Current Knowledge and Conservation Status of *Polyctenium williamsiae* Rollins (Brassicaceae; including *Polyctenium fremontii* var. *confertum* Rollins), the Williams combleaf.

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SUMMARY: *Polyctenium williamsiae* was first discovered and collected in 1946 by Annie M. Alexander and Louise Kellogg in the Long Valley area of northern Washoe County, Nevada, and was formally named and described by Reed Rollins in 1983 based on type material collected in 1982 by Arnold Tiehm from the Virginia Range of Washoe County, Nevada. *Polyctenium fremontii* var. *confertum* also was described by Rollins in 1993 based on 1983 Tiehm collections from Larkin Lake, Mono County, California, citing additional Nevada collections in the Bodie and Pine Grove hills. Both taxa are low, perennial, dull green, rosette-forming herbs with small leaves deeply divided into linear lobes and compact groups of white 4-petaled flowers, the groups elongating somewhat as the short, plump, oval seed pods mature. Both plants are known from an extensively overlapping region of western Nevada and adjacent eastern California, with scattered occurrences in northwest Nevada, northeast California, and southeast Oregon. *Polyctenium williamsiae* is plainly distinct from *P. fremontii*, but the distinction between *P. williamsiae* and *P. fremontii* var. *confertum* proved to be blurred, with the majority of individuals being intermediate in many morphological traits to those of the type descriptions. This report therefore concludes that *Polyctenium williamsiae* is species distinct from *P. fremontii*, but that it includes *P. fremontii* var. *confertum* as a synonym.

As of 1993, *Polyctenium williamsiae* was known from four lake beds, all within a mile of each other at 5680 to 5760 feet (1730-1755 meters) elevation in the Virginia Range northwest of Virginia City in southern Washoe County, Nevada, and from two nearly contiguous lake beds at 8920 to 8935 feet (2720-2725 meters) elevation in the northern Kawich Range of central Nye County, Nevada. *Polyctenium fremontii* var. *confertum* was known from Larkin Lake at 6750-6760 feet (about 2060 meters) elevation in eastern Mono County, California, and from two sites at 5905 to 7920 feet (1800-2415 meters) elevation in the Pine Nut Mountains and Pine Grove Hills of Douglas and Lyon counties, Nevada. Because of

its rarity, limited distribution, and vulnerability to livestock operations, range improvements, off-road vehicle activity, and other impacts to its known habitat, *Polyctenium williamsiae* was listed as critically endangered by the State of Nevada in 1987, and was designated a category-1 candidate for federal listing in 1990. Responding to this concern, the U. S. Fish and Wildlife Service and the Nevada Natural Heritage Program sponsored and assisted with extensive field surveys in 1994, 1995, and 1996 to verify and refine the historical reports, discover additional populations, and document the biology, ecology, and conservation status of all populations. Surveys in these and subsequent years were also conducted by personnel of the Humboldt-Toiyabe National Forest, the Inyo National Forest, the Bureau of Land Management, and most recently by BMP Ecosciences. This report summarizes the results of all known surveys, reviews all previous knowledge of the species, and recommends several conservation and recovery actions.

The field and herbarium surveys conducted and compiled for this report revisited all previously known sites and revealed an additional 25 occupied lake beds (a 178% increase) covering an additional 397 acres (161 ha, a 175% increase) between 4215 and 8280 feet (1285-2525 meters) elevation. These included the first documentation of the species in Mineral County, Nevada. As now documented, *Polyctenium williamsiae* is known worldwide from 34 sites in 15 scattered areas, totaling more than 452,000 individuals and covering about 542 acres (219 ha) of public lands managed by the Bureau of Land Management (Bishop Resource Area, Carson City District, Battle Mountain District, possibly the Surprise Resource Area, and others) by the Bridgeport Ranger District of the Humboldt-Toiyabe National Forest, and by the Inyo National Forest, and of some private lands. No sites are yet known to have been extirpated, although plants could not be found at some sites in certain years after heavy disturbance had occurred, and wide natural fluctuations also seem to occur. In 1995, an estimated 420,000 or 93% of the known individuals covered the large bed of Larkin Lake, but this may have been an exceptional year for the species, as more recent surveys were only able to locate about 1000 individuals at the same site. Several newly-revealed historical sites remain of uncertain status until attempts can be made to relocate them. The most distant two occurrences are separated by about 400 miles (650 km), and the number of extant occurrences is reduced to 21 if a 1 km minimum separation distance is imposed.

