TODSEN'S PENNYROYAL (*Hedeoma todsenii*)

Progress Report to U.S. Fish & Wildlife Service, Region 2
Section 6, Segment 23
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TAXON HISTORY

Todsen's pennyroyal was first collected by Tom Todsen and described by Irving (1979). The holotype specimen is at the New York Botanical Garden, with isotypes at the U.S. National Herbarium and the University of Texas. This may be one of the least collected species. A few additional collections by Spellenberg from the San Andres Mountains and by Howard, Sivinski and Dunmire from the Sacramento Mountains are located at the UNM and NMSU herbaria.

Todsen's pennyroyal was initially known from only two locations in the San Andres Mountains, Sierra County, New Mexico, on White Sands Missile Range. One site is located on a steep north facing hillside, 2 km south of Rhodes Canyon and the Hardin Ranch. The second site is also located on a north-facing slope several km from the first site. Dr. Richard Spellenberg and P. Hoban located an additional population of several 1000 stems in this area during the 1990 field season.

In 1988, a large population of *Hedeoma todsenii* was located by BLM biologist Mike Howard on Domingo Peak at the NW end of the Sacramento Mountains above Tularosa. This occurrence was the subject of an extensive field survey during August 1990 to determine the extent of Todsen's pennyroyal in this portion of the mountain range. The survey was a coordinated effort by personnel from The Nature Conservancy, NM Forestry Division, US Forest Service, Bureau of Land Management and the Alamogordo and Las Cruces Chapters of the NM Native Plant Society. A total of thirteen populations of Todsen's pennyroyal were located.

HABITAT AND DISTRIBUTION

Todsen's pennyroyal appears to be a relic species related to a contemporary species found in the Sierra Madre Mountains of Mexico. At one time its parent species may have extended throughout most of south-central New Mexico. The characteristics of this habitat include a substrate of gypseous soils of the Permian Yeso formation, as well as sheltered areas in mid piñon-juniper woodland with a north-facing aspect. The known range of this species consists of only two distinct areas. The first includes most of the northern portion of the San Andres in the Chalk Hills and Gyp Hills. The second area consists of the elevated gypsum substrates of the northern Sacramento Mountains east of Tularosa. The known and potential habitat for this species occurs on lands administered by the Department of Defense, Bureau of Land Management, Forest Service, Bureau of Indian Affairs and also private lands.

Field studies indicate that this species is confined to a very narrow microhabitat. Specifically, it requires sandy, gypsious soils and a northern facing, sheltered exposure. Greenhouse culture shows that Todsen's pennyroyal grows well in potting soil without the addition of calcium sulfate (Joyce

Maschinski, Arboretum at Flagstaff, pers. comm.). Therefore, its affinity to sandy, gypsum substrates may be the result of better soil structure and water holding capacity than the surrounding silty soils derived exclusively from limestone.

The vegetation at each locality suggests that particular microhabitats retain much more moisture than the surrounding hillsides. A good example of this is the large population in the unnamed canyon in T14S, R11E. The bottom of this canyon is a low elevation (6800 feet) refugium that supports a relictual stand of *Pinus ponderosa, Psuedostuga menzesii,* and many other montane species that typically occur at higher elevations. Other populations occur on generally north-facing slopes in much denser stands of *Pinus edulis, Juniperus monosperma* and *Cercocarpus montanus* than occur on drier exposures. It appears that the Todsen's pennyroyal is a relictual species, hanging on to small fragments of suitable habitat.

The San Andres and Sacramento Mountains have large tracts of gypsum substrate. However, the majority of the San Andres range is dominated by near desert conditions. During the last ice age (with life zones depressed between 2000-4000 feet) most of the San Andres range would have been suitable habitat. With the retreat of these life zones Todsen's pennyroyal would be forced to retreat into remaining fragments of its former habitat. There may well be other isolated populations scattered throughout the range.

