Yermo xanthocephalus Dorn
A Research Report

Richard W. and Beverly J. Scott

May 1, 2009

Agreement No. KAA041037,
Modification No. 5

The Central Wyoming College Herbarium
Riverton, Wyoming 82501
and
Scott Environmental Resources, Inc.
Riverton, Wyoming 82501
In cooperation with
Wyoming Natural Diversity Database
University of Wyoming, Laramie, Wyoming 82071-3381

Table of Contents

Tables and Figures

A Research Report on Yermo xanthocephalus Dorn

Richard W. and Beverly J. Scott

Introduction

In 1990 Robert Dorn encountered an unusual plant that he later described as not only a new species, but a new monotypic genus (Dorn, 1991). The genus was Yermo, based on the Ute Indian name for "desert", and the specific epithet was xanthocephalus, Latin for "yellowhead", yielding the binomial Yermo xanthocephalus Dorn, the desert yellowhead. It is a member of the family Asteraceae, which includes sunflowers, daisies, thistles, and sagebrushes, to name a few. Dorn thought that it had affinities to some species of the senecios in a general sense, or groundsels, most specifically species allied with the genus Cacalia L., although some taxonomic disagreement existed as to the status of Cacalia and other cacalioid genera. Individuals of the new species were discovered a short distance from Wyoming Highway 135 and appeared to be concentrated in a single, quite small area on Beaver Rim in Fremont County, approximately 30 miles southeast of Riverton, Wyoming. Belief by Dorn that there were approximately "500 plants on about 1 hectare" was a considerable underestimation of both the population size and the area occupied. Since the original discovery, no new locations have been found, although several sites in the vicinity have similar, if not exact, characteristics as the type location.

On March 14, 2002, the species was designated as threatened by the U.S. Fish and Wildlife Service (effective April 15, 2002), due to the relatively small number of individuals and restricted distribution pattern. Due to its rareness, its potential as a threatened species, and its later designation as threatened, popular interest in the species has been considerable (Appendix 1), with numerous presentations and reports on its status, including designation of critical habitat and withdrawal from mineral entry (Appendix 2).

Currently, all known individuals of the species are found in three centers of concentration at the original location. The two larger centers are loosely connected by plants scattered along intermittent watercourses, while the third, much smaller, is isolated a short distance from the other two. This report details the information that has been acquired about the species, the centers of concentration, and the habitat during our thirteen-year study in the years 1992 – 2004 following the original discovery and later description of Yermo xanthocephalus by Dorn in 1991.

Location and extent of the Yermo site

The external rectangular boundaries of the Yermo site, at 6730 ft (2051 m), include a small area of 30 hectares (74 acres) on Beaver Rim, approximately three miles southeast of the Rim proper, east of Wyoming Highway 135 and southeast of the Cedar Rim Road. The site is approximately 30 miles (48.3 km) east of the town of Riverton and about 2/3 mile (one km) northeast of Wyoming Highway 135. The boundaries are between approximately 42.6261 and 42.6213 N latitude and 108.1838 and 108.1769 W longitude. Boundaries, location, and size of the site are based on the location and size of our permanent sampling grid, to be described later.

Careful readers of news reports (Appendix 1) and other reports and presentations (Appendix 2) will note sometimes conflicting reports on the size of the Yermo site. Since most, if not all, size estimates originated with us, we wish to clarify these apparent discrepancies. Our sampling grid is 30 hectares, or 74 acres, as stated. The grid is rectangular and covers the outside limits of Yermo plant distribution. However, the number of hectares within the grid that are actually occupied by Yermo plants has varied between 15 and 17 per year. Using this scale, the size of the site would be 17 hectares (42 acres) or less. Each hectare was divided into one hundred 10 x 10 m plots, or ares, for the annual census. Not all ares were occupied by Yermo plants, and the number of ares occupied varied from year to year. The maximum number of ares occupied in any single year was 345, so at that scale the size of the site would be 3.45 hectares (8.5 acres); in other years the size was less. We prefer to use the number 30 hectares (74 acres) to describe the area of the site, because this is a stable size, includes the limits of the entire species as known from the beginning to the end of our studies, and includes critical Yermo habitat.

Regardless of these different scales, this species occupies a remarkably small area that deserves special recognition and management. The site is at the junction of the north margin of the Sweetwater Station and south margin of the Dishpan Butte USGS 7 ½ minute quadrangles, with all known plants falling within S27 and S34, T31N R95W. We have searched far and wide for additional plants, especially at sites with similar geological, geomorphological, and climatological characteristics, with no avail. The search characteristics that we utilized are described later in this report.

The Beaver Rim Area

Beaver Rim is a prominent escarpment that begins at the southeastern tip of the Wind River Range along the Beaver Creek drainage in Fremont County (41.4833N/108.4583W) and continues for approximately 72 miles (116 km) in a northerly/northeasterly direction, finally terminating near Deer Creek valley, (42.8288N/107.4096W), a little more than one mile (1.61 km) south of the Rattlesnake Range of southwestern Natrona County. As a prominent landform in west-central Wyoming, separating the Wind River Basin to the west and the much higher Sweetwater Plateau to the east, Beaver Rim is significant in terms of physiography, biogeography, and ecology.

The vertical rise of Beaver Rim from base to top is as much as 2000 ft (610 m) in some places. Elevations at the base are in the range of 5800 ft (1768 m) to 7400 ft (2256 m), while those at the top are 7100 ft (2164 m) to 7700 ft (2256 m), exceeded in some places by 200 to 400 ft (61 – 122 m) mesas, buttes, and ridgetops. Generally, both base and top elevations rise from the south, northward to the Rattlesnake Range. Springs and small streams flow down the usually steep western face of the escarpment into the Wind River drainage, while, on the east, much more gentle slopes deliver water flows to the Sweetwater River in the Platte River drainage.

Several plant species are confined to the Rim, or at least have distribution patterns centered on the Rim. Some of these are Yermo xanthocephalus Dorn, Phlox pungens Dorn, and Cirsium aridum Dorn. Other species that have a distribution pattern related to Beaver Rim are Physaria eburniflora Rollins, Physaria saximontana Rollins, and Trifolium barnebyi (Isely) Dorn and Lichvar. The Rim is a connecting pathway between the southeasternmost Wind River Range and the Rattlesnake Range. It provides habitat for members of the family Pinaceae, Pinus flexilis James, Pseudotsuga menziezii (Mirb.) Franco, and those of the Cupressaceae, Juniperus osteosperma (Torrey) Little and J. scopulorum Sarg., to freely range along its linear extent.

With the distribution of Pinus ponderosa Laws. & Laws. in eastern Wyoming and the Big Horn Range and its lack in the Wind River Range of Fremont County (in spite of abundant limestone surfaces and soils), we have always thought Beaver Rim would be a convenient post-Pleistocene migratory route southwestward to the Wind River Range or a possible Pleistocene refugium where it survived. We have found a few isolated individuals of this species on the Rim near its southern terminus, but to date consider them introductory plantings, possibly wind breaks, near U.S. Highway 287. At any rate, the abrupt rise of Beaver Rim from the Wind River Basin to the Sweetwater Plateau influences climatic changes and related habitat changes, affecting species assemblages that may be quite different from those of the western lowlands or the eastern highlands.

Geology of the Beaver Rim Area

The structure of Beaver Rim is based on a sequence of Tertiary sediments ranging in age from Eocene to Miocene. Van Houten (1964) described this sequence of nearly horizontal, nonmarine Tertiary rocks as one of the most complete in the Rocky Mountain region. There are four formations in the sequence. Oldest, at the base of the Rim, is the Wind River Formation of early Eocene age. It contains sediments derived from Precambrian rocks, plus some volcanics in the younger layers. The Wind River Formation extends in westerly and northwesterly directions to the Wind River, Absaroka, Owl Creek, and Bridger Ranges, forming the surficial features of the Wind River Basin. The Wagon Bed Formation, of middle and late Eocene age (Van Houten, 1964), is mostly volcanic in origin and in many locations forms the western face of the Beaver Rim escarpment. Above the Wagon Bed is the Oligocene White River

Formation composed of fluvial sediments and volcanic ash deposits. The White River forms many of the present-day surfaces along the top of the Rim. Above the White River is the Miocene Split Rock Formation, so named by Love (1961). On the Rim proper, at its western edge, the Split Rock Formation is represented by disjoined mesas, buttes, and ridges. Further east these Split Rock erosional remnants become confluent and near Jeffrey City form the common surface between the Precambrian rocks of the western edge of the Granite Mountains, which begin in the west with a few isolated outcrops or islands.

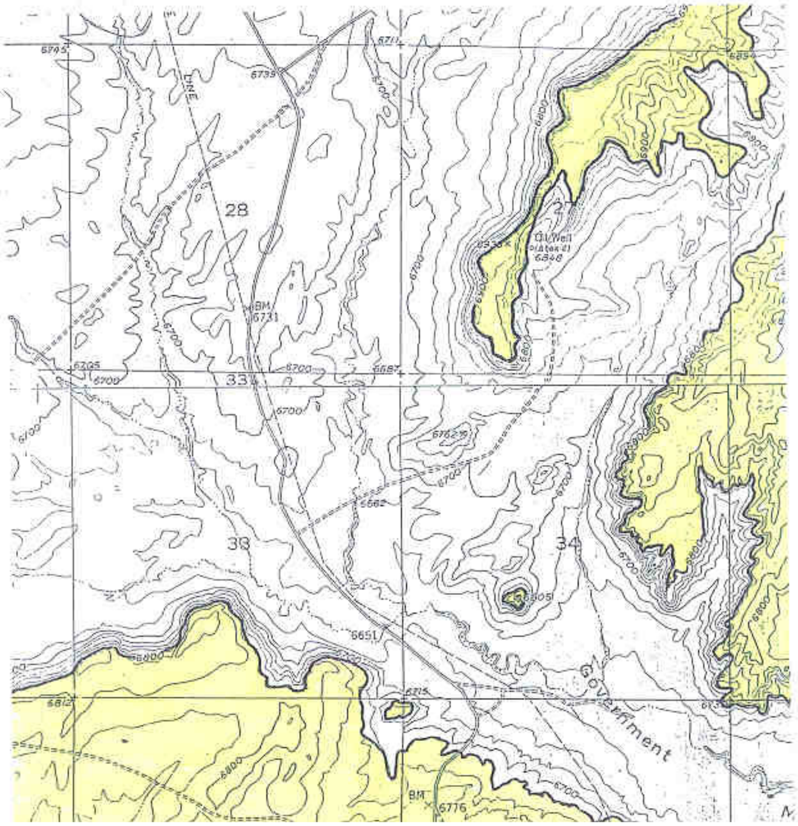


Figure 10. White River and Split Rock Formations on Beaver Rim at the Yermo site. Split Rock is yellow.

The White River Formation figures prominently in the distribution of <u>Yermo</u> and is widely exposed at the site (Figure 1). The White River Formation is characterized by level to gently-sloping surfaces, although steep slopes are present at some locations. At the <u>Yermo</u> site, the White River Formation is represented by the volcanic facies of Van Houten (1964), one of several that have been described in the White River Formation. The volcanic facies is yellowish-gray to light-gray calcite-cemented, volcanic sandstone and tuff interbedded with conglomerate containing angular to subround Tertiary volcanic rocks (Van Houten, 1964) originating in the Yellowstone-Absaroka volcanic field. It is this portion of the White River Formation on which all <u>Yermo</u> plants occur.

Immediately upslope from the Yermo population, and above the White River, is the flat-topped mesa formed by the Miocene Split Rock Formation. This is the formation that produces cliffs and ledges along the upper Beaver Rim escarpment and other mesas, buttes, and rims eastward for a few miles before forming the confluent surface of the Sweetwater Plateau. In the immediate Yermo area, the Split Rock Formation consists of a basal conglomerate capped by sandstone ledges. This sandstone is often poorly consolidated, in places contains calcareous cement, and may be interbedded with flaggy limestone (Van Houten, 1964). Gravity deposits originating from the Split Rock may be intermixed as colluvium with White River sediments at some sites where Yermo plants occur along the north boundary of the population. Contrary to opinions expressed in numerous reports, no Yermo plants occur directly on the Split Rock Formation and, as far as we can tell, the Split Rock Formation has very little or no influence on the distribution of Yermo. If geologic substrate becomes a criterion of interest related to searches for additional Yermo plants, the White River should be the target formation rather than the Split Rock.

Mineral Exploration: Oil and Gas: The Big Sand Draw and South Sand Draw fields contain producing oil and gas wells approximately seven miles north and west of the Yermo site. Other producing wells are on Cedar Rim beginning about five miles north of the site. Numerous non-producing wells have been drilled throughout the area, particularly in the 1940's and 1950's. One of these, Sohio Petroleum Co. Government 1 Unit (NE¼ SE¼ S27 T31N R95W), was drilled in 1952 to a depth of 7343 ft. (Van Houten, 1964) about 1/3 mile (0.5 km) north of the Yermo site. The old access road to this well currently goes through occupied Yermo habitat. The next closest of these old wells is Atlantic Refining Co. Government-Sweetwater Crossing 1 Unit about two miles away (NE¼ NE¼ S8 T30N R95W). More recently, in 1997, Cyanostar Energy, Inc. proposed a drill site, No. 1-33, across Wyoming Highway 135 (NE¼ NW¼ S33 T31N R95W) about 0.75 miles (1.2 km) from our sampling grid. It was later drilled, but the second proposed site off the Cedar Rim Road, No 1-27 (NW¼ NW¼ S27 T31N R95W), about 0.87 miles (1.4) km from the grid, was not.

Uranium and other minerals: The Yermo site has been claim-staked at least once at some time in the past following discovery of uranium in the Gas Hills in 1953. Some evidence of assessment pits exists in the general vicinity, with no evidence of any surface mining activity. Most of the uranium mineralization in the area appears to be in the lower Wind River Formation (Van Houten, 1964), although the upper Wagon Bed Formation and the White River Formation are reported to contain uranium minerals. Gold occurs in quartz veins in Precambrian rocks further to the east in the Granite Mountains, and gravel in S28 T30N R95W, immediately west of the Yermo site, has been used in road construction. Pumicite claims have been staked in the White River Formation about five miles west in S3 T30N R96W (Van Houten, 1964).

Van Houten also reported the presence of opalite (a rock composed of opal and chalcedony), opaline chert, opaline silica, and opal at various locations in the Wind River Formation, Wagon Bed Formation, White River Formation, and Split Rock Formation. In 2005 a small gemstone rush for opals occurred in an area centered three to four miles northeast of the Yermo site. A number of claims were staked along the Cedar Rim Road south of Findlay Springs along the unconformable contact between the Split Rock Formation and the White River Formation. In response to the claim-staking activities, the BLM closed the only road to the Yermo site (which was outside the opal-bearing area), thus denying not only mineral searches, but also much-needed research access to this rare plant.

Habitat

As mentioned previously, the formation directly related to Yermo plants is the Oligocene White River. The White River forms level to somewhat steep surfaces on which the plants occur, while the Miocene Split Rock Formation forms cliffs and ledges above the population immediately to the north. Steep erosional slopes with patchy talus of conglomeritic and calcareous rocks connect and overlap the two formations. Yermo plants extend part-way up the steep slope leading to the Split Rock cliffs, but are eventually limited, apparently by habitat, and do not occur at the top of the slope. The reason for this is not yet completely understood. The slope is obviously steep and unstable, but as will be shown later in this report, Yermo plants seem to be indicators of unstable surfaces and thrive on them. They do not occur on stable surfaces, except occasionally on margins adjacent to unstable ones.

To the northwest and west, Yermo habitat is bounded by a small erosional rim in the White River Formation. The resulting topographic expression is a shallow basin extending eastward from the rim. When we first observed this rim and basin, we were impressed by the similarity to a nivation basin, which is a typical alpine geomorphic feature. However, we have observed similar features in non-alpine environments and consider nivation to be one of the major processes, if not the major process, which forms this part of Yermo habitat. Figure 2 shows the pattern of snow accumulation in the winter that supports nivation as a major habitat-forming process at the site. Mechanisms for the process have been discussed by Gerrard (1990), Price (1981), Thorn (1979), and others. Summer thunderstorms and the rapid and sometimes violent shedding of surface water as sheetwash on both the long, steep north slopes and the much shorter, shallower west slopes also contribute to the geomorphic aspect of this portion of the Yermo habitat. Deflation is a probable, but lesser, contributer to the small basin morphology. On the southwest edge of the Yermo habitat, a small erosional dome provides suitable topographic expression for a second nivation basin that contains another high-density stand of Yermo plants.

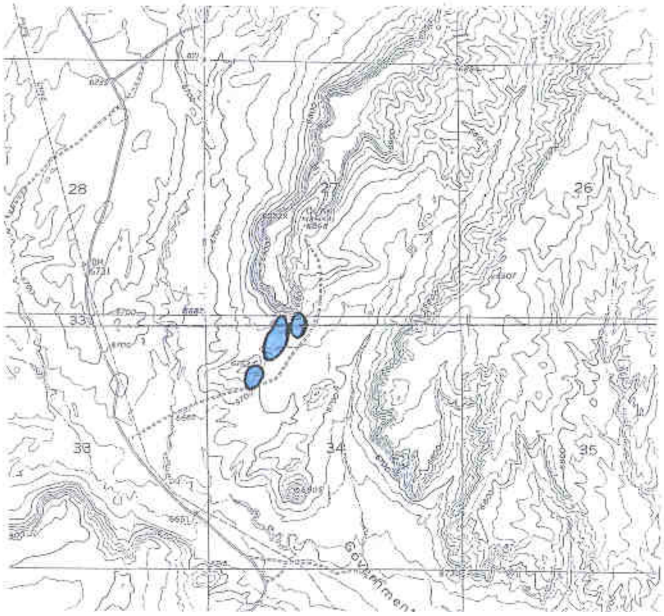


Figure 11. Three prominent snowdrifts at the Yermo site. Sketched January 2, 1993.

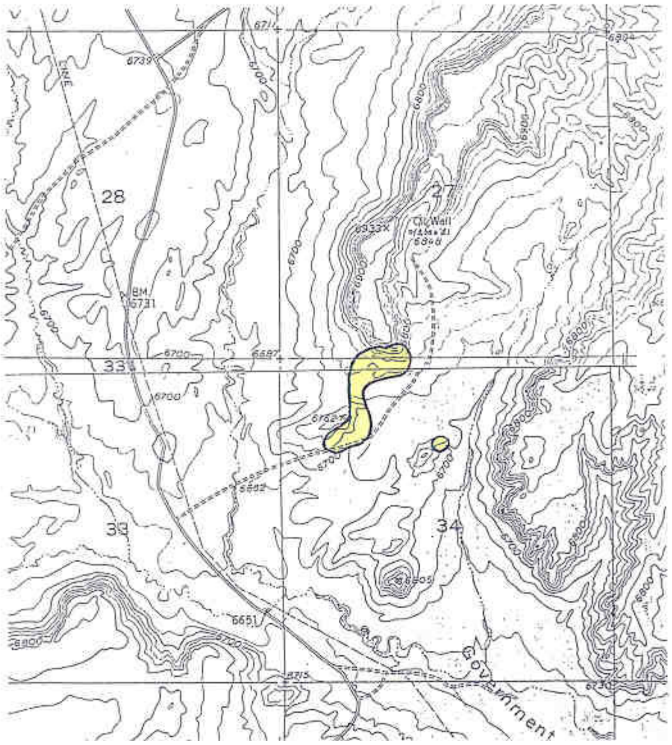


Figure 12. Yermo distribution relative to the snow deposition pattern at the site.

Meltwater and sheetwash from these two basins and the slopes to the north exit the site through stream channels which are deeply eroded and bear evidence of periodic flooding, in addition to intermittent flow. Yermo plants are found in all these channels close to the basins and become less frequent down the channels until the plants finally disappear. Along the southeast edge of the site, the old

Sohio Road (an oilwell road to be discussed later in this report) provides habitat for Yermo plants very similar to the intermittent stream channels. Approximately 180 meters to the southeast of the Sohio Road, a small, shallow, incipient nivation basin, or perhaps a deflation blowout, contains a small group of Yermo plants that has increased in both density and frequency during the ten years of our population density study. This basin is within the White River Formation and occurs close to a small hillock that provides the same topographic expression for winter snow accumulation and subsequent nivation processes as found at the two larger basins (Figure 3).

On the west side of the site, between the small basins, and along all of the east side, habitat is limited by stable surfaces supporting an Artemisia tridentata Nutt. community. Yermo plants have been found adjacent to big sagebrush individuals within optimum habitat where the sagebrush occurs in relative low density, but the Yermo plants do not appear able to invade established stands of sagebrush growing on stable surfaces. Boundaries between the two are usually very sharp and recognizable, not only at the site, but on many of our sampling forms (Appendix 3). Nivation basins and similar erosional features in the White River Formation, especially adjacent to Split Rock slopes and ledges, are one of the characteristics mentioned earlier that were used as indicators in our search for additional stands of Yermo plants along Beaver Rim.

The elevational range for Yermo plants at the site is ca. 6720 – 6800 ft (ca. 2048 – 2073 m). Whether this range has value as a search criterion is unknown, since no other plants have ever been found. However, this range is obviously below the estimated lower elevations of 6800 – 6900 ft for the Split Rock Formation in the general vicinity. The 6800 ft elevation for the Split Rock occurs south of the Yermo site across Wyoming Highway 135, while the 6900 ft elevation describes the approximate lower contact of the Split Rock with the White River Formation at the Yermo site.

Soils

Members of three soil series are in the vicinity of the Yermo site (Figure 4). These are the Cragosen-Rock outcrop-Carmody complex, the Diamondville-Forelle association, and the Ryan Park-Carmody association (Iiams, et al., 1993). The Diamondville-Forelle association lies to the west of the site and supports an extensive Artemisia tridentata community, as does the Ryan Park-Carmody association to the east of the site. All Yermo plants occur within the mapped limits of the Cragosen-Rock outcrop-Carmody complex, which on an areal basis occupies sites on the upper White River and Split Rock formations. Both the Cragosen and Carmody soils are zonal and underlie the stable, or at least relatively stable, surfaces where Artemisia tridentata stands occur. The Carmody soil type is very similar to the Cragosen, but has a deeper profile and occurs at the bottom of slopes near valleys. Based primarily on the shallower profiles present and the upper drainage position, we recognize the zonal soils of the site as Cragosen.

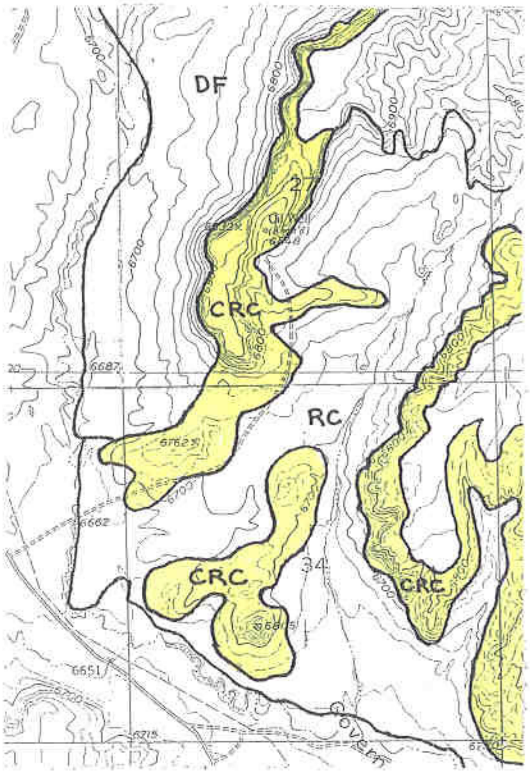


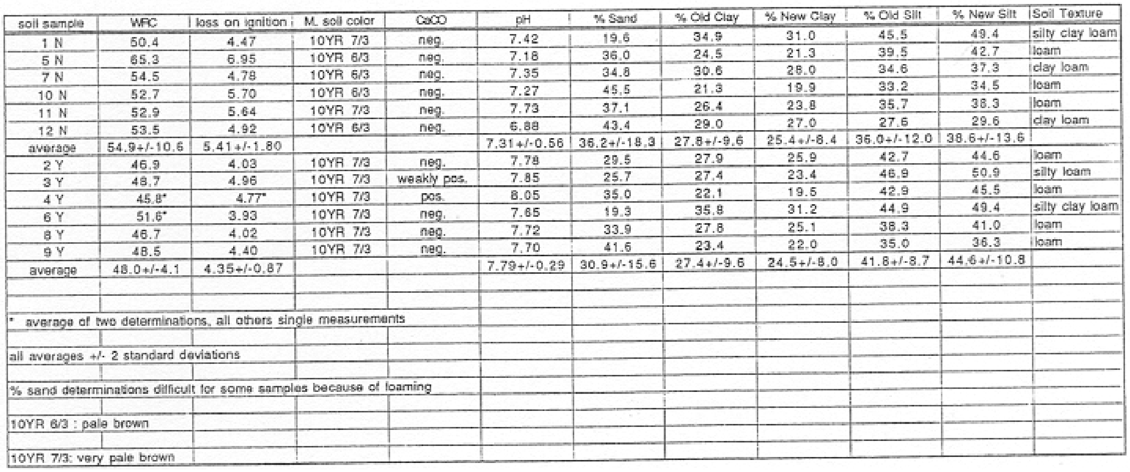
Figure 13. Distribution of the three soil series in the immediate Yermo vicinity (from Iiams, et al., 1993); RC is Ryan Park-Carmody association; CRC is Cragosen-Rock outcrop-Carmody complex; DF is Diamondville-Forelle association.

