, 1987; May 10, 1988
   Bee Creek Preserve: May 12, 1987; May 9, 1988
Mount Bonnell City Park: May 12, 1987; May 10, 1988
Cat Mountain North: May 9, 1988
Wild Basin: May 13, 1987
Emma Long City Park, cliffs and slopes above the river: May 13, 1987; May 10, 1988
Bull Creek Park: May 13, 1987
Devil's Canyon: May 9, 1988

Texas, Caldwell Co.
Lockhart South Roadside Park (roadside park about 6 miles south of Lockhart): May 14, 1987

Texas, Hays Co.
Blanco River (all public road crossings): May 14, 1987

Texas, Blanco Co.
Blanco River (all public road crossings): May 14, 1987

Texas, Kendall Co.
Blanco River (all public road crossings): May 14, 1987

Texas, Medina Co.
Medina Lake Diversion, along road to private picnic area below dam: May 11, 1988
Mico East, road east of Mico: May 11, 1988

Texas, Uvalde Co.
Garner State Park: May 20, 1987; May 11, 1988

3. Site visits by Bill Carr (Texas Natural Heritage Program):

Texas, Travis Co.
North Cat Mountain: April 30, 1982; May 25, 1988
Cat Mountain: April 30, 1983; April 30, 1986 (with Poole); May 25, 1988
Lime Creek Road: June 28, 1990 (with McNeal)
Johnson Road at junction of Hill Drive: June 28, 1990 (with McNeal)
Anderson Mill Road, 0.8 miles west from Oasis Bluff Road: June 28, 1989 (with McNeal)
Bullick Hollow: 175 m NW of RR 520, June 28, 1989 (with McNeal)
Texas, Medina Co.
Diversion Lake: April 1, 1990
Mico East: April 1, 1990 (with McNeal)

4. Site visits by Pat McNeal (Texas Natural Heritage Program):

Texas, Travis Co.
Cat Mountain: April 12, 1989; May 15, 1989
(with Westlund)
Bee Creek Preserve: April 19, 1989 (with Westlund)
Mount Bonnell City Park: April 17, 1989
Barton Creek Greenbelt: May 19, 1989
North Cat Mountain: April 10, 1989; April 26, 1989; May 8, 1989
Loop 360 and Lakewood Drive: April 21, 1989
Line Creek Road: June 28, 1990 (with Carr)
Johnson Road at junction of Hill Drive: June 28, 1990 (with Carr)
Anderson Mill Road, 0.8 miles west from Oasis Bluff Road: May 28, 1989; June 28, 1989
Bullick Hollow: 175 m NW of RR 620, June 28, 1989 (with Carr)
Lake Wood Drive, 30 m NE of Bull Creek low water crossing: May 3, 1989
Bull Creek District Park: April 16, 1989; April 28, 1989
Spicewood Springs Road south of Loop 360: April 16, 1989, April 28, 1989
Bull Creek Park, Bull Creek District Park, Barrow Preserve, and surrounding area: May 13, 1987; April 16, 1989; April 28, 1989; May 12, 1989; July 26, 1989
Devil's Canyon: May 9, 1988; spring 1989
Yaupon Bluffs, in Yaupon Bluffs residential development, including Long Hog Hollow, drainages and slopes along an unnamed tributary of Bull Creek, about 0.6 miles north of the intersection of Loop 360, and Spicewood Springs Road; April 16 and Sept. 16, 1989
Cypress Creek Park: April 16, 1989
Spicewood Springs City Park and vicinity: April 23, 1989
Mount Larson: spring 1989
Steep west-facing slopes, north of Mount Barker and south of Dry Creek: spring 1989
Radio Tower Hill, between Loop 360 and Toro Canyon Road: spring 1989

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Ridgetop and steep south-facing slopes above Lake Austin just west of Loop 360: spring 1989
Post Oak Ridge, west central slopes: spring 1989
Headwaters and west-facing slopes of West Bull Creek: spring 1989
Unnamed tributary of West Bull Creek, slopes and drainages south of RR 2222, approximately 2-3 miles southeast of the intersection with Highway 620: spring 1989
Steck Valley Park: spring 1989
Headwaters of Bullick Hollow: spring 1989
Slopes southeast of Sandy Creek Park: spring 1989
Lime Creek Road near Fisher Hollow: spring 1989
Johnson Road, slopes across the Sandy Creek arm from Jonestown: spring 1989
Barton Creek, from just west of the intersection of Loop 360 and Mo-Pac freeway upstream to the Lost Creek subdivision: spring 1989
Hamilton Pool Preserve: spring 1989
Cypress Creek, from confluence with Pedernales River to about one mile upstream: spring 1989

Texas, Medina Co.
Mico East: April 1, 1990
Medina Lake Diversion: April 1, 1990 (with Carr)

5. Site visits by Patsy Turner (of Espey, Huston & Associates, Inc.):

Texas, Travis Co.
Travis Peak, approximately 1 mile north of Travis Peak: April 17, 1990
Various slopes between Highway 620, FM 2769, and Anderson Mill Road: April 26, 27 and May 11, 1990
Slopes and drainages between Dry Creek and Mount Barker: April 17, 1990
Barton Creek, from Lost Creek Country Club, almost to Hebbingston Hollow (entire area not surveyed) to about 2 miles east of the intersection of Highway 71 and RR 2244: May 7, 8, 11, 15 and 25, 1990
Slopes and drainages between Steck Valley Park and Bull Creek Park and Mayfield Creek: May 9, 1990
Mid-Honey Creek drainage: May 11 and 15, 1990
St. Edwards land, west of Bull Creek and Spicewood Springs Road, about 1.5 miles northwest of the intersection of Loop 360 and Spicewood Springs Road: May 9, 1990
Slopes and drainage between Cat Mountain and North Cat Mountain: May 30, 1990
Northeast drainage of Cat Mountain: May 31, 1990

6. Site under observation by Gregg Dieringer during his 1989 study on the reproductive biology of *Streptanthus bracteatus* conducted from May 9 through July 2, 1989.

Texas, Travis Co.
North Cat Mountain, near Valburn Drive

D. Knowledgeable individuals

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E. Other information sources: Material on file at the Texas Natural Heritage Program

18. Summary of materials on file: Most citations and references available through the Texas Natural Heritage Program.

IV. AUTHORIZATION

19. Initial authorship: Noreen Damude and Jackie M. Poole, Texas Natural Heritage Program, Endangered Resources Branch, Resource Protection Division, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas  78744

20. Maintenance of status report: if listed, Office of Endangered Species, U. S. Fish and Wildlife Service; if not listed, Texas Natural Heritage Program
LITERATURE CITED


Carr, W. R. 1988. Letter to Jackie M. Poole regarding Streptanthus bracteatus locations in Austin. Texas Natural Heritage Program

Carr, W. R. 1990. Site survey of Mico East and Medina Lake Diversion in Medina County, Texas of May 1990. Texas Natural Heritage Program


Gray, A. 1850. Plantae Lindheimerianae: an account of a collection of plants made by F. Lindheimer in the western