POPULATION STUDIES

Hedeoma todsenii is a strongly rhizomatous species. Most of the known populations could conceivably be made up of a single individual plant cloning itself by vegetative reproduction from rhizomes. The rhizomes are often quite shallow extending out from the plant and form a near spider web pattern beneath the surface forming a patch of individual clumps of plants. In 1988 there was a tremendous boom of new plant stems at the paratype locality in the San Andres Mountains. Analysis of the 30 X 50 meter area in this location indicated at least 3000 clumps were present. These plants were regularly spaced across the hillside and nearly carpeted the slope.

The Sacramento Mountain populations of Todsen's pennyroyal usually cover larger areas than the San Andres populations. A more moist soil condition in the Sacramentos may explain this size difference since the Sacramento populations occur at a higher average elevation. Like the San Andres populations, the Sacramento plants usually occur in very dense patches. Plant density was estimated for two patches of Todsen's pennyroyal on Domingo Peak by using three 25 meter point-quarter transects through each patch. A small patch with an area of 30 X 70 meters had 3,300 clumps, and the larger patch of 50 X 150 meters had 66,000 clumps of plants. Therefore, the combined known locations of Todsen's pennyroyal in the Sacramento Mountains probably represent several hundred thousand to a few million plant clumps. However, the number of genetically distinct individuals would be significantly lower, because of this species' rhizomatous nature.

Six permanent study plots were established in October, 1991 in two unnamed canyons west of

Nogal Canyon and south of Mountain Lion Peak of the Sacramento Mountains and monitored each autumn until 1995 (Table 1.). Each plot was randomly established within a patch of Todsen's pennyroyal to document reproductive activities and any fluctuations in clump density. Each plot is a belt transect measuring 10 X 0.4 meters. The density of plants within these plots in 1991 varied from 12 - 41 clumps per square meter. Plant density was fairly consistent from 1991 to 1994, but showed a decrease of approximately 15% in 1995.

A subsequent effort to monitor these plots was undertaken in 2009. However, only four of the six plots could be relocated. The populations in these canyons appeared healthy and similar to the 1995 inspection. There had been no change in land use and no new threats were apparent.

REPRODUCTION

Rhizomatous, asexual recruitment appears to be the most common form of reproduction in Todsen's pennyroyal. Within each population there are numerous clusters of plant clumps that appear to be connected by rhizomes. The majority of these clumps do not attempt sexual reproduction on an annual basis. In fact, less than 20% of all clumps within Todsen's pennyroyal study plots were sexually reproductive during the late summer months of 1991 and 1992 (Table 1).

The Sacramento populations occasionally contain individuals within large groups the have bright yellow flowers rather than the typical reddish orange color. If this is not the result of somatic mutation, these unique plants would indicate at least some sexual recombination occurring within patches.

The most consistent flowering period of Todsen's pennyroyal coincides with the late summer rainy season of August through September. However, if spring and early summer precipitation is favorable, this plant will begin its low level of flowering in late June and continue to produce flowers throughout the summer months. Therefore, our studies that assess fruit production in the early autumn may miss some earlier reproductive attempts by this plant.

Todsen's pennyroyal flowers have a large reddish-orange corolla that should be attractive to many insects and to hummingbirds. After spending several days in the vicinity of these plants, we have not observed any insects or hummingbirds visiting the flowers. In fact there is presently only two sightings of a hummingbird feeding at Todsen's pennyroyal flowers (Dr. Huenneke and Eric Ulaszek, pers. comm.). The flowers are only 5 - 8 cm from the ground, which might present a difficult nectar source to a hovering hummingbird. Another problem is that there are very few hummingbirds in the area. The general lack of hummingbirds is probably related to the scarcity of other red flowered species. There are only a few red-flowered *Ipomopsis* and *Penstemon* scattered around Todsen's pennyroyal habitats. Without a sufficient abundance of the necessary red flowered species, hummingbirds are unlikely to stay in the area. This problem is confounded by the fact that only a few plants within a population are blooming at any point in time during the reproductive season. As a result it appears that one of the most important pollinators may be absent from the area.