All Yermo plants are found on unstable to relatively unstable azonal soils which, at the scale of Iiams, et al. (1993), fit their Rock outcrop soil type of sandstone rocks and conglomerates. Specifically, these sandy, or silty, to somewhat coarse loamy azonal soils which support Yermo plants are Torriorthents. Bynum (1993) classifies one sample as a Lithic Torriorthent. We agree with this classification, and it is the correct description where the lithic contact is less than 50 cm from the surface. This occurs mainly on the upper reaches around the northern border of the area. However, a number of downslope sites in and near stream channels have a lithic contact greater than 50 cm of depth. At these sites, Ustic Torriorthent seems to best fit the azonal soil type. We have observed extreme and prolonged subsurface saturation following periodic intense thunderstorms which suggests that the term Aquic Torriorthent may also apply at some sites. When the upper slopes on the north edge of the site under the Split Rock cliffs and ledges receive rainfall, the water rapidly moves downslope as sheetwash, finally channelizing and draining away. When relatively high amounts of water are received, the runoff pools below the slopes, resulting in subsurface saturation that may be present for days following such an event.

Yermo plants are almost exclusively found on the azonal Torriorthents and only occasionally on the Cragosen zonal soils. In such cases they only colonize sites a very short distance (usually a meter or less) from the azonal soils. This feature is characteristic of pioneer species that may be poor competitors, but are tolerant of instability and are nearly or completely confined to fresh, unstable surfaces with a corresponding low density of other species. According to Clementsian theory, one would expect them to be eventually replaced by other groups of species, but if the underlying cause of the surface instability (upslope erosion, sheetwash, and intermittent flooding) is present for an unlimited time, then one might expect the plants to remain at the site for an indefinite period as long as the unstable site characteristics, to which they appear to be well-adapted, are maintained. These abiotic, or allogenic, environmental changes associated with the azonal soils result in the distinctive grouping and distribution of Yermo plants.

Results of our analyses of soil characteristics are shown in Table 1. The average pH value of 7.79 for the azonal Torriorthents is slightly more alkaline than the 7.31 for the adjacent zonal Cragosen aridosols. Their dry Munsell Color of 10YR 7/3 (very pale brown) is slightly lighter than the Cragosen Munsell color of 10YR 6/3 (pale brown), a characteristic which is also reflected in their lower organic matter and lower Water Retaining Capacity. Particulate analysis demonstrates a higher sand fraction in both soils, followed by lesser amounts of silts and clays. In 2003 we were pleased to have seven soil samples accepted for testing by the NSSC Soil Survey Laboratory (Soil Survey Staff, 2003). Three of these were Yermo soils and four were non-Yermo, including one potential Yermo site. As of this writing the results of these tests have not yet been analyzed.

Table 1. Soils analyses; N = non-Yermo soils, Y = Yermo soils.



soil sample	WRC	loss on ignition	M. soil color	CaCO	pH	% Sand	% Old Clay	% New Clay	% Old Silt	% New Silt	Soil Texture
1 N	50.4	4.47	10YR 7/3	neg.	7.42	19.6	34.9	31.0	45.5	49.4	silty clay loam
5 N	65.3	6.95	10YR 6/3	neg.	7.18	36.0	24.5	21.3	39.5	42.7	loam
7 N	54.5	4.78	10YR 6/3	neg.	7.35	34.8	30.6	28.0	34.6	37.3	clay loam
10 N	52.7	5.70	10YR 6/3	neg.	7.27	45.5	21.3	19.9	33.2	34.5	loam
11 N	52.9	5.64	10YR 7/3	neg.	7.73	37.1	26.4	23.8	35.7	38.3	loam
12 N	53.5	4.92	10YR 6/3	neg.	6.88	43.4	29.0	27.0	27.6	29.6	clay loam
average	54.9+/-10.6	5.41+/-1.80			7.31+/-0.56	36.2+/-18.3	27.8+/-9.6	25.4+/-8.4	36.0+/-12.0	38.6+/-13.6	
2 Y	46.9	4.03	10YR 7/3	neg.	7.78	29.5	27.9	25.9	42.7	44.6	loam
3 Y	48.7	4.96	10YR 7/3	weakly pos.	7.85	25.7	27.4	23.4	46.9	50.9	silty loam
4 Y	45.8*	4.77*	10YR 7/3	pos.	8.05	35.0	22.1	19.5	42.9	45.5	loam
6 Y	51.6*	3.93	10YR 7/3	neg.	7.65	19.3	35.8	31.2	44.9	49.4	silty clay loam
8 Y	46.7	4.02	10YR 7/3	neg.	7.72	33.9	27.8	25.1	38.3	41.0	loam
9 Y	48.5	4.40	10YR 7/3	neg.	7.70	41.6	23.4	22.0	35.0	36.3	loam
average	48.0+/-4.1	4.35+/-0.87			7.79+/-0.29	30.9+/-15.6	27.4+/-9.6	24.5+/-8.0	41.8+/-8.7	44.6+/-10.8	

* average of two determinations, all others single measurements

all averages +/- 2 standard deviations

% sand determinations difficult for some samples because of foaming

10YR 6/3 : pale brown

10YR 7/3: very pale brown

We think that the presence of azonal Torriorthents provides a visual key that is of immense value in the search for, and possible location of, additional Yermo plants or stands. For example, Dishpan Butte, approximately two miles west of the Yermo site, is capped by a Split Rock remnant surrounded by the White River. The soils at Dishpan Butte are classified as the Blackhall–Rock outcrop complex by Iiams, et al. (1993). Blackhall soils are very similar to Cragosen, and Iiams, et al. include some Cragosen soils within this complex. Most important is the presence, within the complex, of Ustic Torriorthents on the east side of the Butte in and around an incipient nivation basin, nearly identical to the small basins of the Yermo site and containing most of the same plant species. Other similar sites exist in the vicinity. We believe that all have high potential as Yermo habitat, but to date have found no new plants.

Taxonomic Description of Yermo

In this section we provide the original description written by Dorn (1991). An updated version in the style of the Flora of North America is available elsewhere (Dorn, 2006).

"Perennial herb, glabrous except sometimes the achenes; stems hollow, to 3 dm high, 1 to several from a thick, elongate taproot; leaves basal and alternate, petioled, coriaceous, lanceolate to ovate or obovate, entire to variously toothed, 4-25 cm long, 1-6 cm wide, gradually reduced upward, generally with a rounded fold lengthwise, the main 3 veins somewhat parallel; heads numerous (25-180), in a crowded corymbiform cyme; involucre cylindrical, 8-15 mm long, the bracts in a single series, usually 5, occasionally 4, rarely 6, strongly keeled, the keel greenish-yellow, the rest bright yellow but drying pale, generally cucullate at tip, usually with a few much reduced bractlets at base; receptacle naked, flat or sometimes with a sharp projection from center; rays none; disk florets usually as many as involucral bracts (4-6) except sometimes fewer by abortion, barely exerted from involucre, yellow, the tube about 3 mm long, the throat about 2 mm long, the lobes linear, widely spreading and about 2 mm long; anthers with a pair of minute lobes at base; style branches obtuse-truncate and pubescent at tip, stigmatic surface covering entire inner face; pappus copious, of capillary bristles, subequal to corolla tube and throat, borne on an expanded disk at top of achene,deciduous in fruit; achenes often short-pubescent, usually about 10 nerved, brown, 6-7 mm long, slightly flattened, elliptic to oblanceolate in outline."

The Architecture of Yermo

Mature plants of Yermo exhibit a well-branched caudex that is easily observed on herbarium specimens and has been frequently illustrated, not only in publications such as Dorn (1991), Scott and Hoster (2000), Heidel (2002), but also on t-shirts (Jones, 1993). Growth at the ends of the caudex branches yields new plants capable of flowering. This is described as modular growth (Smith and Smith, 2001) and is characteristic of a number of asexually reproducing species such as Populus spp. and Fragaria spp., plus others. In a modular species, those plants produced sexually from zygotes are termed genets and those produced asexually from rhizomes, root crowns, or caudices (and other ways) are termed ramets. A genet plus its ramets forms a clone. If some mechanism, either mechanical or biological, breaks the genet/ramet connections, the result is two or more separate, independent plants with the same genotype as the parental genet. Yermo is a modular species, producing genets sexually and ramets asexually. The commonest growth form of Yermo exhibiting this architecture is the "clump" formed in mature plants. This is the form referred to numerous times in this report. These clumps may be a flowering stem surrounded by clusters of leaves, or a complex of leaf clusters and multiple flowering stems. It is not clear how readily or frequently ramets may be isolated as independent plants by breakage of the caudex branches. Field observations, however, suggest that this occurs at least through the process of mechanical damage, or partial inundation by downslope sheetwash and alleviation, followed by death of the covered ramets. The peculiar J-shaped taproot of mature Yermo plants also suggests a rhizomatous nature, potentially producing ramets. This was supported by some field observations, but was never directly investigated.

Yermo Population Density

Establishing the grid: During the summer of 1995 we established a permanent grid that included the total known range occupied by Yermo xanthocephalus. With the able assistance of Albert Foster and Josh Fraley, students at Central Wyoming College, a survey line was run from BM 6731 immediately west of Wyoming Highway 135 (S28 T31N R95W) to a point that was intended to become the northwest corner of the grid. The actual grid, however, was constructed 300 hectares south of this point and was five hectares (north to south) by six hectares (west to east), for a total of 30 hectares (Figure 5). Corners of the hectares were marked by labeled wooden stakes. North/south

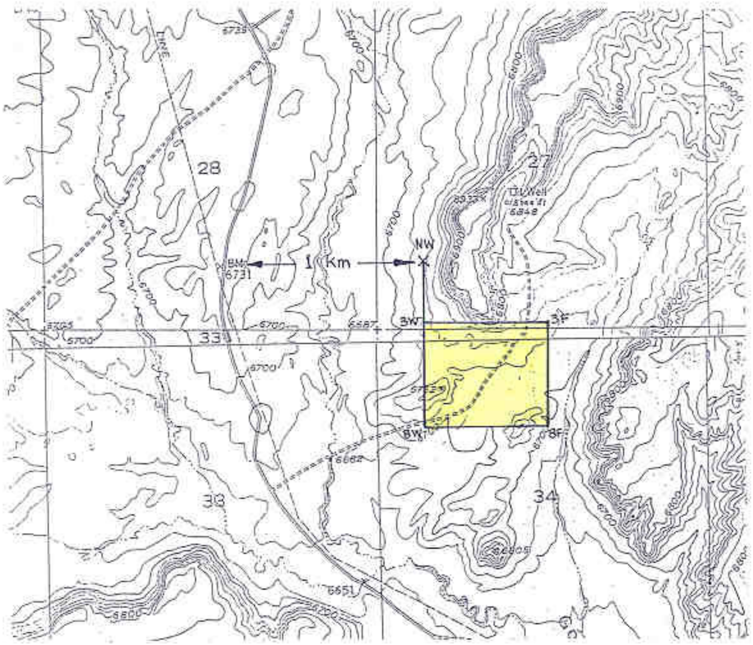
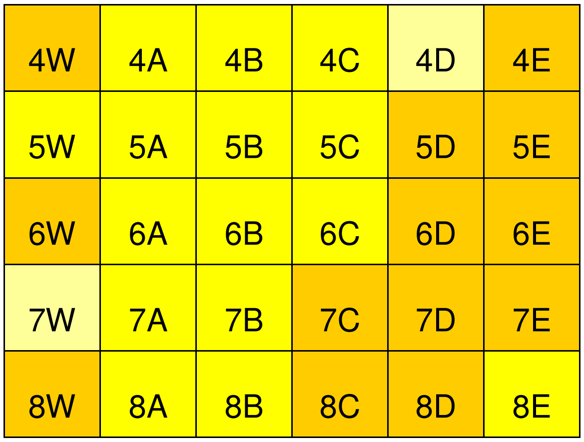


Figure 14. The topographic position of the sampling grid.



4W	4A	4B	4C	4D	4E
5W	5A	5B	5C	5D	5E
6W	6A	6B	6C	6D	6E
7W	7A	7B	7C	7D	7E
8W	8A	8B	8C	8D	8E

Figure 15. The sampling grid. Occupied hectares in 1995 are yellow; additional hectares occupied in 2004 are light yellow; hectares never occupied by Yermo plants during the study are gold.

lines of the grid were identified (west to east) as W, A, B, C, D, E, and F; east/west lines were identified (north to south) as 3, 4, 5, 6, 7, and 8.

At a later date, the original wooden stakes were replaced with metal bolts bearing numbered aluminum markers. Each numbered marker indicated a line intersection, beginning with 1 at the intersection of 3 and W (3W) on the NW corner and continuing consecutively to 42 at the intersection of 8F on the SE corner. The metal bolts were driven to ground level to minimize movement, damage, or loss. Even though these numbered markers are now present within the grid, we still identify the individual hectares by the line intersection code of the southwest corner. For example, the 4A hectare occupies the position between the A and B north/south lines and the 3 and 4 east/west lines. The southwest corner of this hectare is the intersection of line 4 and line A, hence the designation 4A. Hectares are thus numbered from 4W at the northwest corner of the grid to 8E at the southeast corner (Figure 6). The permanent grid was designed to provide a framework for a continuing and reliable annual census of this rare plant. The grid was also designed to be enlarged should the need arise, but no additional or new plants have been found outside the original limits in the ten-year period since the grid was established.

Each hectare was further subdivided, at the time of each census, into 100 10x10 m plots, or ares. Both the B and C lines were permanently marked with bolts at ten meter intervals for control purposes. The ares were identified by their position relative to the SW corner of the hectare, the basis of the hectare designation, for example, 4B. Ten-meter north/south lines were numbered 1 – 9 east of the grid point, the west (B) line being 0 in the are identification system. Likewise, ten-meter east/west lines were numbered 1 – 9 north of the grid point, the south (4) line being 0 in the are identification system. The second are immediately east of the 4B point thus became 4B – 1,0 and the fifth one east became 4B – 4,0 (the intersection at 4B was 0,0 in the are grid). As a last example, the fourth are east of the 4B point and the third north would be designated 4B – 3,2 (Figure 7). The are locations follow the UTM system of eastings and northings from the SW corner.

Census technique: With minor modifications, the census technique used each year was the same as that of the original census in 1995. The timing was set for late July or early August, so that both flowering and vegetative plants could be readily distinguished. One hundred meter surveying tapes were used to outline each hectare as defined by the permanently marked corners. Shorter tapes were then used to divide the hectare into ares (ten by ten meter plots). Each are was the census unit. As the census was conducted in the field, we referred to the hectares as “blocks” and the ares as “plots”. West/east bands of ares were “tiers” and north/south bands were “columns”, as if viewing a N>S oriented map. One hundred ares, or plots, were thus sampled within each hectare. The actual sampling involved counting both vegetative and flowering plants separately.

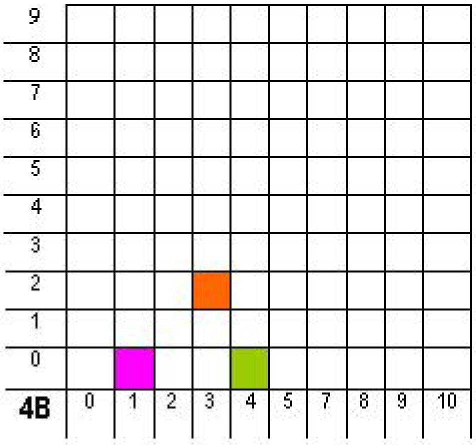


Figure 16. Are designations: pink = are 4B-1,0; orange = are 4B-3,2; green = are 4B-4,0.

Numbers were recorded on mechanical counters and then transferred to sampling sheets in the appropriate are on the form (Appendix 3). Plots with numerous plants were further subdivided, as needed, to prevent double counts, omissions, and general confusion. Plot data were summarized for each hectare, resulting in three levels of analysis: are density, hectare density, and total (species) density. Densities at the three levels could be analyzed as flowering plant density and vegetative plant density.

A major goal was to minimize both sampling error and estimate by counting every plant in the grid utilizing a standardized procedure. In spite of this, a number of problems potentially affected the census outcome and were somewhat difficult to control or to treat in a uniform, standardized manner. Following is a short discussion of these problems and the methods employed to minimize their effect; some are addressed in greater detail later in this report.

1) At the beginning of the study it was recognized that, due to a branched caudex, many older single plants had a clumped appearance similar to an actual clump of two or more separate plants. Separating clumps from individual plants was sometimes difficult. Therefore, if adjacent leaves overlapped, with the resulting appearance of a single unit, the unit was counted as one plant. If adjacent leaves did not overlap, resulting in the appearance of multiple units, each was counted as a separate plant without consideration of whether the units were connected underground.

2) Flowering and vegetative plants were easily distinguished at census time, so we decided at the beginning to count the two kinds separately. Later we became aware of germinating seeds represented by small cotyledons that were sometimes present for more than one year. Although we did initiate a separate cotyledon survey and study, a count of cotyledons was never a part of the annual census. The census thus included only plants with one or more leaves developed beyond the cotyledon stage.

3) Very large numbers of plants in certain ares was often confusing to samplers, because it was difficult to keep track of which plants had been counted and which had not. These high density plots were subdivided into smaller, irregular, but manageable units. While this technique was not employed in all ares, it did minimize losing counts, double counting, and counting omissions in the high density ares.

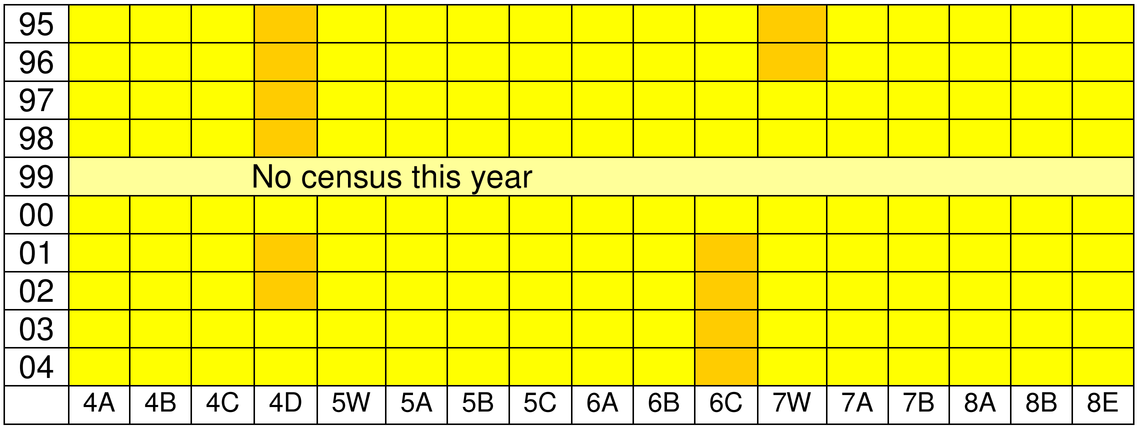
4) After the initial survey and positioning of wooden grid stakes, cows knocked out or uprooted the stakes on numerous occasions. Cows, along with antelope, were also quite fond of uprooting colored pin flags. To minimize this type of damage, we placed sunken eyebolts with metal tags at grid intersections and drove large nails beside the pin flags so they could be repositioned with minimal loss of placement.

5) Afternoon winds sometimes caused billowing of tapes placed between the grid corners to outline and mark both hectares and ares. This was minimized by running the tapes through surveying pin “arrows” to hold them in place, or on level places with the tape near the ground, we would simply use rocks as anchors. By the last year of sampling, a large collection and wide distribution of strategically-placed rocks appeared along the tape lines.

6) During some census years we were joined by a number of volunteers who assisted with the counts. As often as we could, and especially if the samplers were inexperienced, we had them work in pairs so that two people counted each are. If the two counts did not agree, they would be recounted to within 10% or less of the lower total. When this was achieved, half the difference between the two was then added to the lower number and rounded. On such occasions the count difference was very small, usually five or less. Generally, these differences

became evident only in the ares with the highest densities and therefore the greatest potential for losing track of the count.
7) Plants, and even single leaves, of Yermo are so distinctive and different from other plants at the site that we were never concerned that volunteer samplers, even the most inexperienced, would confuse them with other species.

In the 1995 original census, 15 hectares within the 30 hectare grid were occupied by vegetative and flowering plants. This number increased to 16 in 1997 and 17 in 2000 (Figure 8). Although the addition of two hectares in a few years appears significant, this increase involved only a very few plants immediately along or near the margins of previously occupied hectares. For the five years 2000 to 2004, the total occupied fluctuated between 15, 16, or 17 hectares due to the appearance or disappearance of single plants. The occupied hectares are predominantly at the western and northern portions of the 30 hectare grid, with the exception of one outlying group of plants in the southeasternmost 8E hectare. Numbers of plants at the are level and numbers of occupied ares have fluctuated considerably since the original census in 1995.



95	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨
96	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨
97	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
98	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
99	No census this year																
00	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
01	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨
02	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨
03	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨
04	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟧	🟨	🟨	🟨	🟨	🟨	🟨
	4A	4B	4C	4D	5W	5A	5B	5C	6A	6B	6C	7W	7A	7B	8A	8B	8E

Figure 17. Hectare summary; occupied hectares are yellow, unoccupied are gold.

Species density: Because of our grid system we were able to estimate ecological density, a function of habitat space, rather than crude density. Furthermore, because of the restricted range and habitat of Yermo, species density is the same as both population density and total density, and we thus use the terms interchangeably in the sections that follow.

The first census in 1992 yielded a total of 9294 plants, the lowest in ten years of study (Figure 9). By the second year (1993), 11,911 plants were present, a gain of 2617 plants. From that year until the last census in 2004, the population lost or gained as few as 188 plants per year or as many as 1182, while fluctuating around an annual mean of 11,813. The highest annual density was 13,247 plants in 2000. These values represent both vegetative and flowering plants, to be discussed separately in a later section.

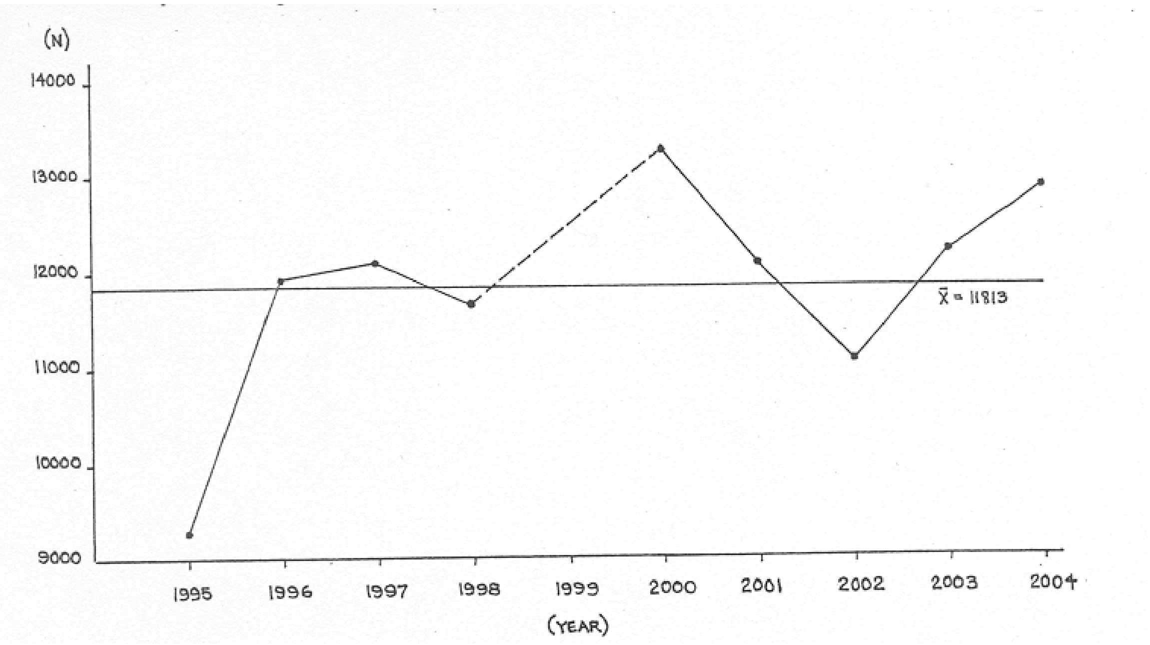


Figure 18. Annual densities of the total population (1995 – 2004). Totals are in Table 2.

Hectare density and are frequency: The highest density recorded during the ten year period was 3759 plants in 5B in 1996, followed by 3725 in the same hectare in 2004 (Table 2). This hectare (5B) consistently supported the highest densities in each of the census periods, with a mean density of 3275 plants for the entire sampling period. Other hectares with the highest average densities were 7A, 4B, 5B, and 5C. Although these fell in the range of 1506 to 1312 plants, the highest is far less than that of the highest density hectare. Even at the hectare level, this illustrates the clumped nature of the Yermo population, and from the higher densities there is a tapering-off in numbers of plants to hectares 4D, 6C, 7W, and 8B with only a few plants, and in two cases hectares with an average of <1 plant/hectare.

Hectare 4B had the highest frequency of occupied ares (Table 3), with 63 in 2000. It also consistently had the highest frequencies in each of the census periods. The year 1997 produced the highest number of occupied ares for a total of 345. Considering all years, the number of occupied ares/hectare varied only slightly from a low of 310 in 1995 to the high of 345 in 1997, all other years falling between these two limits. Some of the same hectares had the highest average frequency of occupied ares/hectare as did those with the highest densities/hectare. Highest in this category is 4B, followed by 5B, 7A, 5A, and 4A. Those three hectares with both the highest densities and highest are frequencies were 4B, 5B, and 7A. A rank correlation between average hectare density and

Table 2. Hectare densities (total plants).

	1995	1996	1997	1998	2000	2001	2002	2003	2004	Average
4A	881	1181	1121	1257	1393	1144	1142	1159	1180	1162
4B	1282	1567	1609	1340	1901	1498	1341	1498	1518	1506
4C	497	579	716	688	709	675	565	618	622	630
4D	0	0	0	0	1	0	0	1	1	<1
5W	256	295	360	408	481	427	331	461	463	387
5A	990	1224	1332	1392	1526	1380	1222	1363	1375	1312
5B	2093	3759	3391	3082	3598	3353	3071	3399	3725	3275
5C	1537	1468	1348	1031	1255	1288	1098	1062	984	1230
6A	42	52	70	62	78	57	56	64	62	60
6B	24	40	38	35	40	34	35	29	71	38
6C	1	1	1	1	1	0	0	0	0	<1
7W	0	0	2	3	4	4	6	4	6	3
7A	1144	1191	1503	1706	1724	1551	1567	1736	1918	1560
7B	466	459	501	508	421	517	477	643	710	522
8A	21	29	44	50	50	57	53	90	100	55
8B	3	3	3	1	3	1	1	2	1	2
8E	57	63	60	71	62	79	76	71	92	70
Total	9294	11911	12099	11635	13247	12065	11041	12200	12828	11813

average frequency of occupied ares/hectare yields a Spearman Coefficient of 0.96, indicating close agreement in number of plants and how they are distributed in a clumped pattern, gradually tapering-off toward the periphery, away from the density centers. On this periphery, the same hectares (4D, 6C, 7W, and 8B) had the lowest average annual frequencies of 1 or <1 occupied are/hectare.

Table 3. Ares occupied/hectare (frequency).

	1995	1996	1997	1998	2000	2001	2002	2003	2004	Average
4A	28	27	29	30	31	29	28	28	29	29
4B	60	61	62	59	63	58	58	59	61	60
4C	20	20	23	24	19	20	22	23	23	22
4D	0	0	0	0	1	0	0	1	1	<1
5W	5	5	5	5	5	5	5	5	5	5
5A	44	44	44	45	44	43	42	43	42	43
5B	52	58	61	58	60	58	56	58	57	58
5C	18	18	19	19	19	18	16	16	16	18
6A	5	7	9	11	9	10	10	11	11	9
6B	3	3	3	3	2	2	2	2	2	2
6C	1	1	1	1	1	0	0	0	0	<1
7W	0	0	1	1	1	1	1	1	1	1
7A	42	41	45	45	43	44	44	44	44	44
7B	18	20	23	23	21	22	21	23	23	22
8A	9	11	13	13	11	11	11	12	11	11
8B	2	2	2	1	2	1	1	1	1	1
8E	3	5	5	5	5	5	5	5	5	5
Total	310	323	345	343	337	327	322	332	332	330

Table 4. Ares with 200 or more total plants.

	1995	1996	1997	1998	2000	2001	2002	2003	2004
4A – 9,1					203			211	
4C – 1,0	320	382	491	496	457	389	348	362	335
5W – 9,3					259	208		227	219
5B – 2,6			202						213
5B – 2,8						222			212
5B – 3,8						200		234	253
5B – 7,7								203	206
5B – 9,7						247	229	215	205
5C – 0,8	318	312	319		204	294	202	246	243
5C - 1,9	297	226	232	267	255			210	
5C – 2,9	290	291	217	267	260	299	372	230	
5C – 2,8	297	292	243						
7A – 6,6			222	241	210	208		217	
7A – 6,7				221	246	250	293	269	335
7A – 7,7									228

Are density: The highest are densities recorded were all in 4C – 1,0 in 1997 – 2000, the single highest being 496 in 1998. With consideration of values ranging from one plant/are to 496/are, we have designated, somewhat arbitrarily, approximately 40% of this highest value as a "high density" are. The result is the identification of 15 ares with densities of 200 or more plants for at least one year of the study. During the entire study period, there were 65 occasions when one or more of these ares had 200 or more plants (Table 4). All other ares at all other times had densities less than 200 plants. The are 4C – 1,0 consistently had the highest densities each year, except 2002 when it was exceeded by 5C – 2,9.

The distribution of the "high density" ares shows the centers of concentration of Yermo plants within the grid, which is the total range of the species. The ares of the northern tiers within hectares 4A, 4B, 4C, plus those within the hectares 5W, 5B, and 5C in the adjacent southern tier, contain most of the plants. The remaining "high density" ares are in 7A. Averages of the 15 ares from the nine census years are (ranked from high to low): 4C – 1,0 (398), 5C – 2,9 (268), 5C – 0,8 (257), 7A – 6,7 (246), 5C – 1,9 (221), 7A – 6,6 (204), 5W – 9,3 (189), 5C – 2,8 (180), 5B – 3,8 (179), 4A – 9,1 (175), 5B – 2,8 (174), 5B – 9,7 (172), 5B – 2,6 (165), 5B – 7,7 (139), and 7A – 7,7 (123). Figure 10 shows that these "high density" ares form five distinct clumps of varying sizes. Adjacent shaded ares assist in defining the clumps and are those for which nine-year density averages have also been calculated. These moat-like borders do not appear to have any consistent density relationships to the high density ares of the clumps. The ranges of these averages are 1 – 118 for the 4A moat, 0 – 152 for the 4C/5B/5C moat, 30 – 102 for the 5W moat, 9 – 136 for the 5B moat, and 0 – 87 for the 7A moat. In many cases, the average densities in ares adjacent to the clumps are much lower or plants are missing altogether, indicating abrupt changes. In others the average densities approach those of the clumps, indicating that the clump in all probability is somewhat larger than the grid, which is superimposed over habitat, would indicate.

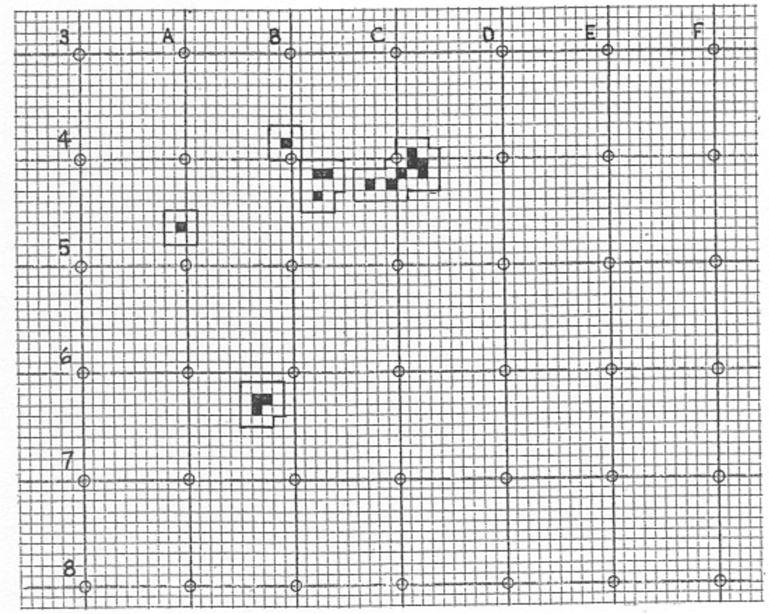


Figure 10. Dark squares are ares with 200 or more plants for at least one year; adjacent moats are ares which have calculated nine year averages.

Stability of the population: Previously (Figure 9) we have shown fluctuations in the total population size from 9294 individuals to 13,247 individuals. The low of 9294 occurred in the first year of sampling, while the high of 13,247 occurred in the year 2000. Other years were characterized by departures from these two extremes. The longest period of increase was two years, from 2002 to 2004, and possibly from 1998 to 2000, although there was no census in 1999. The longest period of decrease was also two years, indicating that it would be reasonable to expect the population to fluctuate on a short-term basis as a result of environmental pressures placed on the species.

Whether the species is spreading into available new habitat is an entirely different question. The pattern of occupied ares has remained approximately the same during our ten-year study period, with increases and decreases in various places. However, if ares that contained plants in 1995, but did not in 2004 (and the reverse) are indicated on our grid map, an interesting pattern emerges (Figure 11). Here we see 17 ares that contained plants in 1995, but not in 2004. This represents 35 plants lost. Most of these ares are peripheral, with a few containing outlying, isolated plants. However, there are 37 ares occupied in 2004 that were not occupied in 1995. These are all on the periphery and contain

104 plants. Some ares show distinct colonization patterns in what appears to be optimum habitat connecting previously occupied ares. As a result, we calculate that the population gained 69 new plants through colonization of new habitat in spite of a decrease at the are level during the ten-year period. This is a relatively small percentage of the 2004 population density of 12,828 plants.

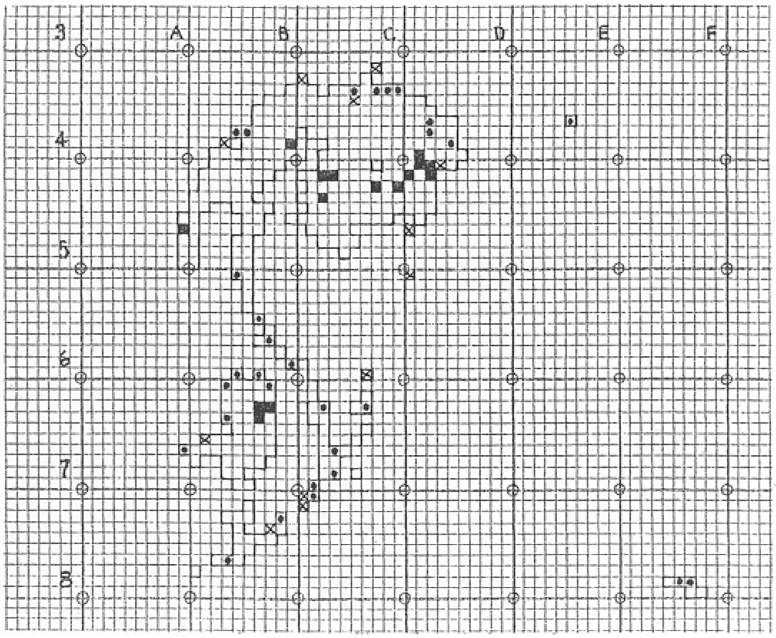


Figure 11. Stability of the population; dots indicate ares occupied in 2004, but not 1995; x's indicate ares occupied in 1995, but not 2004. High density ares from Figure 10 are provided for comparison. See Appendix 13 for detailed site information.

When we began our study in 1995, we found a number of Yermo plants growing on the old Sohio Petroleum Co. Government 1 Unit access road in the southeastern portion of the grid. This was an exciting find, since the well was completed in 1952 and the road was bladed to the well from Wyoming Highway 135, but no further. Evidence suggests no previous road on this route, but, regardless, the construction produced a new, fresh surface. Other roads through the site probably originated with seismograph activity in the 1940s and 1950s. At least one had plants growing on it in places, but we had no means of dating the surface. However, the Sohio Road had an age spread of 43 to 53 years for the surface, and we had an opportunity to show colonization and spread of the plants following the 1952 oil well activity. Plants were growing in suitable habitat, namely intermittent watercourses, adjacent to the road in 1995, but whether they were present in 1952 is, of course, unknown. Furthermore, the road is bordered by Artemisia tridentata stands, which is non-habitat for Yermo. The road thus became a ribbon of suitable habitat extending through non-habitat with an adjacent seed source close by and a convenient migratory pathway where intermittent watercourses crossed the road.

Table 5. Sohio road plants.

Are	1995		1996		1997		1998		2000		2001		2002		2003		2004	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
7B	151	6	146	7	156	9	138	9	160	7	147	7	146	7	146	9	145	9
8A	4	4	6	6	12	8	13	8	6	5	6	5	6	5	9	6	10	5
8B	3	2	3	2	3	2	1	1	3	2	1	1	1	1	2	1	1	1
T	**158**	**12**	**155**	**15**	**171**	**19**	**152**	**18**	**169**	**14**	**154**	**13**	**153**	**13**	**157**	**16**	**156**	**15**

N = number of <u>Yermo</u> plants in the road; A = occupied ares on the road (24 was the total number occupied during the study.

These watercourses appear to be the major routes that <u>Yermo</u> plants follow. Our working hypothesis was as follows: If <u>Yermo</u> was actively colonizing new surfaces, then we should detect an increase in plants on the relatively new surface of the Sohio Road during our study period. If not actively colonizing, then we should see no new plants and a more or less static number of individuals at the same places they occurred in 1995. Periodic post-1952 vehicle activity was probably not a factor, since the Sohio Road was fenced at the highway, did not extend beyond the oil well site, and was transversed by several wash-outs. At the time of our first census, we documented 158 <u>Yermo</u> plants growing on the Sohio Road in portions of the 7B, 8A, and 8B hectares (Table 5). At the last census, ten years later, 156 plants were found in the same three hectares. This is not the entire story, however, as evidenced in Figure 12, which compares the annual census with the occupied ares on the road and shows fluctuation in both numbers of individuals and their distribution on the road. While there does not appear to be any consistent correlation between the two, the year 1997 demonstrates a high in both numbers of plants and ares occupied. The highest population density in 2000 is somewhat reflected in the second-highest number of individuals on the road, but the distribution dropped to only 14 ares from a maximum of 19 in 1997. Thus, we are unable to see any sustained spread of plants during the study period. Figure 13 shows that most of the colonized portions of the road had plants already present in 1995. Some movement did occur after 1995, particularly toward the southerly portions of the grid, but it does not appear to be a great distance.

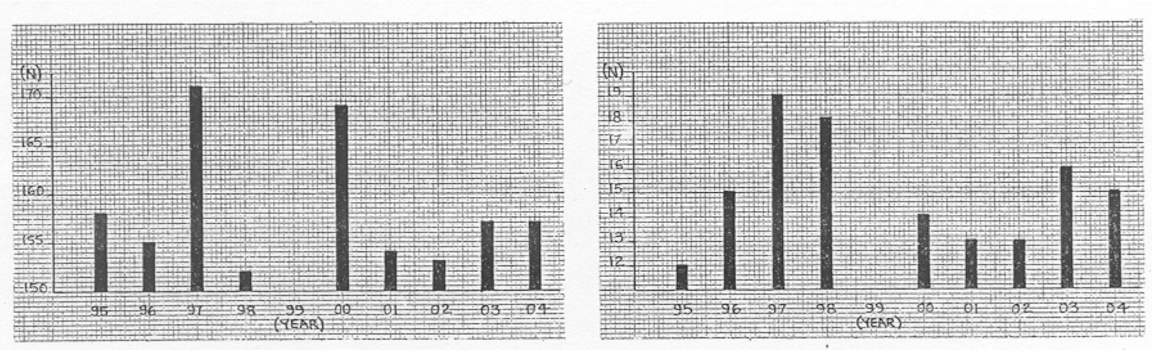


Figure 12. Plants (left) and ares (right) on the Sohio Road.

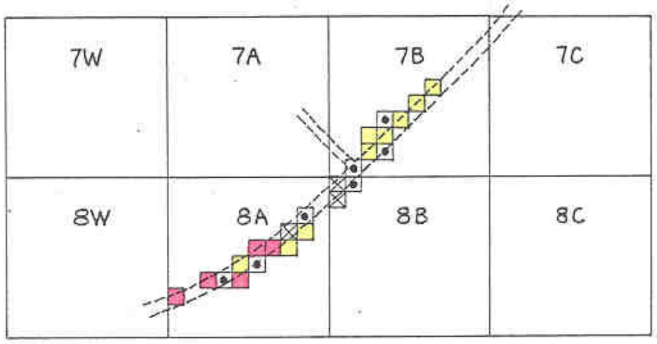


Figure 13. The occupied portion of the Sohio Road: x's were occupied in 1995, not in 2004; dots were occupied in 2004, not in 1995; yellow were occupied in both 1995 and 2004; pink were occupied in neither 1995 nor 2004.

It appears, from the studies of the grid and the Sohio Road, that the Yermo population, at least for our ten-year period, has remained essentially static, neither expanding nor contracting significantly within the general outline of the area occupied. Numbers of individuals have fluctuated considerably, but always within the outline of occupied habitat. Due to a severely shifting and fluctuating habitat, the population appears to respond with fluctuations in both numbers and occupied habitat. If new local surfaces become available, at least some plants colonize them. If local environmental stresses become too severe, the numbers diminish at those sites, while elsewhere within the outline of occupied habitat, they may be increasing. A selected number of these environmental factors and their effects on the plants are discussed in another section. Flowering is also discussed later.

Flowering plant density: Although the first census in 1995 yielded the lowest total of all Yermo plants, that same year produced 1805 flowering plants, the highest recorded during the study (Figure 14, Table 6). The following year, flowering plants dropped to 443, very near the lowest totals recorded during the last two years of the study. Since vegetative plant densities reflect the gains and losses in total density, and flowering densities do not, it is obvious that the flowering process is either responding to different environmental factors or responding in a way different than the vegetative plants. Flowering plant densities were consistently less than 20% of the total densities, varying between

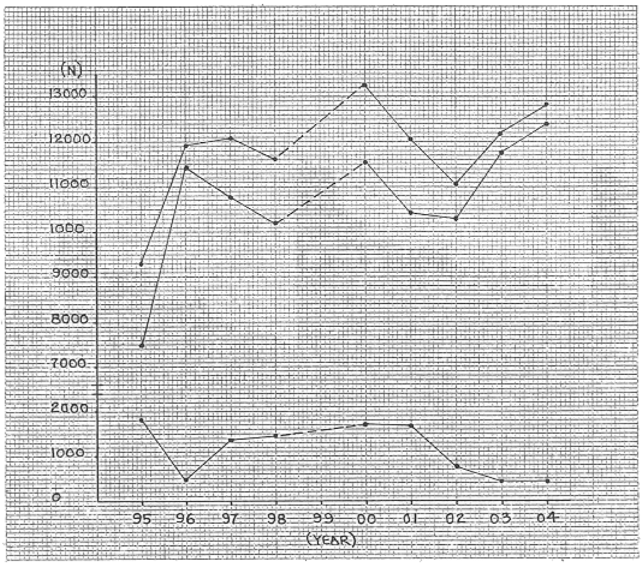


Figure 14. Annual densities (1995 – 2004) of total plants, vegetative plants, and flowering plants.

Table 6. Hectare densities (flowering plants).

	1995	1996	1997	1998	2000	2001	2002	2003	2004	Average
4A	235	21	107	129	119	157	92	37	17	102
4B	183	35	153	171	296	210	94	58	49	139
4C	79	13	50	72	73	38	19	14	20	42
4D	0	0	0	0	1	0	0	0	1	<1
5W	43	7	20	42	29	38	29	12	15	26
5A	214	37	128	105	141	170	128	62	36	113
5B	396	121	406	424	558	551	180	99	152	321
5C	176	70	136	164	228	124	54	27	21	111
6A	20	8	16	8	12	13	6	7	8	11
6B	9	15	13	15	11	14	12	3	2	10
6C	0	0	1	0	0	0	0	0	0	<1
7W	0	0	0	2	0	0	0	1	0	<1
7A	282	71	212	190	174	196	97	73	74	152
7B	146	37	110	97	52	134	56	27	29	76
8A	10	4	12	9	13	14	9	5	3	9
8B	2	1	1	0	0	0	0	0	0	<1
8E	10	3	6	7	2	1	0	2	2	4
Total	1805	443	1371	1435	1709	1660	776	427	429	1117

19.42% and 3.33%. The distribution of flowering plants in the grid appears to follow two different patterns. One is a general pattern where flowering individuals are distributed throughout the population, perhaps randomly, although we didn't test for this. The second pattern is that of small, relatively high density areas of flowering plants, sometimes larger than an are, sometimes smaller. For the duration of the study, flowering densities varied from one plant/are to a high of 58 plants/are. Most of the highest density ares contained approximately 50 flowering plants, again regardless of the year. To examine the question of flowering patterns, we arbitrarily picked 20% of 50, or 10 plants, as the lower limit of “higher density”. A count of all ares for all years produced a pattern which showed concentrations of high density ares distributed mostly through the northern portion of the grid. A count of the flowering plants within those ares produced a distribution pattern closely resembling the overall annual flowering pattern (Figure 15). Linear regression analysis supported this relationship with a very high correlation coefficient of 0.98 (Spearman Rank Coefficient of 0.96). The remaining flowering plants do not show this relationship. This suggests to us that there are flowering plants (in the range of 368 – 703 during our study) that flower frequently throughout the population (Table 7). During optimum seasons for flowering, smaller groups undergo a burst of anthesis, raising the total flowering number. During less than optimum seasons, only the plants in the first

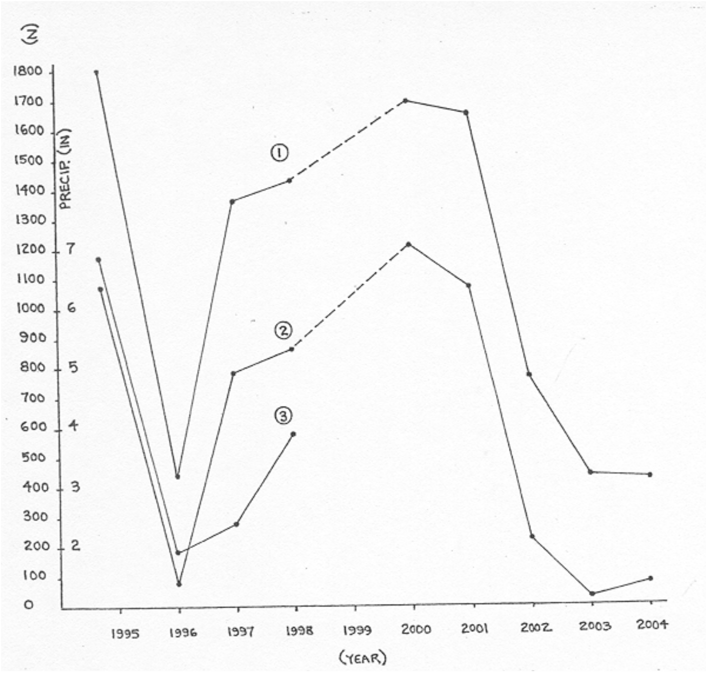


Figure 15. Total flowering plants compared to those of high density ares: 1) Total number of flowering plants for the year; 2) Number of plants in high density ares with 10 or more flowering plants for the year (significance is that high density ares reflect total flowering plants; 3) Partial annual precipitation totals.

group flower. We think this pattern reflects the modular nature of <u>Yermo</u>. The population is a mixture of genets and ramets, with some young plants and other older ones characterized by at least several attached ramets, all of which are capable of flowering. These older plants have deeper taproots and are less susceptible to vagaries of short-term climatic changes. They flower on a more or less continuous basis and therefore compose the first flowering pattern mentioned previously. The second pattern, composed of flowering bursts, is based on younger plants, possibly newer genets, that respond to favorable climatic conditions. During less than optimum years, flowering is low and based only on the older plants. During optimum years, flowering is higher and based on flowering in both types of plants.

Table 7. Flowering plant variation.

Year	1	Rank	2	Rank	3	Rank	4	Rank
1995	59	1	1102	2	1805	1	703	1
1996	5	7.5	74	7	443	7	369	8
1997	48	3	806	5	1371	5	565	4
1998	47	4.5	867	4	1435	4	568	3
2000	47	4.5	1207	1	1709	2	502	6
2001	55	2	1074	3	1660	3	586	2
2002	18	6	227	6	776	6	549	5
2003	1	9	13	9	427	9	414	7
2004	5	7.5	61	8	429	8	368	9

1 = Number of ares with ten or more flowering plants.
2 = Number of plants in ares with ten or more flowering plants.
3 = Total number of flowering plants for the year
4 = Number of flowering plants for the year minus the number of plants in the ares with ten or more plants (3-2). This number represents plants scattered through ares that have fewer than ten plants.