This species has a very low level of seed set (Tables 1 and 2). Three hypotheses have been put forth that might explain this phenomenon. One is the general observation that pollinators are not present to affect pollen transfer between flowers as discussed above. Another is the possibility that this species has a high level of self incompatibility. Todsen's pennyroyal is strongly rhizomatous and adjacent plants within a patch may be incompatible genetic clones. Finally, this mostly asexually reproducing species may not need to greatly rely on reproduction through sexual means. This is suggested by the large number of flowers that produce no seed (Table 1) and the fact that less than the maximum of four nutlets are usually produced in flowers that have been successfully pollinated (Table 2). Nutlet abortion from fertile ovaries is a common event in the Boraginaceae, however, it is more rare in the Lamiaceae and Verbenaceae. Most likely, these isolated, inbreeding populations of Todsen's pennyroyal are burdened with lethal genes that usually prevent the formation of viable embryos.

The five years of reproductive monitoring for the Todsen's pennyroyal in Tables 1 and 2 demonstrate the low reproductive effort of this species. The years 1991 and 1993 are comparable. The years 1991 and 1993 experienced a typical pattern of precipitation with late summer rainfall, whereas, 1992 was unusual with most of the rain falling in the early summer. Since these plots are read during the first week of October, most of the early flowers in 1992 had already shed from the stems and were not counted. 1994 was a very dry summer (Linda Barker, pers. com.) and almost no flowers or seed were produced on the study plots (Tables 1 and 2). Reproductive effort in 2001 (Tables 3 and 4) was not especially good, but was not as low as 1992 and 1994. Successful fruit production greatly fluctuates from year to year and, essentially, is low every year.

To study the breeding characteristics of Todsen's pennyroyal, several cuttings of the San Andres plants were established at the Arboretum at Flagstaff. Deliberate pollination between individuals of these plants failed to produce any seed. In an attempt to outcross this experimental population, additional cuttings were obtained from the Sacramento Mountain population in 1991. Greenhouse cuttings from the Sacramento Mountains and from the San Andres Mountains did bloom in 1993, but not simultaneously. Cross pollination studies could not be completed. To further complicate the study, all but one of the Sacramento Mountains cuttings died in 1994 for unknown reasons. The San Andres cuttings are still alive and available for research, but no further pollination and reproduction studies have been conducted on this greenhouse population.

Table 1. *Hedeoma todsenii* reproduction effort of six study plots in the Sacramento Mountains population.

	HT1	HT2	HT3	HT4	HT5	HT6
1991						
No. plants:	91	163	55	83	48	58
No. flowering:	17	31	0	9	8	5
% plants flowering:	19%	19%	0%	11%	17%	9%
Total No. flrs:	51	127	0	20	20	22
No. Plants w/seed:	8	17	0	3	4	2
Total No. seeds:	44	86	0	5	7	17
% plants making seed:	9%	10%	0%	4%	8%	3%
No. flrs w/seed:	18	35	0	4	6	8
% flrs making seed:	35%	28%	0%	20%	30%	36%
Ave. No. seeds/flr:	0.86	0.68	0	0.25	0.35	0.77
1992						
No. Plants:	111	152	54	70	42	54
No. flowering:	0	22	0	13	7	10
% plants flowering:	0%	7%	0%	19%	17%	19%
Total No. flrs:	0	65	0	38	20	32
No. plants w/seed:	0	10	0	0	0	4
Total No. seeds:	0	25	0	0	0	8
% plants making seed:	0%	7%	0%	0%	0%	7%
No. flrs w/seed:	0	15	0	0	0	6
% flrs making seed:	0%	23%	0%	0%	0%	19%
Ave. No. seeds/flr:	0	0.38	0	0	0	0.25
1993						
No. Plants:	106	170	50	82	54	64
No. flowering:	19	25	0	8	4	20
% plants flowering:	18%	15%	0%	10%	7%	31%
Total No. flrs:	54	73	0	20	7	59
No. plants w/seed:	11	17	0	7	3	11
Total No. seeds:	30	64	0	34	5	60
% plants making seed:	10%	10%	0%	8%	6%	17%
No. flrs w/seed:	16	35	0	16	4	25
% flrs making seed:	30%	45%	0%	80%	57%	42%
Ave. No. seeds/flr:	0.56	0.88	0.00	1.70	0.71	1.02