The Flora

Floristic information in this section is based on a somewhat conservative nomenclature that mostly follows Dorn (1992). Generally, names of authorities are supplied for each binomial at first usage. To conserve space, they are omitted in later discussions. Common names, which are used only for weeds, follow Beetle (1970) and Scott (2007). Voucher specimens supporting species information are housed in the Central Wyoming College Herbarium collection and were collected at various times and intervals during the study period, although most were collected during 1995. The flora at the Yermo site is represented by 21 families, 68 genera, and 105 species, plus one specimen identified only to genus. Seven families are represented by a single species. The largest families are Asteraceae (26 species), Poaceae (16 species), and Fabaceae (15 species). Largest genera are Astragalus (six species), Elymus (six species), and Chrysothamnus (four species). Five genera are represented by three species, namely Cryptantha, Arenaria, Phlox, Poa, and Eriogonum. All other genera are represented by either one or two species.

The flora at the Yermo site may be compared to our upland floristic list of the general vicinity, extending to Beaver Rim (Appendix 4). This list does not include collections from the Government Meadows wetlands a short distance both north and south of the Yermo site. The upland list consists of 41 families, 144 genera, and 278 species. Eighteen families in the larger upland flora are represented by a single species. The largest families are Asteraceae (71 species), Poaceae (33 species), and Brassicaceae (31 species). Largest genera are Astragalus (15 species), Elymus and Erigeron (10 species each), and Artemisia (nine species). Of the 278 species on the upland list, 30 were collected only at the Yermo site. Although a number of these 30 were observed at other sites with similarities to Yermo habitat, they do not seem to have any significant fidelity to such habitats (see Plant Associations). We cannot at present test this, however, since the floristic portion of our study was primarily for purposes of species documentation, rather than comparing assemblages of species at different sites for their relationship to, or potential use as, indicators of Yermo habitat. Approximately 38% of the 278 upland Beaver Rim species are found at the Yermo site.

Biotic and Abiotic Influences

Exotic weed species: Due to the extremely vulnerable position of Yermo xanthocephalus imposed by small habitat size and low population density, the species is particularly susceptible to disturbance by various factors, one of which is invasion by exotic weed species. Results of such an invasion can be lowered ecosystem diversity as well as lowered presence of native species (Billings, 1990). Although it is generally recognized that areas of low species richness (Tilman, 1997) and cover are susceptible to weed invasion, including species-poor islands (Vitousek, P.M., et al., 1996), other studies (Stohlgren, et al., 1999) have shown that even areas of high diversity and resource availability are potentially subject to invasion by exotic species.

In the course of our studies, we have mapped exotic invasives within the immediate vicinity of Yermo, as well as the entire Beaver Rim area approximately eight miles both north and south and much further to the west. To date, we have located and mapped by GPS the following perennial species within four miles of the site: Cardaria chalepensis (L.) Hand.-Mazz. and C. pubescens (Meyer) Jarmol. (whitetop), Centaurea repens L. (Russian knapweed), Cirsium arvense (L.) Scop. (Canada thistle), Elaeagnus angustifolia L. (Russian olive), Halogeton glomeratus (Bieb.) Meyer (halogeton), Hyoscyamus niger L. (black henbane), and Onopordum acanthium L. (Scotch thistle). The closest stands to the Yermo site are Centaurea repens, about 1/3 mi (0.5 km) away on Wyoming Highway 135, Cardaria sp., and Hyoscyamus niger, both about ½ mi (0.8 km) away on the Cedar Rim Road. Of great concern is Onopordum acanthium, which forms very large, pure stands in the vicinity of the Sand Draw Oilfield, about eight mi (12.9 km) away. The nearest individuals of this species have been found about four miles from the Yermo site, as has at least one Elaeagnus angustifolia individual. Tamarix chinensis Lourd., also common at Sand Draw, has been documented at the same site as the latter two.

A second group includes additional perennial or biennial exotic species that are well-established in Fremont County and presently occupy the same elevational range or similar environments to that of the Yermo site: Arctium minus (Hill) Bernh. (burdock), Cynoglossum officinale L. (houndstongue), Euphorbia esula L. (leafy spurge), Linaria dalmatica (L.) Mill. (Dalmatian toadflax), Linaria vulgaris L.

(yellow toadflax), Carduus nutans L. (musk thistle), Centaurea maculosa Lam. (spotted knapweed), Convolvulus arvensis L. (field bindweed), Cirsium vulgare (Savi) Tenore (bull thistle), Glycyrrhiza lepidota Pursh (wild licorice), Lepidium latifolium L. (perennial pepperweed), Potentilla recta L. (sulfur cinquefoil), and Verbascum thapsus L. (mullein). While we have not yet found and mapped these species near the site, numerous stands in a westerly direction closer to the Wind River Range and agricultural holdings are found within 23 mi (37 km) or much less that could function as potential seed sources for invasion of the Yermo site. There are 22 species in the above two groups. Sixteen of the species in these two groups make up 62% of the official Designated Wyoming Weeds List that currently contains 26 species (Appendix 5). All the species are on the Regional List (1991).

Annual weedy species are another concern. While we have not found these in the immediate vicinity of the Yermo site, a number of them are showing up in disturbed areas and in available habitats with low competition. Some of the most common are Alyssum alyssoides (L.) L. (pale alyssum), A. desertorum Stapf (desert alyssum), Bromus tectorum L. (cheat), Chorispora tenella (Pallas) DC. (blue mustard), and Malcolmia africana (L.) R.Br. (African mustard). All have a very high reproductive potential and in some places form extensive mats and very large, pure stands. At the time of our most active work on the site flora (1995), we found no Bromus tectorum. Hopefully the site will remain untouched by this and other invasive species. The best defense and management tool against these invaders is, of course, an active monitoring system with timely follow-up control.

Fire: We did not test the effects of fire on the Yermo population during our studies. The entire site probably has an overall lower susceptibility to direct damage on the Torriorthent soils because of low species cover values and large areas of bare ground (see next section). In the interior portions of the site, there would probably be little direct damage to most Yermo plants because of their perennial nature and extensive and deep root systems, often with a branched caudex in mature plants. Those plants on the edges of the site, however, might suffer in a hot fire moving though the Artemisia tridentata stands with their high cover values (see next section). Juvenile plants, which are much more susceptible to environmental disturbances than mature plants, would also suffer (see biology section). Our sampling has shown that the majority of plants are vegetative, and a large percentage of these are juvenile and young plants. They not only have small above-ground biomass, but also small, shallow root systems.

Although fire suppression and protection is considered detrimental in some communities, we consider it essential here because of the small occupied area and relatively low density of the species. Furthermore, the well-documented effects of increased radiation, temperatures, net mineralization rates, leaching of nutrients, changes in chemical and biological soil properties, and effects on species composition (Smith and Smith, 2001) are bound to have an influence on any surviving plants. Since most of the native species in both the Yermo species assemblage and the Artemisia tridentata assemblage are perennials, they would require much more time to rebound from disturbances such as fire.

In the aftermath of a fire, the most serious effect would be the opening of migratory pathways for weeds, increasing the susceptibility to invasion by exotic species, especially annuals such as Bromus tectorum (cheat) and biennials like Carduus nutans (musk thistle). Many large areas dominated by cheat have already become established on burned and other disturbed surfaces along the base and top of Beaver Rim. A serious combination of musk thistle/cheat has recently been moving in on mountain foothills burn surfaces along the southern Wind River Front. The result is a high density of these two species in a short time following disturbance, which appears to exclude most, if not all, native species for periods in excess of ten years, based on current observations. The interested reader is encouraged to observe the southeast-facing slopes of Sinks Canyon south of Lander, at an elevation of 6920 -7300 ft (2109 -2225 m), a slightly higher elevation than the Yermo site, for an example of this type of invasion and establishment. In Sinks Canyon, the establishment of these two invasive species is in a former widespread Artemisia tridentata/Purshia tridentata community. These community dominants, which are important winter browse for mule deer, no longer exist at many sites due to fire followed by the invasion of exotic weed species.

Grazing and browsing: Domestic livestock at and around the Yermo site are represented by cattle and occasional small groups of sheep. Wildlife species are primarily antelope and wild horses, with occasional mule deer. Forage of better quality than the Yermo site is available at Government Meadows1.25 mi (2.01 km) north and 0.5 mi (0.8 km) south. Water is available at the lower southern Government Meadows and at the Government Windmill 2.5 mi (4.02 km) north. Based on our observations during the 13 year study period, we do not think that grazing by domestic livestock or wildlife has any major effect on Yermo. Cattle do make trails through the site and occasionally trample plants, sometimes those in flowering or early fruiting condition. To minimize this, permittees at one time were requested by the BLM to place salt blocks at some distance from the site. Ideally, it seems that careful and strategic placement of salt blocks relative to water sources and best forage supply should minimize livestock damage. Wild horses are in the vicinity, but are very infrequent at the site. Antelope are common, but their small hooves don't damage the plants.

We have seen evidence of attempts to graze Yermo plants by both cattle and antelope. In such cases, the plants, or portions thereof, were clipped off and within a very short distance there was a mass of spit-out leaves and stems. Medicinal values have been documented in the related (i.e., tussilaginoid) species Psacalium decompositum (A. Gray) H. Robins. and Psacalium peltatum (H.B.K.) Cass. (Alarcon-Aguilar, et al., 1997). On one occasion, an adventuresome pair, consisting of a certain researcher and a BLM employee, sampled a small portion of the leaves and documented a distinct burning/numbing sensation in their mouths. Based on the results of this experiential research, plus the evidence of pre-chewed/spit-out piles of leaves left by cattle and antelope, we conclude that grazing will never be a major problem for this species. Mechanical damage is certainly possible, however, due to trampling or any circumstances causing a congregation of large, hooved mammals. We were never able to detect any significant damage to the population due to other mammals or insects. However, we dutifully note the occasional loss of a plant due to one or more badger diggings.

Hunting and recreation: We treat these topics separately due to the seasonality of hunting. During the 13 years of our studies, we monitored vehicular and recreational activities on our approach to the site and when we were present at the site. This was frequently on a weekly basis during the growing season from May through September or October. Vehicular traffic could be placed in two categories. The first category consisted of occasional hunters during antelope season. Such visits were infrequent during September, but did sometimes result in broken stems and damaged plants from occasional use of the two-track road that traverses portions of 4W, 5W, 5A, 5B, and 5C. No other use of old roads at the site was ever noted. The second category, which we considered recreational, consisted of people visiting the site to observe Yermo. We established a parking spot on the nivation rim in 5W, outside occupied habitat, and, as far as we know, everyone in this latter category respected and used the established parking spot. To our knowledge there has never been any ATV (or similar vehicle) transgression at the site. Vehicle tracks during antelope season were from full-size vehicles rather than smaller ORVs. We think the minor effects from vehicles are due to the shape and structure of established roads in the area. The Cedar Rim Road, northwest of the Yermo site, tends to draw vehicles to the north (cf. Figures 1, 2, 3). A main two-track road turning east off the Cedar Rim Road leads vehicles generally eastward, but north of the Yermo site. To reach the Yermo site, vehicles must turn southwesterly from this latter road and travel back toward Highway 135, which is visible in the distance. Most off-road enthusiasts and recreationalists seem to trend away from highways and proceed in other directions, rather than turn southwesterly toward the Yermo site and the highway. Whatever the cause, vehicular users are very infrequent at the site. In our opinion, it would be a simple procedure for managers to permanently alter the road system so that interested visitors could view the Yermo site, but have limited vehicular access to it. Current road closures in the area are no more than a temporary band-aid approach.

Vegetation (Plant Associations)

Even the casual visitor to the Yermo site notices the strong difference between the unstable Torriorthent surfaces where Yermo xanthocephalus occurs and the more stable surfaces supporting stands of Artemisia tridentata, with associated species. In our earlier stages of observation, particularly after the sketches of the snowdrift pattern in 1993 (Figure 2), we suspected that Yermo and associated plants made up a low-elevation snowbed community similar to those found in alpine areas (Scott, 1974) and caused by a snow-induced, shortened growing season. Later observations changed our opinion somewhat, and we thought that snowmelt occurred early enough at the site elevation to lack direct influence on the growing season and the species assemblage. Meltwater was present, however, in the early part of the growing season, and there was a definite difference between the species assemblage at this site and similar ones lacking Yermo, compared to that of adjacent areas. In 1995 we decided to quantify and describe this difference as one of the goals in our overall study.

A second goal, related to the first, was to provide a list of the associated species that might be of value in the search for other Yermo plants nearby or elsewhere. We sampled 62 square-meter quadrats in both Yermo and non-Yermo habitat. They were randomly located using our grid coordinates, first locating the hectare to be sampled, then within the hectare the are to be sampled, then within the are the square meter for sampling (Figure 16). The relevé method of Benninghoff (1966) was used, resulting in a species list (the relevé), a cover-abundance value, and a sociability value (an index of association) for each quadrat. The method utilizes seven cover-abundance values representing the range from one individual to a maximum 75 – 100% cover, while the five possible sociability values represent a range from a single shoot, stem, or leaf to a large, dense, homogeneous patch. Other descriptors, such as bare ground, may also be recorded if desired.

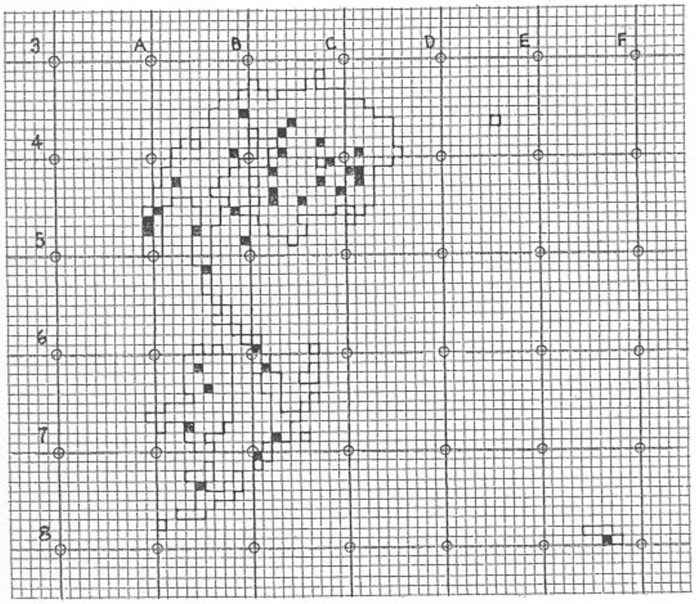


Figure 16. Areas with one or more quadrats, including permanent quadrats.

We sampled 34 quadrats containing Yermo plants and 28 quadrats containing no Yermo plants. All but two of the 28 non-Yermo quadrats contained Artemisia tridentata with dominant combinations of cover-abundance/sociability. All of the

34 Yermo quadrats had relatively large bare ground values estimated at 50% to 97%, averaging 85%. In spite of these large bare ground values, we were surprised to find higher species richness in the Yermo quadrats than in the non-Yermo quadrats. Mean richness in the Yermo quadrats was 9.41176 (median – 10), with a range of 2 – 17 species. That of the non-Yermo quadrats was 7.64286 (median – 8), with a range of 4 – 11 species. Numbers of quadrats and their respective species are illustrated in Figure 17. In contrast to the large bare ground values of the Yermo quadrats, the non-Yermo quadrats had up to 4.4 cover-abundance/ sociability values for Artemisia tridentata, which converts to 50 – 75% cover due to the nearly closed canopy of the plants of this species. The sociability value of 4 describes dense heterogenous patches in which other species are mixed. In aspect, then, there appear to be two vegetation units at the site, one of which is characterized by low cover, higher species richness, and the presence of Yermo xanthocephalus. The other unit has high cover, lower species richness, and for the most part the presence of A. tridentata. Two of the non-Yermo quadrats had neither Y. xanthocephalus nor A. tridentata.

Our quadrat sampling program included 54 taxa from the floristic site list of 106 species. Of the 54 taxa, 47 were identified to species. The remaining 7 were identified to genus only. From the list of 54 taxa, 23 taxa (21 species and two identified only to genus) were only found in the 34 quadrats associated with Yermo xanthocephalus. The 21 species were Yermo xanthocephalus, Arenaria stricta Michx., Chaenactis douglasii (Hook.) H. & A., Cirsium aridum Dorn, Cryptantha caespitosa (A. Nels.) Payson, Elymus spicatus, Erigeron compositus Pursh, Haplopappus nuttallii T. & G., Hymenoxys acaulis (Pursh) Parker, Ivesia gordonii, Linum perenne, Lomatium nuttallii (Gray) Macbr., Lupinus argenteus Pursh, Lygodesmia juncea (Pursh) D. Don ex Hook., Penstemon paysoniorum Keck, Physaria eburniflora Rollins , Psoralidium lanceolatum (Pursh) Rydberg, Senecio canus Hook., Taraxacum officinale Weber, Thermopsis rhombifolia (Nutt. ex Pursh) Nutt. ex Richards., and Zigadenus venenosus Wats.. Of the remaining species, those that were associated with Artemisia tridentata were also found in some combination in the Yermo quadrats. This suggests an indicator plant association occurring adjacent

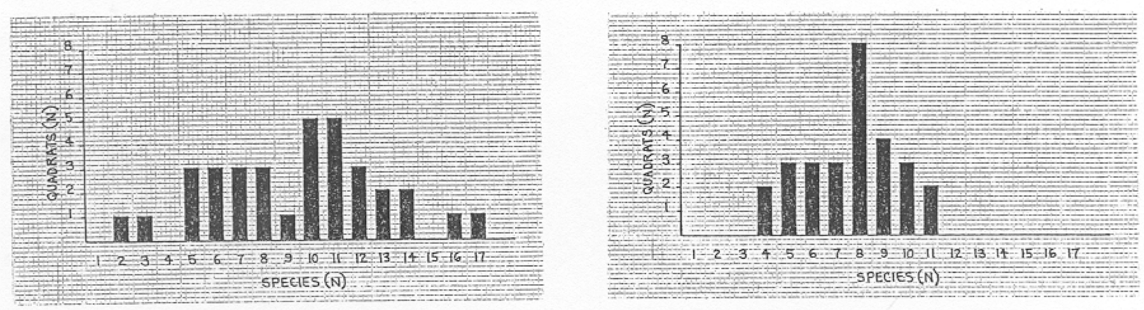


Figure 17. Quadrat richness. Yermo quadrats left (34); non-Yermo quadrats right (28).

to the A. tridentata association that is adapted and more or less confined to the Torriorthent habitat. These species do not, or possibly can not, invade the more stable Cragosen habitat with A. tridentata. However, many of the species associated with A. tridentata are able to colonize sites within Yermo xanthocephalus habitat, but apparently never take hold for any extended period of time as long as the habitat remains unstable. If this is the case, our findings suggest that Y. xanthocephalus and associated species are poor competitors unable to penetrate the stable habitat occupied by A. tridentata and associated species.

These findings are based on a relatively small number of quadrats, but seem to support the concept of two vegetation units present at the site. With additional sampling, our lists would probably change somewhat, since field observations suggest species additions to the quadrat data. However, we wish to emphasize that, in spite of support for a dichotomy of vegetation units at the site, no unique, site-specific assemblage occurs on the Torriorthents. With the exception of Yermo xanthocephalus (100%), the species with the highest frequencies in this unit are species that are common on most all highly eroded surfaces in the general vicinity, along Beaver Rim, and in the foothills of the Wind River Range. These are: Ivesia gordonii, Haplopappus nuttallii (57% each); Thermopsis rhombifolia, Elymus spicatus (41% each); Cirsium aridum (26%); Linum perenne (24%); Lygodesmia juncea (18%); Erigeron compositus, Penstemon paysoniorum, Senecio canus (15% each); and Lupinus argenteus, Lomatium nuttallii (12% each). All remaining species restricted to the Yermo association have frequencies of 9% or less.

Also found in the Yermo association is a second group of 19 species that occurs in both Yermo and non-Yermo quadrats. Like the previous group, many of these are common on eroded surfaces along Beaver Rim. Members of this second group, arranged from highest frequency to lowest, are: Arenaria hookeri Nutt. (41%); Cordylanthus ramosus Nutt. ex Benth. , Haplopappus acaulis (Nutt.) Gray (38%); Oryzopsis hymenoides (R. & S.) Ricker ex Piper (35%); Koeleria macrantha (Ledeb.) Schultes, Machaeranthera canescens (Pursh) Gray (32%); Phlox muscoides Nutt. (29%); Phlox hoodii Richards. (24%); Artemisia tridentata Nutt., Eriogonum brevicaule Nutt. (21%); Elymus lanceolatus (Scribn. & Smith) Gould (18%); Antennaria microphylla Rydb. (15%); and Leptodactylon pungens (Torr.) Nutt., Eriogonum ovalifolium Nutt. (12%). The remaining five species in this group have frequencies of 9% or less.

There were 31 taxa (26 species and five identified only to genus) that were found in the non-Yermo quadrats, which we are tentatively identifying as an Artemisia tridentata association. These species, also arranged from highest frequency to lowest are: Artemisia tridentata Nutt., Cordylanthus ramosus Nutt. ex Benth. (93%); Elymus trachycaulus (Link) Gould ex Shinners (75%); Festuca ovina L. (61%); Gilia tweedyi Rydb., Phlox hoodii Richards. (46%); Arenaria hookeri Nutt. (43%); Stipa comata Trin. & Rupr., Oryzopsis contracta (Johnson) Shechter, Leptodactylon pungens (Torr.) Nutt. (29%); Allium textile Nels. & Macbr., Trifolium hybridum L., Elymus lanceolatus (Scribn. & Smith) Gould (25%); Carex filifolia Nutt. (21%); Oryzopsis hymenoides (R. & S.) Ricker ex Piper (18%); Gutierrezia sarothrae (Pursh) Britt. & Rusby (14%); and Antennaria microphylla Rydb., Koeleria macrantha (Ledeb.) Schultes (11%). The remaining species in this group have frequencies of 7% or less. Some members of this group were not found in any of the Yermo quadrats. These eight species were Allium textile, Carex filifolia, Elymus trachycaulus, Gilia tweedyi, Orobanche fasciculata Nutt., Oryzopsis contracta, Stipa comata, and Trifolium hybridum.

Presence data, based on relevé sampling, were used to examine similarity between Yermo and non-Yermo quadrats and the concept of two associations or vegetation units. Similarity was based on the commonly used Bray-Curtis equation of $C = 2w/a + b$ where a = number of species in one quadrat, b = number of species in the second quadrat, and w = number of species in common to the two quadrats. This coefficient of similarity was then converted to dissimilarity. Cluster analysis based on dissimilarities (Figure 18) indicates additional, but not clearcut, support for two vegetation units at the site. Strongest clustering occurs in a set of 27 of the total 34 Yermo quadrats. As might be expected, these are the quadrats with the largest number of the relatively high-frequency species discussed above. Some weak clustering, plus mixing of the remaining seven Yermo quadrats with those exhibiting Artemisia tridentata dominance and fidelity (based on their frequencies), illustrates the encroachment of this second group of species into Yermo habitat. We visualize a dynamic, changing composition of a segment of the Yermo association based on members of this latter group because of the open, unstable surfaces on which Yermo xanthocephalus and associated species are found.

Clustering of the non-Yermo quadrats is less coherent than those of Yermo. The two strongest clusters in this category exhibiting similarity approximately equal to that of the Yermo group are a group of 16 species in ten quadrats and a second group of 22 species in seven quadrats (Figure 18). The 22 members of these groups show the same high frequencies within the two groups, collectively, as found in the total 28 non-Yermo quadrats. The species, arranged from highest frequency to lowest, are: Artemisia tridentata, Cordylanthus ramosus (100%); Festuca ovina (82%); Elymus trachycaulus (76%); Gilia tweedyi (47%); Phlox hoodii (41%); Elymus lanceolatus, Stipa comata (35%); Arenaria hookeri, Trifolium hybridum (29%); Allium textile, Leptodactylon pungens, Oryzopsis contracta (24%); and Carex filifolia (18%). The remaining eight species all have frequencies of 12% or less.