Table 1 cont.

1994						
No. Plants:	109	136	50	80	51	63
No. flowering:	6	4	0	0	3	7
% plants flowering:	6%	3%	0%	0%	6%	11%
Total No. flrs:	12	5	0	0	7	17
No. plants w/seed:	0	0	0	0	1	4
Total No. seeds:	0	0	0	0	1	11
% plants making seed:	0%	0%	0%	0%	2%	6%
No. flrs w/seed:	0	0	0	0	1	5
% flrs making seed:	0%	0%	0%	0%	14%	29%
Ave. No. seeds/flr:	0	0	0	0	1	0.65
1995						
No. Plants:	90	123	44	69	46	51
No. flowering:	18	22	0	10	10	3
% plants flowering:	20%	18%	0%	14%	22%	6%
Total No. flrs:	36	80	0	26	38	7
No. plants w/seed:	4	15	0	1	3	0
Total No. seeds:	10	47	0	1	4	0
% plants making seed:	4%	12%	0%	1%	7%	0%
No. flrs w/seed:	5	24	0	1	3	0
% flrs making seed:	14%	30%	0%	4%	8%	0%
Ave. No. seeds/flr:	0.3	0.6	0	0.04	0.1	0

Table 2. Number of nutlets matured[1] per fertile ovary of *Hedeoma todsenii* in the Sacramento Mountains study plots.

	No. Fertile Flowers	Percent of Total
1991		
1 nutlet/flower	19	27
2 nutlets/flower	23	33
3 nutlets/flower	17	24
4 nutlets/flower	11	16
Total	70	100
1992		
1 nutlet/flower	12	57
2 nutlets/flower	6	28
3 nutlets/flower	2	10
4 nutlets/flower	1	5
Total	21	100
1993		
1 nutlet/flower	36	38
2 nutlets/flower	29	30
3 nutlets/flower	19	20
4 nutlets/flower	12	12
Total	96	100
1994		
1 nutlet/flower	3	50
2 nutlets/flower	1	17
3 nutlets/flower	1	17
4 nutlets/flower	1	17
Total	6	100
1995		
1 nutlet/flower	14	42
2 nutlets/flower	10	30
3 nutlets/flower	8	25
4 nutlets/flower	1	3
Total	33	100

[1]Members of the Lamiaceae usually produce the maximum of four nutlets per fertile ovary.

Table 3. 2009 *Hedeoma todsenii* reproduction effort of five study plots in the Sacramento Mountains population.

	HT1	HT3	HT5	HT6
2009				
No. plants:	50	23	86	47
No. flowering:	6	5	11	9
% plants flowering:	10%	22%	13%	19%
Total No. flrs:	18	19	26	15
No. Plants w/seed:	1	3	3	3
Total No. seeds:	2	6	4	4
% plants making seed:	2%	13%	3%	6%
No. flrs w/seed:	2	5	4	4
% flrs making seed:	11%	26%	15%	27%
Ave. No. seeds/flr:	0.11	0.32	0.15	0.27

Table 4. Number of nutlets matured per fertile ovary of *Hedeoma todsenii* in the Sacramento Mountains study plots.

	No. Fertile Flowers	Percent of Total
2009		
1 nutlet/flower	13	93
2 nutlets/flower	1	7
3 nutlets/flower	0	0
4 nutlets/flower	0	3
Total	14	100

To further study the hypothesis of self-incompatibility, Dr. Laura Huenneke conducted a program of hand pollination on the Sacramento Mountains population in the summer of 1992. Only the selfed, within patch, and between adjacent patch, pollinations produced any seed and the number produced per flower was usually less than the maximum of four nutlets. The between population pollinations did not produce any seed. This result does not lend credibility to the hypotheses of pollinator scarcity and self-incompatibility. In-breeding depression and a burden of lethal alleles is still the most viable hypothesis.

Fruits develop 4-6 weeks after anthesis. Field observations indicate that the calyces retain the nutlets and are dispersed as a unit. After dispersal, the seeds become mucilaginous when they are moistened, which would allow them to adhere to the soil. About half way down the length of the calyx tube, a series of stiff hairs extend inward and upward from the walls of the calyx and form cone whose point is aligned toward the mouth of the calyx. These hairs form a convex barrier that retains the nutlets within the calyx and may prevent the entry of some insects, which prey upon the seeds. Despite this barrier, a few fertile ovaries where observed to be eaten by some unknown insect. Flowers that were preyed upon had a hole chewed through the base of the calyx that appeared to be an emergence hole. Therefore, each infected flower probably received the insect egg while it was in bloom and the ovary was accessible through the corolla tube.

Seeds of Todsen's pennyroyal probably germinate near the end of the summer rainy season. In laboratory germination attempts only one out of 20 seeds germinated under conditions that have been used successfully for other *Hedeoma* species (Irving, 1980). Twenty four seeds were collected from the Sacramento Mountain population in 1992 for a viability test. They were soaked in tetrazolium chloride for twenty four hours and then dissected. Sixteen were found to be empty and only eight had endosperm. All eight of the filled seed had stained, viable embryos.

CONCLUSIONS

Todsen's Pennyroyal is a relictual species, restricted to the isolated microhabitats that can now support can provide suitable habitat. The gypsum deposits on which it occurs are scattered throughout the Tularosa Basin, but this species is presently known from only two small portions of this outcrop in the San Andres and Sacramento Mountains. It is likely that other tiny pockets of this species could occur throughout the mountains the Tularosa Basin. A full scale search of all potential habitat in the San Andres Range and the Mescalero Apache Reservation may discover additional populations.

This species has been observed to have an extremely low sexual reproductive effort. Its sexual reproductive activity is characterized by few plants within a population flowering in any year, few seeds being produced by the plants that bloom, and flowers that usually mature fewer than the maximum of four nutlets per fertilized flower. Seed set is not significantly enhanced by deliberate hand-pollination. It appears that reproduction is mainly vegetative, although some viable seed is produced through a low level of sexual reproduction. The question at this point is whether a low rate of sexual recombination contributes to this species' rarity and is important to its recovery. If the two known populations have become reproductively depressed by genetic homogeneity, this low level of seed set may be a significant issue for the recovery of Todsen's pennyroyal. The most satisfactory way of resolving this question is to experimentally cross the two most genetically different populations. If this crossing significantly affects seed production, a recovery plan could be adopted that would transfer new gene pools to each population and enhance sexual reproduction.

At this time, we suspect that the apparent rarity of Todsen's pennyroyal is caused by the limited amount of suitable habitat on which it can occur. If crosses between genetically different populations fail to increase seed production, then we accept the fact that a low level of sexual reproduction is characteristic of this species and does not contribute to its rarity. Therefore, recovery efforts for this species may be better directed toward reducing any threats that may still exist or reintroducing it to suitable vacant habitats.

The monitoring plots in the Sacramento Mountains were established in 1991 to reproductive effort and population trends. Only four of the six plots were relocated in 2009 monitoring. Stem densities in these plots were both higher and lower than observations during 1991 to 1995. These patches of plants appeared healthy and some flowering and seed set had occurred in each plot.