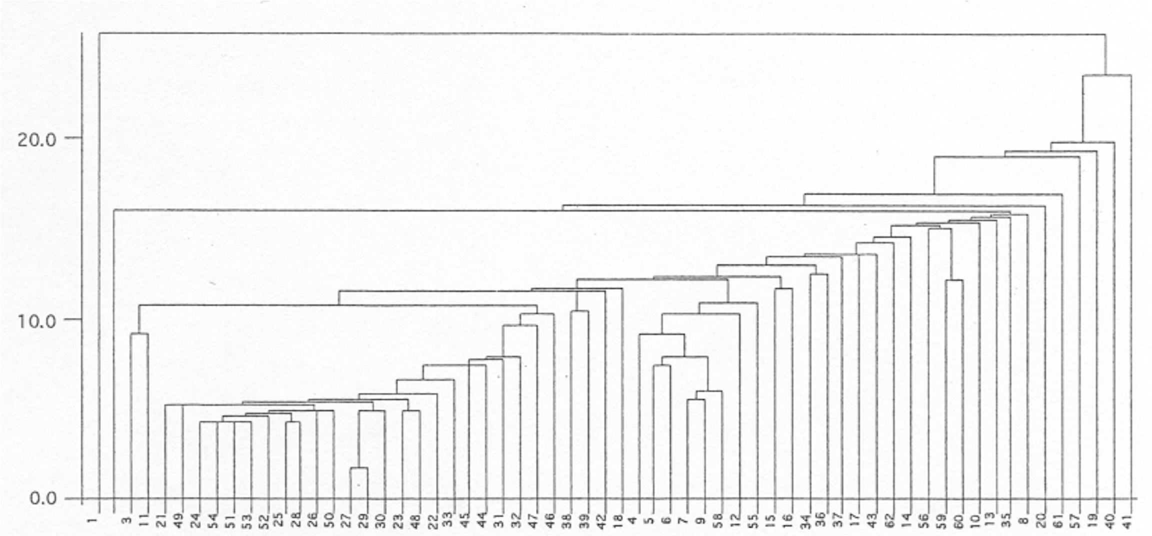


Figure 18. Cluster diagram of the 62 Yermo and non-Yermo quadrats. Among the 34 Yermo quadrats, the strongest clustering is exhibited in the sequence 21, 49, 24, 54, 51, 53, 52, 25, 28, 26, 50, 27, 29, 30, 23, 48, 22, 33, 45, 44, 31, 32, 47, 46, 38, 39, 42. The remaining seven Yermo quadrats (34, 36, 37, 43, 35, 40, 41) show weaker clustering and some affinity with the non-Yermo quadrats. Strongest clustering in the non-Yermo quadrats occurs in the two groups of 4, 5, 6, 7, 9, 58, 12, 55, 15, 16 and 62, 14, 56, 59, 60, 10, 13. These are later joined by both Yermo and additional non-Yermo quadrats.

The Biology of Yermo

Introduction: On August 18, 1992 we initiated a study of Yermo xanthocephalus centered on phenology and related biological events. It continued for the following 12 years. From observations of plants at the site that initial year, we visualized a life cycle somewhat similar to many bromeliads and others, where a few leaves eventually lead to a large basal tuft, then a stalk (stem or peduncle), followed by flowering and fruiting. It looked to us that flowering might then continue with the addition of new inflorescences and flowers until the plant eventually died. Our plant selection for the phenology study was based roughly on this pattern. We chose six groups of five plants each (Table 8), based on a vegetative state of 2, 3, 4, 5, 6, and 7+ leaves, for a total of 30 plants. Individual plants within a group were labeled A,B,C,D,E. Next we selected seven flowering plants with one inflorescence (A,B,C,D,E,F,G), followed by a second group of eight flowering plants with two or more inflorescences (A,B,C,D,E,F,G,H). Both these groups had gone to seed by the middle of August. However, a few plants had very short stems(<5 cm) and compact, nearly basal inflorescences. Within these inflorescences were flowers in bud, or just beginning to open. We selected five of these plants (A,B,C,D,E) and loosely described them as “fall flowering” although it was late summer at the time. Plants in all groups were selected on the basis of being single, somewhat removed from others, and robust in appearance. This gave us a group of 50 plants that we identified by labeled wooden stakes, with colored pin flags for backup, and designated by the number of leaves (i.e., 2A, 2B ,2C ,2D ,2E; 3A, 3B, 3C, 3D, 3E; 4A…;5A…, etc.). Flowering plants were designated F1A, etc. for those with one inflorescence, and F2+A, etc. for those with more than two inflorescences. The five plants in bud were designated FFA, FFB, etc. The phenology plants were described as to phenological state at least every other week, sometimes weekly if possible. Because of other commitments some years, the preceding schedule was not always followed to the letter. For phenology we developed a code (Table 9) for describing each developmental state during the growing season. Fourteen stages were represented in the code. Each stage represented field observations during the latter part of 1992 or the first sampling in 1993. The plants in Stage 1, leaves only, were described by the number of leaves in parentheses following the stage number. Other stages were represented by a number only.

Table 8. Designations for the fifty plants in the phenology study.

2 (A, B, C, D, E)	Two leaves, no flowers
3 (A, B, C, D, E)	Three leaves, no flowers
4 (A, B, C, D, E)	Four leaves, no flowers
5 (A, B, C, D, E)	Five leaves, no flowers
6 (A, B, C, D, E)	Six leaves, no flowers
7+ (A, B, C, D, E)	Seven or more leaves, no flowers
F1 (A, B, C, D, E, F, G)	One inflorescence
F2+ (A, B, C, D, E, F, G, H)	Two or more inflorescences
FF (A, B, C, D, E)	Fall flowering

Groups were identified by vegetative or flowering condition; vegetative plants were grouped by leaf number.

Table 9. Key to phenology symbols.

Phenological stages

No above-ground structures visible	0
Emerging leaves	0.5
Leaves only	1
Green buds	2
Yellow buds, no obvious branches	3
Yellow buds, branches (late bud)	4
Flowering	5
Early flower senescence	6
Fruiting (pappus visible)	7
Fruit dissemination	8
Late season flowering	9
Early plant senescence (early yellow)	10
Plant senescence (yellow)	11
Fall death (dry)	12

(x) = number of leaves in stage 1

Ten permanent square-meter quadrats were placed and marked in 1993. A field sketch map was made of the 10 quadrats and 50 phenology plants. In spite of being a sketch map, it proved easy to follow to each of the positions because of the distinct pattern of intermittent watercourses which extended through the site and on which the positions were located. Later the positions of the phenology plants and permanent quadrats were mapped relative to the sampling grid (Figure 19). The permanent quadrats were "read" once a year to record Yermo patterns within.

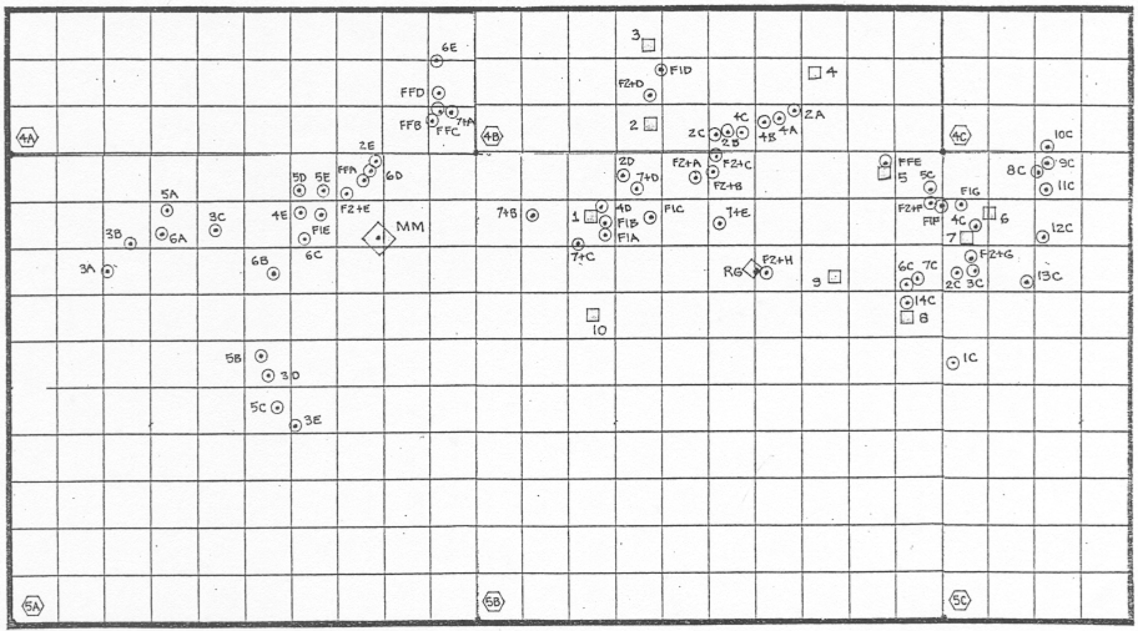


Figure 19. Phenology plants, permanent quadrats (1-10), cotyledon study (1C-14C), and instrument pod (MM).

Permanent quadrats: The permanent square-meter quadrats provided a scale of observation and record that complemented those at the hectare and are levels. We followed the presence of vegetative plants, flowering plants, and cotyledons through a one-time/year recording, usually at or near the end of the growing season (Figure 20). Numbers of vegetative plants varied from 0 to 24/square meter, flowering plants from 0 to 8/square meter, and cotyledons from 0 to 10/square meter. Flowering plants in the permanent quadrats do show some correlation with the total flowering observed in the ares of the grid (Spearman Rank Coefficient of 0.8214), but this is not evident when total plants and vegetative plants are compared with the grid. On an annual basis, it is interesting to note the total of 33 cotyledons in the ten quadrats in 1995. This is the highest number recorded and is based on cotyledons found in nine out of the ten quadrats, two of which had 10 each. The highest number of total plants (94) occurred in 2000, followed by 87 in 1999 and 85 in 1995, which was a high precipitation year. The same three years had the highest number of vegetative plants. Highest flowering years were 2000 (17), 1994 (16), and 1995 (10).

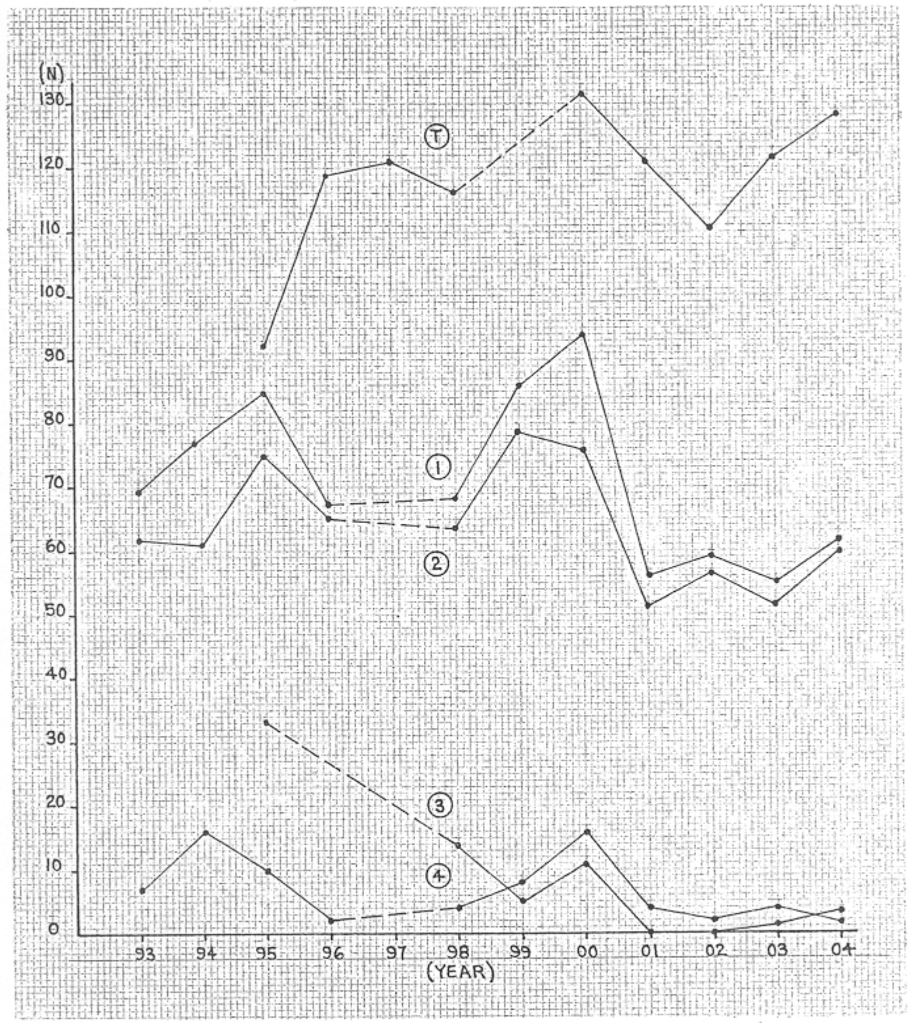


Figure 20. Annual changes in the permanent quadrats: 1) total plants; 2) vegetative plants; 3) plantlets, as evidenced by paired cotyledons; 4) flowering plants. Number of total plants of the species (N/100) indicated by T is provided for comparison.

Phenology: The hypothetical framework of development outlined previously proved to be only partially true, but it provided a usable framework for our work with phenology. There was wide variation in the degree of development that occurred in any single growing season. The year 1993 produced 19 flowering plants. This was 38% of our original 50 plants and simply reflects the 20 flowering, or 40% of the 50 plants that we marked in 1992. After this, the highest number of flowering plants was 12, or 32% of the 37 surviving plants (Appendix 6). A representative pattern of flowering plant development for 1996 is illustrated in Figure 21. (See also Appendix 11.) Values are the codes for development

Table 10. Length of growing season.

Year	Beginning Date	Ending Date	Number of Days
1995	May 15	October 9	125
1996	May 20	September 10	110
1997	May 18	September 6	112
1998	May 16	October 10	127
1999	May 23	September 18	119
2001	May 16*	September 30	138
2002	May 27	September 29	126
2003	May 26	September 22	120
2004	May 9	September 22	137

Mean = 124 days

(Table 9), while the descriptors of low and high indicate the values (codes) for the least and most advanced developmental state of the flowering plants only for that particular year. Flowering began as early as June 15 some years (1994) and as late as August 18 in others (1992). Senescence occurred as early as September 5 (1994) and as late as October 8 (1995). Generally, by August 1, regardless of the year, all plants with potential to flower were either in flower or fruit, although some did flower as late as August 18 as indicated previously. The time interval from emergence of the leaves until plant senescence represented the growing season and varied somewhat from year to year. For a few years we had incomplete data on both development and growing season length, which is why development apparently begins with flowering on June 17 in Appendix 11. Generally, we defined the beginning of the growing season when approximately 50% of the plants exhibited emerging leaves (code 0.5) and the end when approximately 50% of the plants were in senescence (code 12). At least one of the shorter growing seasons was defined by a deep September snow. Growing seasons are indicated in Table 10.

We observed the first plant mortality in 1994, the third year of our phenology study. As we expected, according to our working hypothesis, some mortality occurred in the oldest plant groups (five plants), but there was also a loss of two younger plants for a total of seven plants. Generally, mortality was fairly constant during the 13 years of our study, resulting in a remainder of 13 plants in 2004, a loss of 37 from the initial group of 50 (Figure 22). Some of this loss occurred in vegetative plants that never flowered during the period of our observations. These eight plants are illustrated in Table 11. The remaining 42 plants flowered at least once during the study.

Our initial expectation was that the plants would begin above-ground life with only a few leaves, then add leaves until at some point flowering and fruit production would take place. After the initial flowering, we assumed that the plant would continue to flower for some period before senescence and death. In

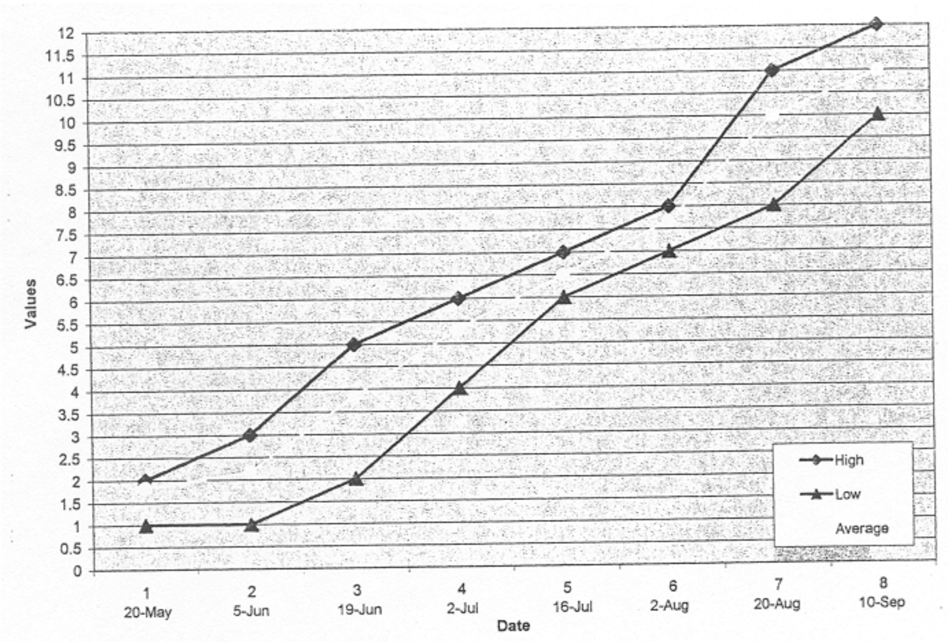


Figure 21. Yermo development for 1996. High values represent the maximum developmental stage for all plants on a given date; low is the minimum developmental stage; average is based on the high and low values.

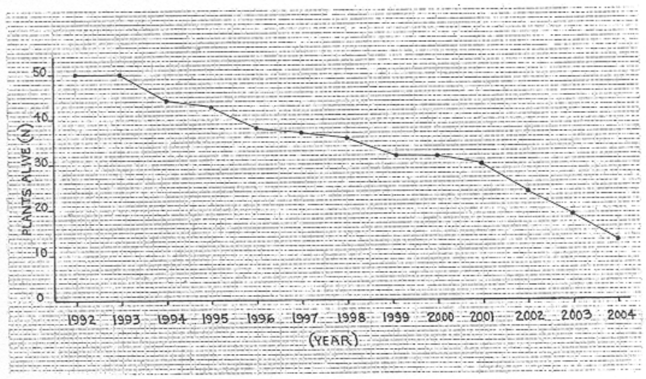


Figure 22. Mortality in Yermo phenology plants.

Table 11. Phenology plants that remained vegetative throughout the study.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
2A	V	V	V	V									
3B	V	V	V	V									
3C	V	V	V	V	V	V	V	V	V	V	V	V	V
3E	V	V	V	V	V	V	V	V	V	V	V	V	V
4A	V	V	V	V	V	V	V	V	V	V	V		
4C	V	V	V	V	V	V	V	V	V	V	V	V	V
4D	V	V											
5E	V	V	V	V	V	V	V	V	V	V			

All plants with six or more leaves flowered.

Table 12. Number of basal leaves produced prior to flowering.

Group	Elapsed Time	Flowering Year	Plants	Leaves
2	5 years	1997	2	7, 12
3	5 years	1997	1	6
4	3 years	1995	2	5, 6
5	1 year	1993	3	5
6	1 year	1993	3	6
7	1 year	1993	3	10

Group numbers are based on leaf number in August, 1992; plants refers to number of flowering plants; leaves refers to number of basal leaves at flowering.

actuality, we found no consistency in either vegetative or flowering patterns (Appendix 6). We did find that a basal cluster of leaves had to develop before flowering would occur. Flowering seemed to follow leaf development rather than a certain time period. In other words, we found that flowering never occurred until a minimum of five leaves was present in the basal cluster. In some plants it occurred later, but never earlier. Table12 shows this relationship in the vegetative groups 2, 3, 4, 5, 6, 7+. Each group contained five vegetative plants with beginning leaf numbers corresponding to the group designation. Four of the plants flowered after five basal leaves had developed, while five plants flowered after six leaves had developed. One plant flowered after seven leaves, and three after ten leaves developed. Lastly, one of the original 2-leaved plants flowered after 12 leaves had developed. The elapsed time for this last plant, however, was the same as the other group member that flowered after a basal cluster of seven leaves. While a basal tuft of at least five leaves was associated with the potential for flowering, it did not, in any way, imply that flowering was imminent, since we found some plants that remained in the vegetative state and developed as many as 56 leaves in the basal tuft without flowering. Figure 23 shows leaf changes in 4C that was initially identified as a four-leaf plant, survived for the 13 years of the study, never flowered, and underwent changes from as few as three to as many as 25 leaves during that time.

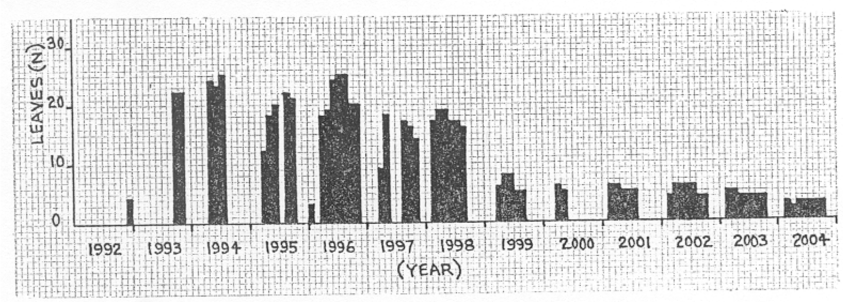


Figure 23. Changes in leaf numbers in 4C. Each year is represented by two squares for May, June, July, August, and September. One square = the first half of the month, the other is the second half. Gaps are either missing data, late emergence, or senescence.

Once a plant flowered, there were three possible outcomes: another flowering cycle, reversion to the vegetative state, or senescence and death. Appendix 6 shows these combinations in the study plants. We could find no correlation as to which outcome was most likely. However, we did develop a flowering index that relates to the three outcomes (Table 13). To construct this table, we recorded the flowering years and the vegetative years during the periods following (and including) the first flowering event until death. The flowering years during this period were then divided by the total years of survival. For example, 6A first flowered in 1993 and flowered three more times, for a total of four, until it died at the end of 1998 (Appendix 6). During the six year period, it was vegetative for two years. Dividing the flowering years by the total years yields an index of 0.667. The index thus decreases from a value of 1.000 (Table 14) for those plants that flowered every year until death, to some lesser value based on the ratio of flowering to vegetative years.

Table 13. Flowering index of phenology plants.

Plant	Flowering Years	Vegetative Years	Total Years	Flowering Index		Plant	Flowering Years	Vegetative Years	Total Years	Flowering Index
2B	1	1	2	0.500		**F1D**	2	3	5	0.400
2C	3	4	7	0.428		**F1E**	2	0	2	1.000
2D	4	0	4	1.000		**F1F**	4	5	9	0.444
4B	1	7	8	0.125		**F1G**	2	0	2	1.000
4E	1	2	3	0.333		**F2+A**	5	6	11	0.454
6A	4	2	6	0.667		**F2+B**	7	3	10	0.700
6B	1	0	2	0.500		**F2+C**	2	3	5	0.400
***6C**	3	8	11	0.273		**F2+D**	7	4	11	0.636
6D	3	2	5	0.600		**F2+E**	1	1	2	0.500
6E	1	9	10	0.100		**F2+F**	7	0	7	1.000
7+A	2	7	9	0.222		**F2+G**	3	4	7	0.428
7+D	3	8	11	0.273		***FFA**	5	5	10	0.500
7+E	4	5	9	0.444		**FFB**	2	1	3	0.667
F1A	2	0	2	1.000		**FFC**	6	4	10	0.600
F1B	1	1	2	0.500		**FFD**	4	6	10	0.400
F1C	2	8	10	0.200		**FFE**	1	2	3	0.333

Shown are the number of flowering years, vegetative years, and the total years after and including the year flowering first appeared in the phenology study. Only plants that died before the end of the study are included. For example, if the pattern for a plant for five consecutive years is F, V, V, F, V, and then it died, the values are 2 flowering years, 3 vegetative years, and 5 total years. Flowering index = flowering years/ total years (frequency).
* Indicates no data for one or two years, so missing data are counted as a vegetative year.

When we began the phenology study, we expected the youngest plants to exhibit the greatest longevity and the oldest plant group the lowest. The younger plants would flower less with time due to more vegetative growth, and the older plants would flower more due to less vegetative growth. Or, the older plants would show greater mortality if they died after flowering. To test this, we treated each

Table 14. Flowering index.

Flowering Index	Number of Plants	Total Years	Phenology Plants
1.000	5	2, 2, 2, 4, 7	F1A, F1E, F1G, 2D, F2+F
0.700	1	10	F2+B
0.667	2	3, 6	FFB, 6A
0.636	1	11	F2+D
0.600	2	5, 10	6D, FFC
0.500	5	2, 2, 2, 2, 10	2B, 6B, F1B, F2+E, FFA
0.454	1	11	F2+A
0.444	2	9, 9	7+E, F1F
0.428	2	7, 7	2C, F2+G
0.400	3	5, 5, 10	F1D, F2+C, FFD
0.333	2	3, 3	4E, FFE
0.273	2	11, 11	6C, 7+D
0.222	1	9	7+A
0.200	1	10	F1C
0.125	1	8	4B
0.100	1	10	6E

Table 15. Phenology summary.

Group	Total Possible Years	Total Years Growth	Total Vegetative Years	(Total Possible Years) % Vegetative	Total Flowering Years	(Total Possible Years) % Flowering	% Growth Years	% Vegetative	% Flowering
2	65	48	39	60	9	14	74	81	19
3	65	56	52	80	4	6	86	93	7
4	65	43	41	63	2	3	66	95	5
5	65	62	57	88	5	8	95	92	8
6	65	40	28	43	12	18	62	70	30
7	65	60	43	66	17	26	92	72	28
F1	91	32	17	19	15	16	35	53	47
F2+	104	67	31	30	36	35	64	46	54
FF	65	36	18	28	18	28	55	50	50

of our sampling groups as a year-block (Table 15). For example, the 2 group contained five plants that during the 13 year-study could have remained vegetative, flowered, or died. There were 65 possible years (13 x 5) in the matrix, or block, in which any one of the three variables could occur. Generally, the year-blocks show the most vegetative growth in the younger groups (the numbers represent the number of leaves in the basal cluster at the initial measurement in 1992). The number of flowering years increases as the age of the groups increase, with the lowest number of vegetative years coupled with the highest flowering years in the three sampling groups that were flowering when the study began. The relationship between age and vegetative and flowering frequency is not quite as linear as we had expected, but there is a distinct association present in the results of this analysis. The highest vegetative percentage and lowest flowering percentage is in sampling group 4 (four leaves in 1992), while the lowest vegetative percentage and highest flowering percentage is in sampling group F2+, all of which had two or more inflorescences at the beginning of the study in 1992.

Germination: Early observations of Yermo akenes suggested morphological differences between those that were viable and those that were non-viable. Later studies supported these observations, making it easy to distinguish viable from non-viable in the field. While length, width, and weight were all significantly different (Scott and Hoster, 2000), we found in the field that plumpness, darker color, and larger size distinguished viable ones from non-viable ones. In 1999 a culture of fresh akenes collected in the late growing season resulted in 55% germination, while those of the previous 1998 growing season yielded a 44% germination (Scott and Hoster, 2000). Cold treatment was not one of the experimental variables of this study, but it is interesting to note the relatively high germination percentages in the two sets of non-cold treated akenes.

During our census in August, 1995, we were surprised to observe throughout the site, and within the permanent quadrats, a large crop of new Yermo plants, represented by two cotyledons per plant. This was a surprise, because we assumed that, as in the case of many cold-temperate plants, some cold treatment and/or dormancy period was required for germination. Our response was twofold: first, we began recording cotyledons in the permanent quadrats. Second, we staked out 14 additional locations with cotyledons, 12 of which were occupied by a single plant (single pair of cotyledons) and two which had 13 and 12 plants respectively. Each location was flagged, surrounded by a cage of woven wire for protection, and mapped on the grid (Figure 19). Our first observation of the locations on June 5, 1996 showed cotyledons at six of the locations and no cotyledons at eight. By July 16 of that year we recorded cotyledons at nine locations. Our first observation of the following year, May 18, 1997, showed cotyledons at seven locations and none at the remaining seven. Our last observation on September 6, 1997 documented cotyledons at seven sites and lacking at seven sites. The first observation on May 16, 1998 showed cotyledons at six sites, none at eight. By May 30 we thought we could distinguish primary leaves at the six. At the last observation on October 10, four plants remained, represented by a total of six leaves, at two sites. The following year no plants were present at any of the 14 caged sites.

The results of this portion of the study are confusing, and we can only suggest conclusions in a general sense. It appears that the cotyledon stage can be maintained in a quiescent state for some time in Yermo, and that overwintering can take place in this stage without the development of primary leaves. A second possibility is delayed germination in some seeds. At any rate, primary leaves do not necessarily appear in short order following cotyledon emergence and expansion above ground. Related to this time lag, the mortality rate of the young plantlets seems to be very high. This might explain why so few new plants are available for replacement and colonization each year.

Seed production: During the field season of 1995, we sampled the inflorescences of randomly selected flowering plants in the northern portion of the grid. For each of the plants we recorded the number of inflorescences per plant (95 samples), the number of heads per inflorescence (50 samples), and the number of viable and non-viable akenes per head (50 samples). Average values for these were 1.4 inflorescences/plant, 40.67 heads/inflorescence, 5.04 akenes/head, and 1.2 viable akenes/head. Table 16 illustrates the use of this information to estimate viable seed production for each year of the study. Large crops of viable seeds were estimated for each year of the study, with a minimum of 29,185 (2003) and a maximum of 123,328 (1995). Applying our laboratory seed germination percentages of 55% and 44%, a large crop of young plantlets should have been available for replacement and colonization each year. For example, using the preceding minimum and maximum numbers, we would expect a potential for as few as 16,052 plantlets in 2003 and as many as 67,830 in 1995. Generally, we began observing young plantlets, represented by two cotyledons, in August of each year. Some years they were quite common. Other years they were very scarce. We assumed these differences were due to dry, hot conditions in the latter part of the growing season, but we never specifically tested this. We did, however, examine cotyledon/plantlet longevity, which is discussed in the permanent quadrat and germination sections.

Table 16. Yermo seed crop.

	Flowering	Inflorescences	Heads	Akenes	Mature Akenes
1995	1,805	2,527	102,773	517,976	123,328
1996	443	620	25,215	127,083	30,258
1997	1,371	1,919	78,045	393,346	93,654
1998	1,435	2,009	81,706	411,798	98,047
2000	1,709	2,393	97,323	490,508	116,788
2001	1,660	2,324	94,517	476,366	113,420
2002	776	1,086	44,168	222,607	53,002
2003	427	598	24,321	122,578	29,185
2004	429	601	24,443	123,193	29,332

Pollination: Pollination was not an objective when we began our studies on Yermo. However, the bright yellow flowers and their tubular shape suggested insect pollination by members of some group with a relatively long proboscis. As we conducted other research, we noticed at least one species of butterfly that regularly visited the plants when they were in flower. We captured two of these and, although they appear to belong to the group popularly known as skippers, family Hesperiidae, they have never been identified by a lepidopterist. Howe (1975) notes that all adults of this family feed and most species visit flowers.

Possibly several species and more than one genus have been present on the flowers at one time or another.

As a result of our observations of the butterflies, we constructed fine mesh bags from nylon stockings and placed them over the young inflorescences of ten plants in the bud stage. They were snugly tied around the stem below the base of the inflorescence and were allowed to develop during the growing season. We intended to exclude all potential insect vectors, particularly large insects such as Lepidopterans. Two of the plants were lost during the period, resulting in eight from which we collected data. The results are in Table 17. Immediately apparent is the large difference between non-viable and viable akenes. Two plants had no viable akenes compared to 853 non-viable. The remaining six plants had some, but not a great number, of viable akenes, compared to large numbers of non-viable. This could be an indication of an apomictic mechanism, but we suspect penetration of our exclusion bags by some insect vector. At any rate, the large difference between non-viable and viable akenes strongly suggests insect pollination, and, based on our observations, it suggests pollination by butterflies. In order to test our pollination findings, we used our seed production data to predict the number of expected viable and non-viable akenes had the inflorescences not been mesh-covered. The results show a distinct difference between the observed numbers of akenes and the expected number of akenes based on our field data. Testing by a technique such as Chi-Square analysis is suggested by the results, but we consider it unnecessary due to the very strong differences that are evident.

Table 17. Number of viable or non-viable akenes in the pollination study of Yermo.

	Observed			Expected		
Plant No.	Non-Viable	Viable	Total	Non-Viable	Viable	Total
1	278	0	278	212	66	278
2	575	0	575	438	137	575
3	223	3	226	172	54	226
4	246	1	247	188	59	247
5	377	2	379	289	90	379
6	420	19	439	335	104	439
7	253	4	257	196	61	257
8	280	2	282	215	67	282
Total	2652	31	2683	2045	638	2683

The life cycle of Yermo xanthocephalus: Any current year seed crop has the potential to germinate and begin growth near the latter part of that growing season. Unfortunately, we did not study seed dormancy and have no figures on possible seed beds of non-germinated seeds. We do have data for one-year old seeds, however, that show a drop in viability of about 11% from 55% to 44% after one year of storage or equivalent seed bedding. In all probability, a certain portion of the annual seed crop would be available to germinate and grow for at least several seasons following production. The process of germination from seed (the akene) to a fully-formed plantlet with a primary root and two cotyledons took 24 days in the laboratory (Appendix 7). If germination began late in the growing season, there seems to be a good chance that development would be terminated by cold weather. However, in our cotyledon study, we observed what we considered to be overwintering by plants in the cotyledon stage. Some cotyledons persisted for more than one year. As discussed in that section of this report, this is a confusing area of study, and we are not sure how long the young plants can survive in the cotyledon stage. However long it might be, all the plantlets that we observed were dead by the beginning of the fourth year. The obvious conclusion from our few plantlets is that mortality is very high in the juvenile stages and may, in fact, be the greatest limiting factor in the size of the population. However, a second obvious conclusion is that some do survive, leading to the first and second leaves, which is the developmental state where we began our phenology study. The two-leaf and other stages are illustrated in Appendix 7.

From our phenology study, it appears that a minimum of five years of development is required before flowering takes place (Table 12). After flowering, there are three possible outcomes: death, another flowering cycle, or a return to the vegetative state for one or more years. Since we were able to follow some plants for 13 years, including the flowering year, it is not unreasonable to expect survival for a number of additional years beyond 13. The plants to which we refer (groups F1, FF, and F2+ in Table 13, Appendix 6) were in flower at the time of our first observation in 1992. Taking into account germination, vegetative development, and subsequent flowering cycles, we can roughly predict that at least some Yermo plants have a lifespan of a minimum of 21 years (approximately three years to the two-leaf stage, a minimum of five years to flowering, and flowering/vegetative cycles following for at least 13 years). At the same time, some plants could possibly remain in the vegetative state for the same duration or a little less (Plant 4C in Figure 23). Selected stages of development beyond the events of germination, leading to large, mature plants, are illustrated in Appendix 7.

The Morphology of Yermo

When Dorn (1991) described Yermo xanthocephalus, he included it in the tribe Senecioneae, possibly allied with the genus Cacalia L., section Conophora. At that time, he noted a history of disagreement as to the status of Cacalia and related genera. More recently, Barkley (1999) included it in Senecioneae, subtribe Tussilagininae (Cass.) Dumort., along with other genera, some of which represent the now-rejected Cacalia L. Where they were previously “cacalioids”, Yermo and other members of its subtribe are now appropriately referred to as the “tussilaginoids”. In the original description, several morphological characteristics were singled out by Dorn for special mention, namely yellow involucral bracts, yellow corollas, and a thick, elongate taproot. The single ecological characteristic of cold desert habitat was also mentioned. These characteristics, as well as several others, were of interest to us in our studies of the species. The other characteristics were the two types of leaves, basal and cauline, the relatively large number of heads, and the relatively small number of disk florets. Our floret numbers were consistent with Dorn's range of 4 – 6, with most heads having five disk florets, producing an average 5.04 akenes/head (at maturity 1.2 of these were viable and 3.8 non-viable). The distinctive taproots, inflorescences, and heads were also of interest to us, and their significance is discussed elsewhere in this report. The distinctive branched caudex of Yermo was omitted from the original description by Dorn, although it was well-illustrated. Because of it, some mature individuals are very robust and visible, especially to pollinating vectors. We think this caudex has valuable adaptive significance for the species in the distinctive habitat that it occupies, also discussed elsewhere.

We were curious as to how the characteristics of Yermo, taken as a group, related to those of other members of the then cacalioid, now tussilaginoid, assemblage of species. Under supervision of the senior author of this report, a numerical taxonomic study (Van Vleet, 1996) was undertaken, with the goal of addressing the question of similarities, or lack of them, between selected species and Yermo. For comparison we chose five additional species represented by specimens kindly supplied by the Rocky Mountain Herbarium, University of Wyoming. The species and reasons for selection were as follows: 1. Arnoglossum atriplicifolium (L.) H. Robins. – midwestern distribution (Nebraska), similar overall morphology; 2. Arnoglossum reniforme (Hook.) H. Robins. – eastern distribution; 3. Arnoglossum plantagineum Raf. – midwestern distribution (Nebraska); 4. Mikania cordifolia (L. f.) Willd. – southeastern distribution (Florida), different morphology, member of a non-tussilaginoid tribe; and 5. Psacalium silphiifolium (Robins. & Greenm.) H. Robins. & R.D. Brettell – Mexico distribution, similar overall morphology. Forty-nine characters were chosen, measured, and recorded. No attempt was made to weight any of the characters. Those discussed by Cronquist (1955) as primitive in the Asteraceae, or those considered to be advanced, were evaluated the same as all other characters. The 12 groups of characters, in alphabetical order with the group first and numbers of characters second, were: akenes – 2, flowers – 2, habit – 1, head – 1, inflorescences – 3, involucres – 7, leaves – 14, pappi – 3, petioles – 6, receptacles – 2, roots – 2, stems – 2. Two-dimensional ordination derived from Bray-Curtis similarity values among the six species produced the results in Figure 24 (a. and b.).

For the purpose of this report, we are presenting these results without further detailed analysis or extensive discussion, since they are preliminary and based on relatively small samples. Regardless of the limits selected, it is evident that the cluster of Yermo xanthocepthalus is the tightest of four species that have measurements from more than one specimen. This indicates less variation in the characters of Yermo than the others, in addition to forming at a discreet distance,

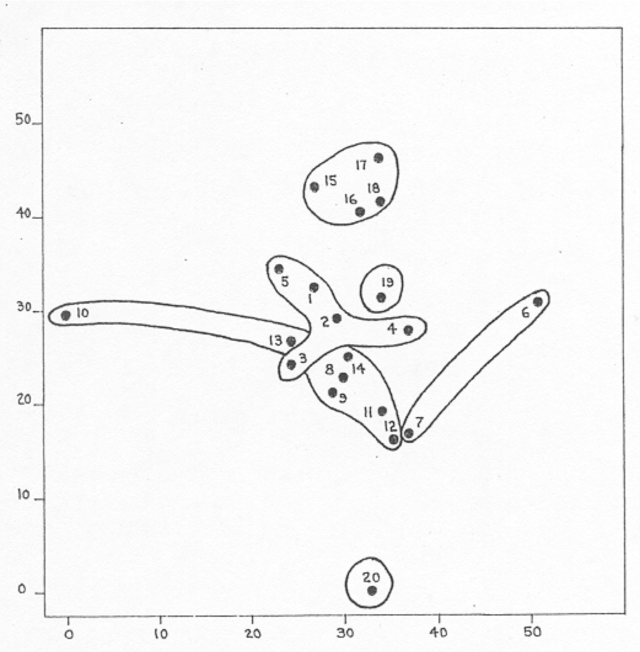


Figure 24a. Taxonomic clustering, based on species identity. Clusters are: (1-5) A. atriplicifolium; (6-7) A. reniforme; (8-14) A. plantagineum; (15-18) Y. xanthocephalus; (19) M. cordifolia; (20) P. silphiifolium.

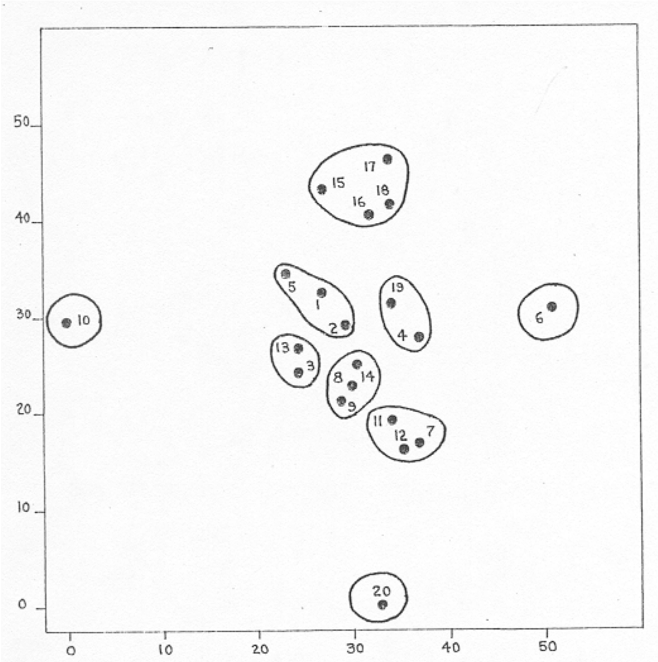


Figure 24b. Morphological clustering, based on pattern. Clusters are: (1,2,5) A. atriplicifolium; (4,19) A. atriplicifolium, M. cordifolia; (3-13) A. atriplicifolium, A. plantagineum; (8,9,14) A. plantagineum; (7,11,12) A. reniforme, A. plantagineum; (6) A. reniforme; (10) A. plantagineum; (20) P. silphiifolium;
(15–18) Y. xanthocephalus.

suggesting dissimilarity. Of the other three species, one of the six specimens of A. plantagineum is far removed from the cluster of the remaining five, a situation for which we do not have an immediate explanation, except that it is different. Arnoglossum atriplicifolium forms a rather diffuse cluster with overlap between it and A. plantagineum. Mikania cordifolia and P. silphiifolium are represented by single specimens. Psacalium silphiifolium, with a distant distribution in Mexico, represents a distinct morphological distance from the other five species in the ordination. Mikania cordifolia is a member of the tribe Eupatorieae, different from that of the other five species (Senecioneae), but does not show a corresponding difference in the ordination pattern.

Climate at the Yermo site

We first began recording climatic data during the winter of 1992/93 when we packed in a stripchart recorder and rain gauge to the site on skis. The instruments were placed in a shelter in the northeast corner of 5A in our grid system at the coordinates 5A-7,8. The location was centered within the highest density of Yermo plants, yet beyond the annual snowdrifts that formed along the west rim of the nivation basin. This shelter structure was later replaced by a battery-powered remote station, also packed into the site on skis. This station (the “instrument pod”) recorded air temperature, relative humidity, wind speed and direction, and rainfall. The pod recorders were supplemented by small soil temperature sensors and back-up air temperature sensors. We had varied success with the overall setup due to the remoteness of the Yermo site and lapses of the sensors for various time increments due to various reasons. As a result, some of our data are fragmentary. Regardless, we soon found that conditions at the Yermo site were not as extreme as we had expected. We think the reason for this is the shape and orientation of the nivation basin where most of the plants occur and where the sensors and pod were placed near its edge. Unless specified otherwise, the following discussion of climate is based on five years of recorded data from 1994 through 1998. Additional years of data were recorded, but have not yet been analyzed. Those that have been analyzed are summarized in the following sections. Their relationships to the Yermo population are discussed elsewhere.

Precipitation and air temperature: Most of the annual precipitation occurs during the months of April, May, and June, although one year the highest precipitation occurrerd in July (1998). Lowest total for the three-month period was 2.58 in (1997), while the highest was 9.37 in (1995). Growing season amounts (in inches) from May through September for the five years 1994 – 1998 were 1.16, 6.91, 1.88 (no data for August and September, 1996), 2.29, 3.47. The maximum monthly precipitation of 4.71 in occurred in May, 1995.

Average monthly temperatures conformed to the expected, steep-sided bell curve with maxima in July or August and minima in December, January, and February, occasionally in March. Average monthly temperatures were generally less than 20C (68F). The highest temperature recorded during the five year period was 35.47C (95.85F) in July of 1998, while the lowest was -27.43C (-17.37F) in January, 1997. Average growing season temperatures from May through September for the five years 1994 – 1998 were 15.63C (60.13F), 13.65C (56.6F), 14.21C (57.58F), 15.27C (59.49F), and 13.15C (55.67F). Warm season temperature averages for July, August, and September for six years beginning in 1993 were 16.61C (61.89F), 17.44C (63.75F), 16.77C (62.19F), 15.40 (59.72F), 16.75C (62.15F), and 18.29C (64.92F). Average monthly precipitation and air temperatures are illustrated in Figure 25 and Appendix 8.

Relative humidity: The <u>Yermo</u> site on Beaver Rim is characterized by often dry air that fluctuates between a value near zero to at or near 100% rH at least one diurnal cycle a month. Figure 26 illlustrates the common pattern of average rH that we measured, with higher values during the winter and before the growing season, lowered values during the growing season, followed by increasing values during the latter part of the year. Generally, the lowest values for rH occurred in July and August and the highest values in the late winter and early spring months of March, April, and May.

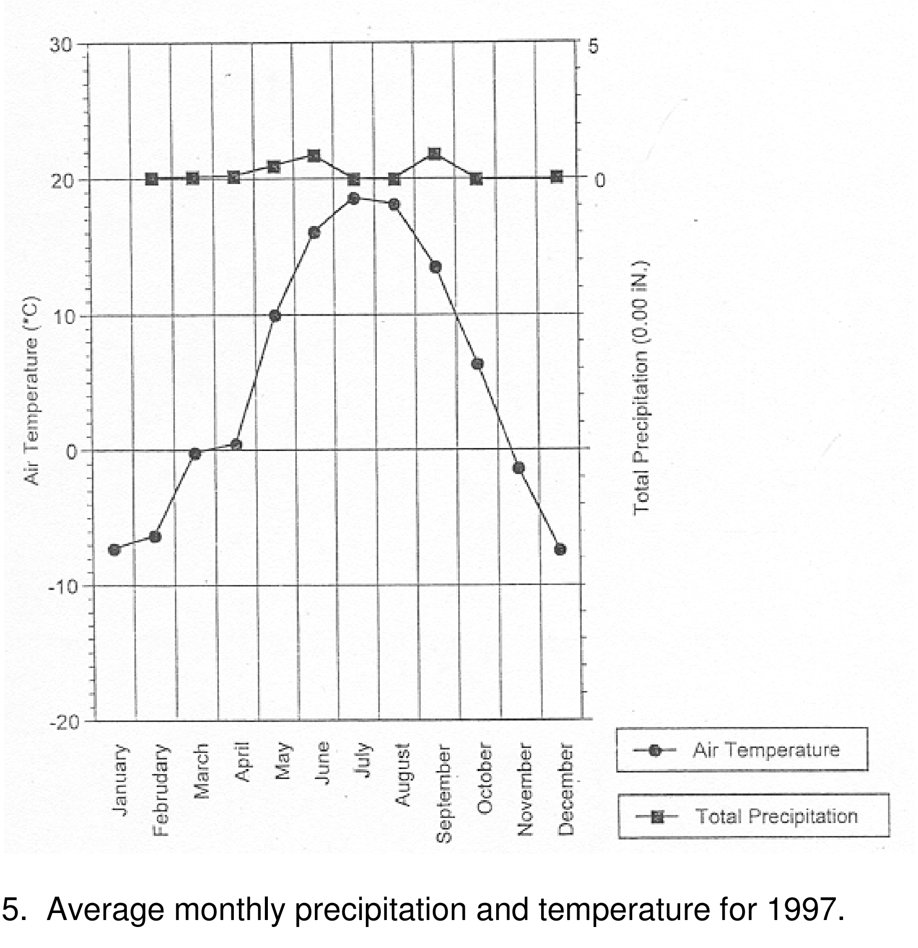


Figure 25. Average monthly precipitation and temperature for 1997.

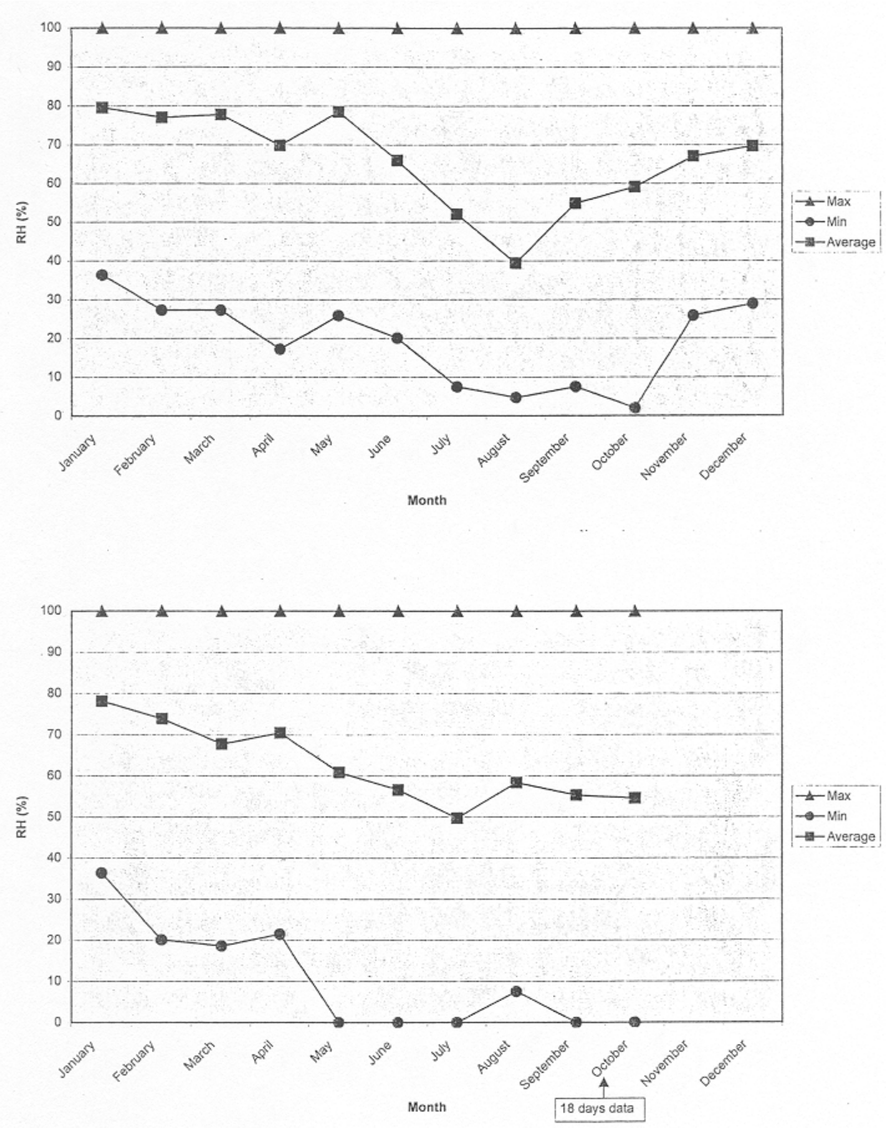


Figure 26. Relative humidity during 1995 (above) and 1997 (below).

Wind direction and velocity: The Yermo site is sheltered, as evidenced by the relatively low wind velocities that were measured. Generally, as a daily average, they were 10 mph or less in the summer, although winter daily averages were recorded as high as 37.29 mph on February 23, 1994. For the most part, January and February were the windiest months. Growing season monthly averages in mph for the period 1994 to 1998 were: May (5.88, 5.66, 7.21, 5.42, 5.05), June (--, 6.03, 6.35, 5.90, 5.45), July (5.17, 4.75, 5.80, 6.00, 4.92), August (5.44, 6.16, --, 5.63, 4.95), and September (5.13, --, --, 6.05, 4.90). July is the month of lowest wind velocities.

There does not seem to be a narrowly preferred wind direction, probably because of the immediate surrounding terrain. Occasional northerly, northeasterly, or northwesterly winds did occur, but most of the winds were southerly, either southwesterly or southeasterly, between 90 and 270 degrees (Figure 27). Average daily growing season winds exhibited a distinct clustering from the south in the range of 140 – 225 degrees for the same period of 1994 to 1998, namely May (155.3, 188.3, 208.9, 194.3, 162.5), June (--, 188.6, 193.6, 191.7, 183.9), July (188.1, 174.2, 192.6, 191.5, 146.8), August (180.3, 222.8, --, 192.1, 141.4), and September (190.6, --, --, 198.4, 143.9). Early in our studies, we used the July, August, and September wind directions to project a downwind plume which would be the most likely path of seed (akene) dissemination. The plume provided pathways to follow in our search for additional Yermo plants, but to no avail.

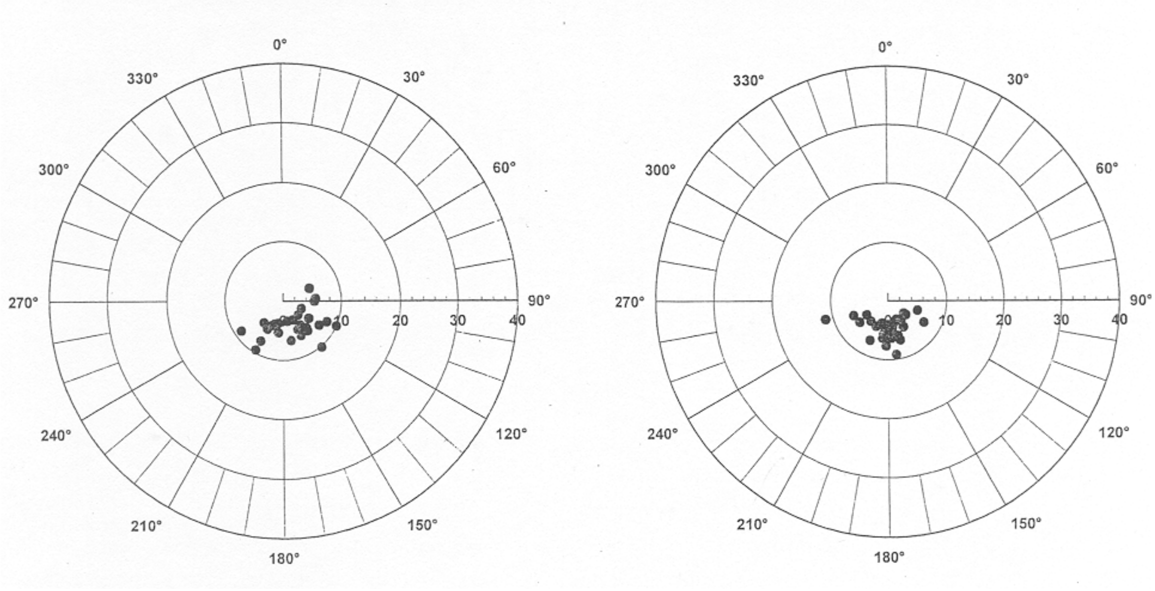


Figure 27. Wind velocity (mph) and direction (degrees) for May (left) and August (right), 1994.

Soil temperature: Sensors to measure soil temperatures were placed at depths of 10 cm (3.94 in) and 20 cm (7.9 in). Placement was at the site of the instrument pod, under open terrain to minimize the effect of drifted winter snow from the nival rim should it persist into the growing season. This did not prove to be a problem, however. The annual pattern of average soil temperature changes at the two levels is illustrated in Appendix 10. As the soil lost heat in the late fall and winter, the temperatures converged and remained close until the spring energy gain caused warmer temperatures at the upper depth and divergence from those of the lower depth. Lack of winter snow cover maintained as much as a 3C lower average monthly temperature at the 20 cm depth than at the 10 cm depth. During the growing season, the difference between the two depths became more pronounced as both depths became warmer, reaching a peak in August. The August peak was consistently present in the five years of monthly data that we have analyzed to date. Generally, the growing season (and the seasonal developmental cycle of Yermo) is easily defined by the spring steepening of the two soil temperature graphs around the beginning of May. Likewise, the flattening in late September to middle October coincides with the end of the growing season. Average daily soil temperatures (Figures 28 and 29) illustrate the early season increase and late season decrease that occur on an annual basis.

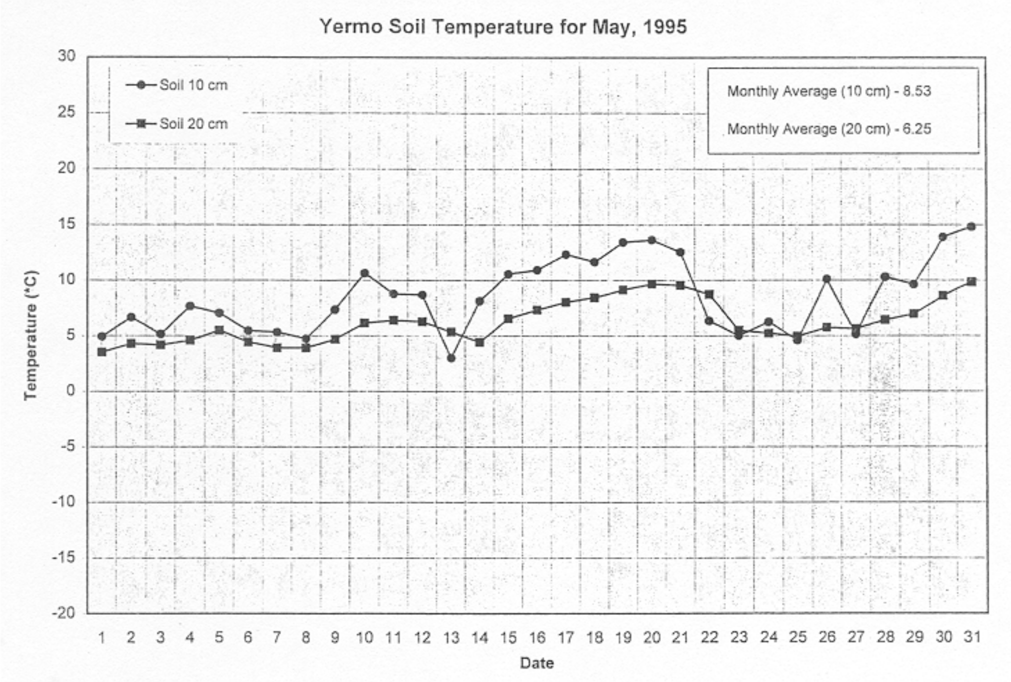


Figure 28. Soil temperatures at two depths for May, 1995.

Yermo and the Environment

The spring flush of growth begins with leaf development either at the root crown in young plants or at the ends of the caudex branches in older, established plants. This event generally occurs about May 15 of each year and coincides with an average monthly air temperature of 8.7C (6.0C – 10.0C), up an average 5.9C from the April average of 2.8C (2.0C – 4.6C). Average soil temperatures at this time of year increase from 3.26C in April to 10.23C in May at 10 cm. Increase during the same period at 20 cm is from -0.35C in April to 6.24C in May. In response to these changes, 20 of 50 phenology plants showed emerging leaves on May 15, 1995, while 38 of 50 were visible on May 20, 1996. Overwintering juvenile plantlets with cotyledons may develop additional leaves during this early part of the growing season. However, both young and established plants may remain vegetative for the entire growing season. Those plants with at least five years of vegetative growth may begin stem development, followed by flower buds and flowering. Flowering can occur as early as June 15 and as late as August 18, resulting in a flowering period as long as 64 days.

Precipitation appears to have the major influence on flowering, followed by air temperature. The years 1995 (1805 flowering plants) and 1996 (443 flowering plants) had the highest and nearly lowest flowering during the study (lowest was in 2003, with 427 flowering plants). Precipitation through June, 1995 was 6.95 in, the highest recorded for the period during the study, while in 1996 it dropped to 1.98 in for the same period. The highest cotyledon production of 33/square meter occurred in 1995. Average monthly temperatures during the growing seasons for the two years show an inverse relationship to the two precipitation differences for the earlier part of the season. In 1995, air temperatures were generally cooler at the beginning (April – 2.51C; May – 5.95C; June – 11.99C; July – 17.42; August – 19.6; September – 13.3) than 1996 (April – 4.3; May – 8.76; June – 16.07; July – 19.52; August – 17.90; September – 8.79). Average October air temperatures at the ends of the seasons were nearly identical for the two years (1995 – 4.97; 1996 – 4.98).

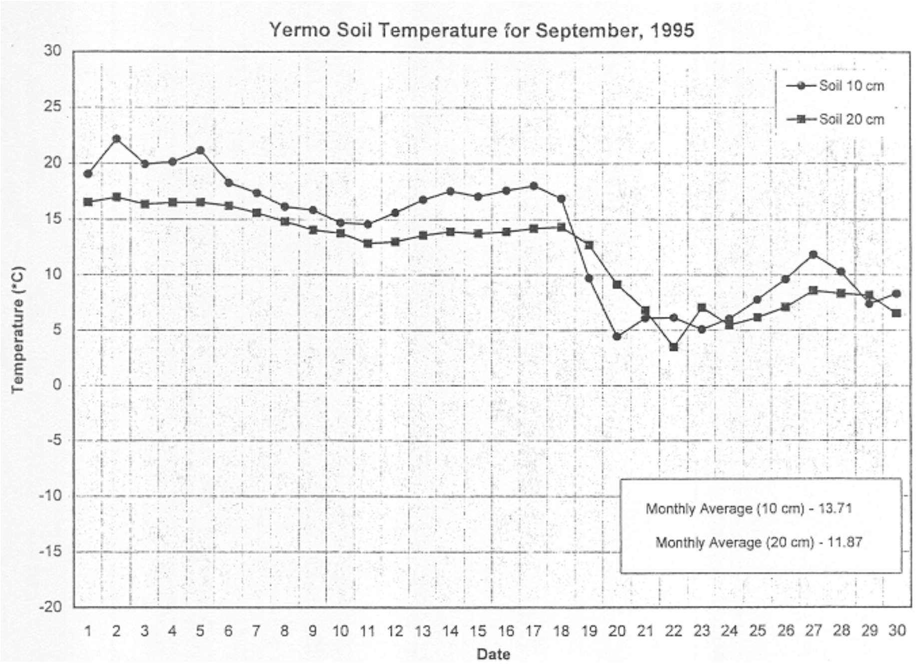


Figure 29. Soil temperatures at two depths for September, 1995.

Instances of September flowering were always in modular plants with two or more ramets. Insect pollination occurs during this period, involving at least some members of the Lepidoptera. Fertile akenes, however, are few, averaging 1.2/head out of the usually five ovaries. Whether this low number is a result of lack of pollination or gametic incompatibility is unknown. Relatively large numbers of fertile akenes are estimated in the total annual crop, ranging from 29,185 (2003) to 123,328 (1995), and they have the ability to germinate during the season of production. We measured 55% viability for the year akenes are produced and 44% for the previous year's akenes. How long they retain their viability is unknown. Fruiting, as measured by a visible pappus, occurs as early as July 12. Seed dissemination begins in early-flowering plants by July 28 and continues until plant senescence. The high average monthly temperature of 19.08C (16.92C – 20.42C) occurs during this time in July or August, depending on the year.

Once the seeds are released, they are apparently not transported for any great distances. The pappus of barbellulate bristles, which is eventually deciduous, or "falling tardily" (Dorn, 2006), does not appear to provide the buoyancy for long-distance atmospheric transport found in other members of the Asteraceae. We envision a short-distance tumbling pattern of dissemination as the result of local convective winds. However, the obvious pattern of plants along watercourses and drainages suggests that the coarse pappus may aid in water dissemination during episodes of flooding following rains and rapid snowmelt. These intermittent floods and surges of water also create an environment hazardous to Yermo plants. Runoff, sometimes strongly channelized, is a powerful erosional feature at the site (Fig. 30). Short storms, whether violent or not, have a magnified effect at the base of the north slopes. Here, sheetwash eventually becomes channelized floodwater that can remove plants and alter the surface of the landscape. At some locations deposition, rather than erosion, is the problem. We have observed stakes and other markers covered, in addition to entire plants inundated by sediment deep enough to leave no trace of the plant. In other cases, where partial inundation occurs, the surviving ramet continues to grow. We think this is a most important structural and asexual reproductive feature (Fig. 31), increasing survival chances of Yermo plants in a fluctuating environment with often unstable substrates.

Generally, seed dissemination is completed by the end of September, when plant senescence occurs, followed by dormancy in October. This is associated with an average monthly air temperature of 13.5C (8.8C – 16.0C) in September, followed by the lowering to an average 8.0C to 5.5C (5.0C – 6.4C) in October.

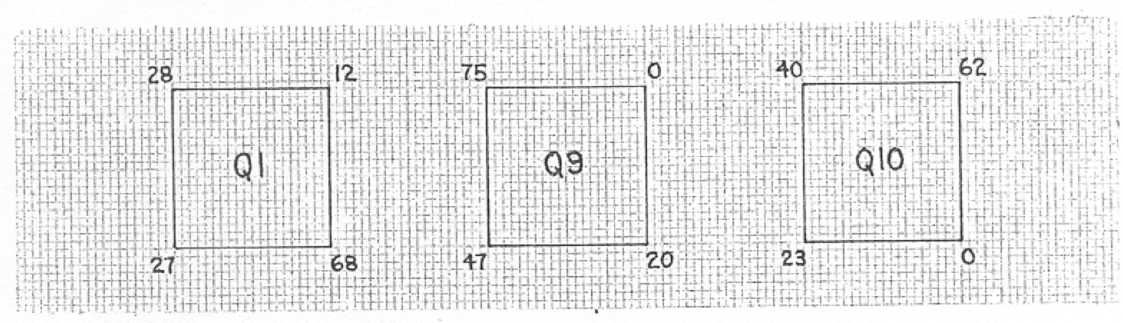


Figure 30. Erosion at corner stakes of three permanent quadrats (cf. Fig. 19). Measurements were made on May 15, 1995. Corner stakes were set flush with the surface and marked with colored pin flags. Numbers at the corners are mm of sediment removed at each quadrat corner by water during a single storm.

Average soil temperatures show an abrupt decrease of 9.02C from 14.46C to 5.44C at 10cm from September to October due to atmospheric heat loss. Similar, but somewhat less, cooling occurs at the 20cm level, where the temperature drops 8.07C from 12.13C to 4.06C. Based on our studies, the maximum limits of the annual growing season from leaf emergence to senescence is 138 days, which was the length attained in 2001. However, in spite of adult plant senescence, the latter part of the growing season is the time when green cotyledons of small plantlets remain visible where, at least in some spots, they are apparently able to overwinter until the next growing season. In some years, dry hot weather can cause high cotyledon mortality before the end of the growing season. As mentioned previously, the entire aspect of the cotyledons remains a puzzling and somewhat confusing part of the Yermo growth cycle, which we have not yet been able to clearly interpret. Considering viable seed production up to 123,328 per year and at least 55% germination, one would expect the population to increase or decrease proportionately with respect to this factor. The fact that it does not suggests very high juvenile mortality. Annual changes in total plant density thus appear to be caused by the balance of older ramet survival and mortality and, to a lesser degree, younger genet survival and mortality.

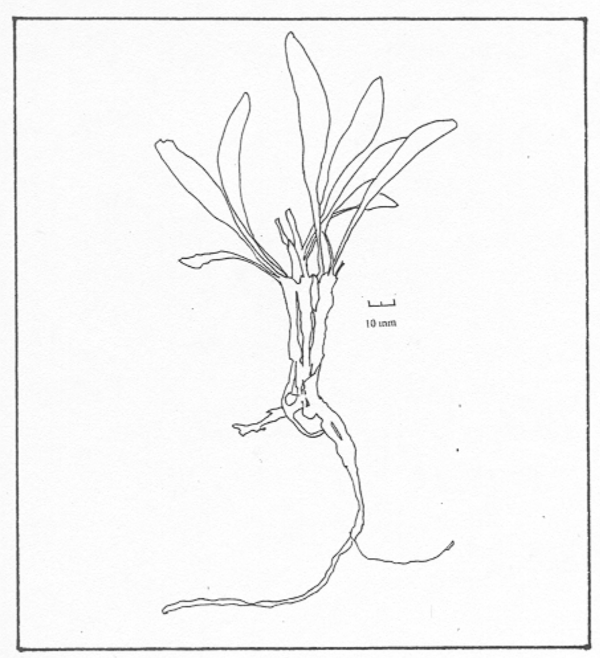


Figure 31. Branched caudex of Yermo. Traced from a herbarium specimen (Cooper, 108; Central Wyoming College Herbarium).

Yermo seems to be best described as an S-R species or strategist, following the classification of Grime (1977), as discussed in Smith and Smith (2001). Fertig (1995) visioned Yermo as a “classic K strategist” from the concept of r and K species (MacArthur and Wilson, 1967), which are named for their relationship to the well-known logistic growth curve. However, we have found many r traits (the large number of fertile akenes each year) as well as K traits (the longevity of some individuals), making it difficult for us to fit Yermo into this unidimensional r – K continuum (certainly not as a "classic" K strategist), and thus prefer the S-R designation. Briefly, S strategists are stress-tolerant and can survive in disturbed habitats, while R strategists are ruderal species adapted to habitats with severe or extreme environments. The intermediate S-R type is thus described as a stress-tolerant species occurring in an extreme environment (Smith and Smith, 2001).

The Origin of Yermo

Three frequently-asked questions regarding Yermo xanthocephalus are: 1. What is it doing at the site? 2. Where did it come from? 3. How did it get to the site? We don't have a definitive answer to any of them, but in this section would like to address some current hypotheses and provide comment based on our data. The hypotheses can be categorized as postulating an old (ancient) origin or a relatively new (modern) origin. All reflect the accepted fact that there is not a single species that resembles or appears to be related to Yermo anywhere close to the present-day population.

According to the ancient origin hypothesis, Yermo is a relict species derived from a Miocene ancestor, finally becoming very restricted in its distribution. At least part of this hypothesis is based on misinformation that Yermo occurs on the Miocene Split Rock Formation, which we now know is not the case. However, the fact that it now occurs on the earlier Oligocene White River Formation does not have any bearing on whether the species is derived from a Miocene ancestor. Presence and orgin are not necessarily related. It would be much clearer to simply refer to a mid-Tertiary ancestor and make no attempt to associate origin with where Yermo specifically occurs today. As an example, the presence of a species growing on Precambrian granitic rocks doesn't imply a 600 my+ origin at, or even near, the rocks where it is growing. Interestingly enough, Love (1961) reports "…the earliest regional pollen record of the genus Artemisia …" and "…unidentified Compositae…" pollen from the Split Rock Formation. In later conversations with us, Love (1996) was of the opinion that the supporting USGS paleobotanical microslides for these records were still in existence. Our efforts to track them down have not been successful, but they would be extremely interesting to view, especially to compare with Yermo pollen.

The strongest support for the ancient origin hypothesis is the extremely restricted distribution pattern of Yermo and the absence of the species on adjacent surfaces which are similar, if not identical. While it can colonize new, immediately adjacent surfaces, it apparently cannot readily disperse over medium to long distances, measured in miles or kilometers. This fits the rigid species concept of Hultén (1937), a result of range restriction due to environmental pressures acting on the population, with concomitant loss of genotypic plasticity. Examination of species on glaciated surfaces in Alaska found distributions consistent with the Hultén concept (Scott, 1974), and it is easy to visualize the gradual narrowing of the Yermo range over time due to selective pressures caused by the wide swings of environmental change that have occurred since the mid-Tertiary (Moody, 1970; Graham, 1993; Delcourt and Delcourt, 1993). However, we think that a species as old as mid-Tertiary would demonstrate at least a certain degree of adaptation to the modern environment, since it has been subjected to, and survived, those selective pressures for approximately 24 my during four epochs. Yermo doesn't seem to show this adaptation. The strongest argument against the ancient origin hypothesis, as shown by our data, is the lack of a preferred flowering period, the apparent lack of a cold requirement in the seeds with germination possible the year they are produced, and the apparently high juvenile mortality rate.

Two hypotheses center on a more recent origin of Yermo than mid-Tertiary. One is based on instant speciation, or cataclysmic evolution (Volpe, 1970), which is the appearance of a new species where there was none previously. The well-known and documented mechanism (Stebbins, 1966) for this is polyploidy, an increase in sets of chromosomes from one or more diploid parents. Autopolyploidy, a spontaneous doubling (or more) of the parental genotype, results in a new reproductively isolated generation that resembles the dipoid parent, but is usually larger or more robust. Not only is this rare, or at least uncommon (Grant, 1981), but lack of immediate potential candidates for the diploid parent, at least based on resemblance, seems sufficient reason to reject this mechanism. However, alloploidy, which is based on a fertilization of gametes from two different parental species, followed by one or more chromosomal doublings, is a viable mechanism. It is a mechanism that could produce a new species with little or no direct resemblance to the parents. This type of speciation is well-documented in hybrid tobacco, Nicotiana tabacum L., an alloploid species derived from N. otophora Griseb. (Solbrig, 1966) or N. tomentosa Ruiz & Pav. (Strickberger, 1972) and N. sylvestris Speg. & Comes, as well as modern hexaploid wheat, Triticum aestivum L., derived from three parents (Raven and Johnson, 1999). Intermediate between autoploids and alloploids are segmental allopolyploids which generally have reduced fertility (Solbrig, 1966; Davis and Heywood, 1963). A new species derived through allopolyploidy or segmental allopolyploidy would be an isolated form, both morphologically and reproductively, and possibly geographically. Since our studies did not involve genetic work, we can only offer brief comments on this hypothesis. We did note, however, in examining mature akenes in the heads of Yermo xanthocephalus, that there was only one case out of 50 in which all akenes matured, with an average of 1.2 mature akenes/head. With only two exceptions out of 50, there were five florets in each head, which means that an average of 3.8 akenes/head were sterile. This could be due to a pollination problem, or it could be the result of gametic nonviability.

The strongest support for an alloploid species is the obvious isolation of Yermo, both geographically and morphologically. Geographically, not a single similar species occurs within hundreds of miles. Morphologically, the genus Yermo is monotypic, containing only the single species Y. xanthocephalus. Our numerical comparison of Yermo with selected species of tussilaginoids, plus one other, supports its lack of similarity to them. An argument against an alloploid origin might be the lack of potential parental species nearby, but without cytogenetic evidence we don't know what species those might be. Once cytogenetic evidence is obtained from Yermo, tussilaginoid species, and possibly others, the alloploid hypothesis can be addressed directly.

The second of the recent origin hypotheses envisions Yermo as a disjunct population, originating by migration from some distant location. According to this hypothesis, the source population may now be extinct or it may still be present at the distant location. Support for this hypothesis may be found in species such as Wyoming's endangered Penstemon haydenii S. Wats., which occurs in a similarly isolated, small area of sand dunes in Carbon County, south of the Ferris Mountains. It is disjunct from the only other population known, in north-central Nebraska, by a distance of approximately 330 miles (531 km). The nearest extant tussilaginoid species (Arnoglossum atriplicifolium and A. plantagineum) to Yermo are also in Nebraska, a distance of approximately 460 and 550 miles (740 and 885 km), respectively. These species are not considered a source population for Yermo, but until rejected, they might remain candidates for possible parental species. The strongest evidence from our data that supports a disjunct origin is the same group of characteristics that provide argument against the ancient origin hypothesis. These are lack of a preferred flowering period, the apparent lack of a cold requirement in the seeds, the characteristic of seeds germinating the year they are produced, and the apparently high juvenile mortality rate. In combination, these suggest a species that is poorly adapted to its environment, which is "hanging on" at a location where it arrived fortuitously. The fact that it has not spread, nor is spreading, from the present site further suggests an outlying stronghold of a disjunct population. The strongest argument against this hypothesis is the obvious; a source population has not been found. However, if the source population is now extinct at a former location, it never will be.

Summary

1) All known individuals of Yermo xanthocephalus occur in a very small area within a 30 ha grid on Beaver Rim. They occur on azonal Torriorthent soils that are derived primarily from the upper White River Formation. The site has both stable and unstable surfaces formed by the combined effects of nivation, deflation, and alluviation. Short-term erosion following storms can be severe and strongly influences surface stability. In spite of this, Yermo, as an S-R strategist, is able to occupy some of the least stable and most exposed surfaces.
2) The area surrounding the Yermo site on Beaver Rim has a history of mineral exploration extending back at least to the 1950s, with some potential for continued prospecting and exploration in the future.

3) Both the genus and species of Yermo xanthocephalus were described by Dorn in 1990. Although related to other tussilaginoids, it does not appear to be a close relative. Ordination with selected species illustrates its distinctness. It is a perennial, with both sexual genets and asexual ramets. The branched caudex that produces the ramets appears to be a most important structural feature, enabling the species to survive the unstable conditions present at the site.
4) Establishment of a metric grid allowed total density of the species to be determined on an annual basis. It also provided a framework to show how numbers of plants varied from place to place at the site, and where centers of density occurred. In 2004, for example, four out of the 17 hectares occupied by Yermo had six or less plants. All other plants were concentrated in the remaining 13 hectares. Of those, 3725 (29% of all individuals) were in a single hectare, specifically, 5B. Within the 5B hectare, plants occurred in 57 ares, which was 17% of the total occupied area of 33,200 square meters for that year. This means that 29% of the plants were concentrated in 17% of the total occupied area. The remaining 9103 individuals (71% of the plants) were scattered in the remaining 83%, or 27,500 square meters, of occupied area (cf. Tables 2, 3). The number of occupied ares varied from year to year, and while Yermo plants can colonize new surfaces, the general outline of the population within the grid has remained essentially stable during our studies and apparently since the early 1950s. No outward movement any greater than a few meters from occupied ares has apparently taken place over time.
5) The flora at the site consists of 105 species, or approximately 38% of the 278 upland Beaver Rim species from the surrounding vicinity.
6) Potential biotic and abiotic influences are exotic weeds, fire, grazing and browsing, and hunting and recreation. Weed species are of great concern and occur as close as 0.5 km to the site. Both annual and perennial weeds have the potential for colonization of the site. Susceptibility of Yermo plants to fire is unknown, although the site is unlikely to sustain a hot fire. The major concern associated with fire is the creation of pathways for weed invasion. Hunting and recreation (especially 4wd) have not been a problem to date. Occasional broken-off stems and plants damaged by vehicles have been observed a few times on one old two-track road that runs through 4W, 5W, 5A, 5B, and 5C at the site.
7) A thoughtful road management plan focused on Yermo is badly needed for the area, since the species is a unique component of the landscape and environment.
8) Two plant associations are present at the site. One is dominated by Artemisia tridentata, occurs on stable surfaces, and is characterized by high cover values and low species richness. The other association is the Yermo assemblage, typical of unstable surfaces and characterized by low cover values and higher species richness than that of the Artemisia tridentata association. Members of the Yermo species assemblage, minus Yermo, are common along Beaver Rim, where they occur on similar sites in the White River Formation.
9) Vegetative growth of Yermo begins between May 9 and May 27 of each year, with senescence in the range of September 6 to October 10, yielding an average

growing season of 124 days. Limits of the growing season are 110 to 138 days. Flowering may begin as early as June 15 and as late as August 18 and is usually well underway by the first week of July. Some plants may remain vegetative for their entire lifespans, while others flower continuously for a few years, or on an irregular basis. Observed lifespans were as long as 13 years, and by inference could be at least 21 years.

10) The life cycle of Yermo begins with vegetative growth at a caudex branch in the case of a ramet, or seed germination in the case of a genet. Seed viability is relatively high and occurs readily at any favorable time of the year. Plantlets, as evidenced by two above-ground cotyledons, may remain essentially quiescent for as long as three years. Mortality is high during this time. If the plantlet survives and additional leaves are added, it appears to take at least five years before flowering takes place. After flowering there are three possible outcomes: death, another flowering cycle, or a return to the vegetative state. Pollination of the flowers is insect-related and known to involve at least some members of the Hesperiidae. The average of five flowers/head produce approximately 1.2 viable akenes, leading to an estimated range of 30,258 to 123,328 viable akenes/year for the entire species, depending on environmental conditions in a particular year. The pappus of barbellulate bristles does not appear to function particularly well for long-distance dispersal.

11) The environment at the Yermo site reflects a typical cold-temperate, high plains/steppe climate. Most of the annual precipitation occurs during April, May, and June. Temperature maxima are in July and August, with minima in December, January, and February. The air is generally dry, although rH can vary from near zero to 100% in one diurnal cycle, particularly during the growing season. The Yermo site is topographically sheltered by low hillocks and the nivation rim on the west, which results in relatively low wind velocities. Both air temperatures and soil temperatures coincide with the beginning and ending of the Yermo growing season. Precipitation appears to have the major influence on flowering.

12) Hypotheses relating to the origin of Yermo may be conveniently categorized as ancient origin (Yermo is a relict species) or modern origin (Yermo is an alloploid species, possibly a segmental alloploid, or it is a disjunct outlier from either an extant or extinct population). At present, none of the hypotheses is a clear favorite over the others. All three have both strong points in their favor and weak points in their disfavor.

Bibliography

Anderson, L. 2006. Arnoglossum Rafinesque. In Flora of North America, Vol. 20. Oxford Univ. Press. N.Y.

Bell, A.D. and P.B. Tomlinson. 1980. Adaptive architecture in rhizomatous plants. Bot. J. Linn. Soc. 80:125 – 159.

Chambers, J.C. and J.A. MacMahon. 1994. A day in the life of a seed: Movements and fates of seeds and their implications for natural and managed systems. Ann. Rev. Ecol. and Syst. 25:263 – 292.

Chiang, J.C. and D.G. Baker. 1968. Utilization of soil temperature data for ecological work. Ecology 49:1155 – 1160.

Dorn, R.D. 2001. Vascular plants of Wyoming, 3rd Edition. Mountain West Pub., Cheyenne, Wyoming.

Fertig, W. 1999. Blowout penstemon: Wyoming's first endangered plant. Castilleja 18:4.

Harper, J.L. and J. Ogden. 1970. The reproductive strategy of higher plants. J. Ecology 58:681 – 698.

Heywood, V.H., et al., eds. 1977. The biology and chemistry of the Compositae, Vol. 1. Am. Press Inc., N.Y.

Heywood, V.H., et al., eds. 1977. The biology and chemistry of the Compositae, Vol. 2. Am. Press Inc., N.Y.

Leppik, E.E. 1960. Early evolution of flower types. Lloydia 23:72 – 92.

Jackson, M.T. 1966. Effects of microclimate on spring flowering phenology. Ecology 47:407 – 415.

Lohman, K.E. and W.A. George. 1968. Late Eocene nonmarine diatoms from the Beaver Divide area, Fremont County, Wyoming. U.S. Geological Survey Prof. Pap. 593.

Love, J.D. 1970. Cenozoic geology of the Granite Mountains area, central Wyoming. U.S. Geological Survey Prof. Pap. 495-C. U.S. Govt. Printing Office. Washington, D.C.

Marchand, P.J. and D.A. Roach. 1980. Reproductive strategies of pioneering alpine species: seed production, dispersal, and germination. Arctic and Alpine Research 12:137 -146.

Menges, E.S. 1990. Population viability analysis for an endangered plant. Cons. Biology 4:52 – 62.

Pavlik, B.M. and E. Manning. 1993. Assessing limitations on the growth of endangered plant populations, I. Experimental demography of Erysimum capitatum ssp. angustatum and Oenothera deltoides ssp. howellii. Biolog. Cons. 65:257 -265.

Pippen, R.W. 1978. Cacalia. North Am. Flora 10:151 – 159.

Regelin, W.L., et al. 1977. Effects of snowdrifts on mountain shrub communities. XIIIth Int. Congr. of Game Biol. 414 – 419. Wildl. Soc. Wildl. Manage. Inst., Washington D.C.

Robinson, H. and R.D. Brettell. 1973. Studies in the Senecioneae (Asteraceae). III. The genus Psacalium. Phytologia 27:254 – 264.

Semple, J.C. 1978. The cytogeography of Aster pilosus (Compositae): Ontario and the adjacent United States. Can. J. Bot. 56:1274 – 1279.

Soil Survey Staff. 1987. Keys to soil taxonomy (third printing). SMSS Tech. Monogr. No. 6. Ithaca, New York.

Soister, P.E. 1968. Stratigraphy of the Wind River Formation in south-central Wind River Basin, Wyoming. U.S. Geological Survey Prof. Pap. 594.

Stanley, L.A. 1992. Taxonomic issues in rare species protection. Rhodora 94:218 -242.

Turner, B.L., et al. 1961. Chromosome numbers in the Compositae IV. North American species with phyletic interpretations. Am. J. Bot. 48:216 – 233.

Van Houten, F.B. 1954. Geology of the Long Creek, Beaver Divide Area, Fremont County, Wyoming. U.S. Geological Survey OM. 140.

Van Houten, F.B. 1957. Tertiary rocks of southern Wind River Basin area, Central Wyoming. Wyo. Geol. Assoc. Guidebook, 12th Annual Field Conference:79 – 88.

West, N.E. and M.C. Martyn. 1983. Snow as a factor in salt desert shrub vegetation patterns in Curlew Valley, Utah. Am. Midl. Nat. 109:376 – 379.

Literature Cited

Alarcon-Aguilar, F.J., et al. 1997. Effects of three Mexican medicinal plants (Asteraceae) on blood glucose levels in healthy mice and rabbits. Journ. Ethnopharmacology 55:171-177.

Barkley, T.M. 1999. The segregates of Senecio, s.l., and Cacalia, s.l., in The Flora of North America North of Mexico. Sida 18:661-672.

Barkley, T.M., et al. 2006. Asteraceae Martinov. In Flora of North America, Vol. 19. Oxford Univ. Press. N.Y.

Benninghoff, W.S. 1966. The relevé method for describing vegetation. Mich. Bot. 5:109 – 114.

Beetle, A.A. 1970. Recommended plant names. Res. Journ. 31. Ag. Expt. Sta., Univ. of Wyoming, Laramie, Wyoming.

Billings, W.D. 1990. Bromus tectorum, a biotic cause of ecosystem impoverishment in the Great Basin. In G.M. Woodwell, ed. The earth in transition: patterns and processes of biotic impoverishment. Cambridge Univ. Press. Cambridge, UK.

Bynum, M. 1993. Soils term project, a report submitted in Soils 5120. University of Wyoming. Unpub.

Cronquist, A. 1955. Phylogeny and taxonomy of the Compositae. Am. Midl. Nat. 53:478-511.

Davis, P.H. and V.H. Heywood. 1963. Principles of angiosperm taxonomy. Oliver and Boyd. Edinburgh.

Delcourt, P.A. and H.R. Delcourt. 1993. Paleoclimates, paleovegetation and paleofloras during the late Quaternary. In Flora of North America, Vol. 1. Oxford Univ. Press. N.Y.

Dorn, R.D. 1991. Yermo xanthocephalus (Asteraceae: Senecioneae): A new genus and species from Wyoming. Madroño 38:198 – 201.

Dorn, R.D. 1992. Vascular plants of Wyoming, 2nd Edition. Mountain West Pub. Cheyenne, Wyoming.

Dorn, R.D. 2006. Yermo Dorn. In Flora of North America, Vol. 20. Oxford Univ. Press. N.Y.

Fertig, W. 1995. Status report on Yermo xanthocephalus in central Wyoming. Wyoming Natural Diversity Database. Laramie, Wyoming.

Gerrard, A.J. 1990. Mountain environments. MIT Press. Cambridge, Massachusetts.

Graham, A. 1993. History of the vegetation: Cretaceous (Maastrichtian) – Tertiary. In Flora of North America, Vol. 1. Oxford Univ. Press. N.Y.

Grant, V. 1981. Plant speciation, 2nd ed. Columbia Univ. Press. N.Y.

Grime, J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. Am. Nat. 111: 1169 – 1194.

Heidel, B. 2002. Status report on desert yellowhead (Yermo xanthocephalus) in Wyoming. Wyoming Natural Diversity Database. Laramie, Wyoming.

Howe, W.H., ed. 1975. The butterflies of North America. Doubleday and Co., Inc. Garden City, N.Y.

Hultén, E. 1937. Outline of the history of arctic and boreal biota during the Quarternary Period. Bokförlags Aktiebolaget Thule. Stockholm.

Iiams, J.E., et al. 1993. Soil survey of Fremont County, east part and Dubois area, Wyoming. USDA Soil Conservation Service. U.S. Govt. Printing Office. Washington, D.C.

Jones, R. 1993. Yermo xanthocephalus t-shirt design. Sponsored by Wyoming Native Plant Society. Laramie, Wyoming.

Love, J.D. 1961. Split Rock Formation (Miocene) and Moonstone Formation (Pliocene) in central Wyoming. U.S. Geological Survey Bulletin 1121-I. U.S. Govt. Printing Office. Washington, D.C.

Love, J.D. 1996. Miocene Split Rock Formation and paleobotanical fossils. Personal communication.

MacArthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press. Princeton, N.J.

Moody, P.A. 1970. Introduction to evolution, 3rd. ed. Harper and Row, Pub. N.Y.

Price, L.W. 1981. Mountains and man: A study of process and environment. University of California Press. Berkeley and Los Angeles, California.

Raven, P.H. and G.B. Johnson. 1999. Biology, 5th ed. WCB McGraw-Hill. Boston.

Scott, R. 1974. Floristic and ecological phytogeography of the southeastern Wrangell Mountains, Alaska. In Bushnell, V.C. and M.G. Marcus, eds. Icefield Ranges Research Project, Scientific Results: Vol. 4. Amer. Geogr. Soc. and Arctic Institute of North America. Washington, D.C.

Scott, R. 1974. The effect of snow duration on alpine plant community composition and distribution. In Bushnell, V.C. and M.G. Marcus, eds. Icefield Ranges Research Project, Scientific Results: Vol. 4. Amer. Geogr. Soc. and Arctic Institute of North America. Washington, D.C.

Scott, R. 2007. The spring flora of Fremont County, Wyoming. Unpub. Ms.

Scott, R. and B. Hoster. 2000. On the germination and viability of Yermo xanthocephalus akenes. Castilleja 19:4 – 6.

Soil Survey Staff. 2003. National soil survey characterization data. Soil Survey Laboratory, National Soil Survey Center, USDA-NRCS. Lincoln, Nebraska.

Solbrig, O. 1966. Evolution and systematics. The MacMillan Co. N.Y.

Smith, R.L. and T.M. Smith. 2001. Ecology and field biology, 6th ed. Addison Wesley Longman, Inc. San Francisco, California.

Stebbins, G.L. 1966. Processes of organic evolution. Prentice-Hall, Inc. Englewood Cliffs, N.J.

Stohlgren, T.J., et al. 1999. Exotic plant species invade hot spots of native plant diversity. Ecol. Monogr. 69:25 – 46.

Strickberger, M. 1972. Genetics. The MacMillan Co. N.Y.

Thorn, C.E. 1979. Ground temperatures and surficial transport in colluvium during snowpatch meltout; Colorado Front Range. Arctic and Alpine Research 11:41 – 52.

Tilman, D. 1997. Community invisibility, recruitment limitation, and grassland biodiversity. Ecology 78:81 – 92.

Van Houten, F.B. 1964. Tertiary geology of the Beaver Rim area, Fremont and Natrona Counties, Wyoming. Geological Survey Bull. 1164. U.S. Govt. Printing Office. Washington, D.C.

Van Vleet, M. 1996. Numerical taxonomy of Yermo xanthocephalus and selected species. Directed study project. Central Wyoming College, Riverton. Unpub.

Vitousek, P.M., et al. 1996. Biological invasions as global environmental change. Amer. Scientist 84:468 – 478.

Volpe, E.P. 1970. Understanding evolution, 2nd. Ed. Wm. C. Brown Co. Pub. Dubuque, Iowa.

__________. 1973. Munsell soil color charts. Macbeth Color & Photometry Division, Kollmorgen Corp. Baltimore, Maryland.

__________. 1991. Regional designated noxious weed list. Unpub.

Appendix 1. News and Popular Reports.

1998, December 24. Marsden, Jason. Feds propose listing rare desert sunflower. Casper Star Tribune, Casper, Wyoming.

1998, December 29. Hafner, Jennifer. Restrictions possible for rare flower. The Ranger, Riverton, Wyoming.

1999, January 1. Marsden, Jason. Oil and gas developers cooperative on flower. Casper Star Tribune, Casper, Wyoming.

1999, January 2. Milius, Susan. Unknown plants under our noses. Science News, Vol. 155(1): 8, 9.

1999, March 12. Hafner, Jennifer. Don’t list rare plant, Allen says. Riverton Ranger, Riverton, Wyoming.

1999, August 18. Over, Ernie. County seeks hearing on flower. Riverton Ranger, Riverton, Wyoming.

1999, August. Hafner, Jennifer. BLM proposes land withdrawal to protect rare Beaver Rim flower. Riverton Ranger, Riverton, Wyoming.

1999, October 24. Svan, Darren. How to best protect rare plant? Sunday Ranger, Riverton, Wyoming.

2000, January 7. Hafner, Jennifer. Plant protection worries rancher. Riverton Ranger, Riverton, Wyoming.

2000, September 6. Unknown author. Public Notice (reopening comment period on listing of the desert yellowhead). Riverton Ranger, Riverton, Wyoming.

2000, September 6. Hafner-Svan, Jennifer. Drought impacts desert yellowhead. Riverton Ranger, Riverton, Wyoming.

2000, September 10. Unknown author. Drought takes toll on desert yellowhead. Casper Star Tribune, Casper, Wyoming.

2000, September 18. Unknown author. Drought may have taken toll on listed flower. Wyoming Livestock Roundup.

2001, November 9. Gearino, Jeff. Conversationalists [sic] file lawsuit to save rare plant. Casper Star Tribune, Casper, Wyoming.

2001, November 15. Unknown author. Groups: Protect rare sunflower. Riverton Ranger, Riverton, Wyoming.

2002, March 15. Staff/wire reports. Beaver Rim plant gets ESA listing. Riverton Ranger, Riverton, Wyoming.

2003, March 21. Farquhar, B. Yellowhead habitat protection planned. Casper Star Tribune, Casper, Wyoming.

2003, March 30. Beers, Cody. Feds want “critical habitat” for plant. Riverton Ranger, Riverton, Wyoming.

2003, June 26. Case, Betty. Desert yellowhead is one of a kind. Riverton Ranger, Riverton, Wyoming.

2004, March 17. Cooke, Sarah. Plant adopted to protect wildflower habitat. Casper Star Tribune, Casper, Wyoming.

2005, March 10. Farquhar, B. Opal rush swamps officials. Casper Star Tribune, Casper, Wyoming.

2008, February 22. Prevost, Ruffin. Flower’s mysteries stump researchers. Billings Gazette, Billings, Montana.

2008, February 25. Prevost, Ruffin. A botanical mystery. Casper Star Tribune, Casper, Wyoming.

2009, Wyoming’s threatened and endangered plant species: desert yellowhead. BLM Fact Sheet. BLM/WY/AE-09/008+1150.

Appendix 2. Chronology of historical events and reports related to Yermo xanthocephalus.

1990. Robert Dorn collected an unknown plant specimen from Beaver Rim ca. 10 km north of Sweetwater Station on June 28.

1991. Robert Dorn described his unknown plant specimen as a new genus and species, Yermo xanthocephalus. Madrono 38(3): 198-201.

1992. Richard and Beverly Scott began long-term research on Yermo by staking 50 plants in August for phenological study.

1993. Proposal was made for a Great Buffalo Herd Monument to be constructed a short distance southwest of the Yermo site.

1995. Fertig, W. Status report on Yermo xanthocephalus in central Wyoming. Wyoming Natural Diversity Database. Univ. Wyoming, Laramie, Wyoming, 28 February 1995.

1995. Richard and Beverly Scott established a permanent metric grid which covered the entire known area occupied by Yermo plants. This grid was used for the first census of the species.

1997. Cyanostar Energy, Inc. proposed to drill two gas wells adjacent to the Yermo site. One of these, Beaver Rim No. 1-33, less than one mile to the west, was drilled in the NW¼ S33 T31N R95W. The other, in the NW¼ S27 T31N R95W, less than one mile north, was not drilled.

1997. Carlton, D.C. Biodiversity Legal Foundation submits letter regarding desert yellowhead to Al Pierson, State Director, and Michael Stewart, Acting Area Manager, BLM.

1998. Yermo xanthocephalus was proposed for listing in the Federal Register on December 22. (USDI Fish and Wildlife Service. Endangered and threatened wildlife and plants: Proposed threatened status for the plant Yermo xanthocephalus. Federal Register 63(245): 70745-70751.)

1998. First news release about Yermo in the Casper Star Tribune, Jason Marsden, on December 24.

1999. Scott, Richard W. and Beverly J. Demographic studies of desert yellowhead (Yermo xanthocephalus). Wyoming Rare Plants Conference, Rawlins, Wyoming, March 17.

1999. Proposed minerals/lands withdrawal of 3750 acres published in the Federal Register on August 9, giving the BLM a two-year period to complete a minerals potential report, write an environmental assessment, and obtain public input.

1999. Field tour of the Yermo site hosted by the Fremont County Commissioners on October 22.

1999. Breckenridge, C. Conservation agreement, assessment and strategy. USDI, Bureau of Land Management, USDI Fish and Wildlife Services, Mountain-Prairie Region. 15 pp.

2000. Scott, Richard W. and Hoster, Brandi. On the germination and viability of Yermo xanthocephalus. Castilleja 19(1): 6-7.

2000. Draft copy of the Yermo xanthocephalus (desert yellowhead) Conservation Agreement released for review by the BLM on March 24. Earlier versions were released in 1998 and 1999.

2000. In the Federal Register, dated September 5, 2000, the USFWS reopened the comment period on the proposal to list Yermo xanthocephalus as a threatened species until October 5, 2000.

2000. Scott, R.W. Field studies on Yermo xanthocephalus Dorn. BLM Cooperative Agreement No. KAA000003. Final Report. October 24, 2000.

2001. Richard and Beverly Scott survey and map all roads, trails, springs, and other disturbed sites within an eight-mile area around the Yermo site for the presence of weeds.

2002. Yermo xanthocephalus was listed as a Threatened Species in the Federal Register on March 14, 2002, becoming effective on April 15, 2002.

2002. Dorn, Robert. Desert yellowhead, a threatened species. Bighorn Nat. Plt. Soc. 3(1): 6-7.

2002. Heidel, Bonnie. Status report on desert yellowhead (Yermo xanthocephalus) in Wyoming. Wyoming Natural Diversity Database. Univ. Wyoming, Laramie, Wyoming, 30 March 2002. 24 pp.

2002. Scott, Richard W. and Beverly J. Research on the vascular plant Yermo xanthocephalus Dorn. Central Wy. Coll. Herb. Report. 3 pp.

2003. USFWS proposal to designate critical habitat for Yermo xanthocephalus published in the Federal Register on March 14. Additional comments were solicited until February 13, 2004.

2004. Scott, Richard W. and Beverly J. Yermo xanthocephalus species density, Census Report. Central Wy. Coll. Herb. Report. 2pp.

2005. An amended biological opinion was filed by the USFWS with the BLM on June 7.

2006. Heidel, Bonnie. One long year for Yermo. Castilleja, Vol. 25(1): 7.

2008. McKee, J. Recovery outline for Yermo xanthocephalus (desert yellowhead). Draft copy received for review.