Polyctenium williamsiae was almost entirely restricted to the relatively barren sandy to sandy-clay or mud margins and bottoms of non-alkaline seasonal lakes and playas perched over siliceous volcanic bedrock in the sagebrush, pinyon-juniper, and mountain sagebrush zones. Very rarely it was also found in seasonally wet drainages near such lakes. The lakes may be turbid or clear, and they vary widely in the depth and duration of standing water from year to year based on seasonal precipitation, resulting in wide fluctuations in the associated combleaf populations. The combleafs over-winter under water as vegetative caudices, then leaf out, flower, and set fruit once the water has receded in spring or early summer. The plants usually occur at low densities, frequently with tens of meters between individuals.

Recent surveys focusing on 77 additional sites, comprising 108 lake beds or other habitat patches on over 3300 acres (1335 ha) of potential habitat revealed no further populations of *Polyctenium williamsiae*. Another 162 sites, comprising 264 habitat patches on over 8800 acres (3560 ha) of potential habitat, were identified but could not be visited due to constraints of access, time, and funding, but a large majority of these are in far northwest Nevada and are most likely to support *Polyctenium fremontii*. In addition, several populations have been documented from eastern California and southeastern Oregon, but there has been no systematic survey or identification of potential habitat there. Because of the remaining potential for undiscovered populations, their difficult access, and the wide size fluctuations and disjunctions in the known populations, the true global population of *Polyctenium williamsiae* may be up to about 150%, though more likely less than 50%, larger than that now documented.

Despite the plants' broad regional distribution, the known populations consist of a few tens or hundreds of plants scattered over several acres. All of the lakes are used by livestock, feral horses, and other wildlife, and most have been dredged locally to create watering ponds. Salt blocks set out at the lakes further focuses trampling and increases susceptibility to invasion of the habitat by non-native weed species. Most of the lake beds are also accessible or even bisected by roads and are attractive to off-road vehicle users. Significant impacts from one or more of these factors have already been observed or reported at most of the known sites. *Polyctenium williamsiae* does not appear to tolerate much soil

disturbance, or to be capable of colonizing disturbed or undisturbed soil in other habitat types. The species is currently managed as a special status species by the Bureau of Land Management, as a sensitive species by the Forest Service, and as a fully protected plant species under Nevada state law. The Virginia Range sites have been included in a BLM Area of Critical Environmental Concern (ACEC), and another such area is proposed in the Pine Nut Mountains. Despite all of these protective designations, significant impacts continue.

Based on the best available scientific evidence, *Polyctenium williamsiae* currently meets the definition of a candidate for listing as threatened under the Endangered Species Act. Its long term viability remains a concern absent more complete and effective protective management, and it could become an Endangered species in the future. It therefore continues to meet criteria for existing protective designations by BLM, the U. S. Forest Service, and the State of Nevada. This report recommends several conservation and recovery measures which, if successfully implemented, offer the best chance to prevent *Polyctenium williamsiae* from becoming further endangered. Primary among these are filling and restoration of dredged watering ponds within all seasonal lake beds and strict prohibition of such dredging in the future, placement of livestock supplements no less than 0.25 mile (0.4 km) from the nearest edge of any seasonal lake bed, possible creation of fenced corridors for access to the lakes by large animals, prohibition of off-road vehicle use on and near the lake beds and effective enforcement of same, careful preventative monitoring for potential noxious weed invasions at all of the known sites, long-term monitoring, surveys of additional potential habitat particularly in California and Oregon, and development of a cooperative management plan and conservation strategy for the species.

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All information contained in this report was believed current and complete on the date it was printed. Please submit any and all additions, corrections, updates, comments, or suggestions, whatever their magnitude, to either of the addresses above.

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I. CLASSIFICATION AND SYSTEMATICS

Scientific Name: *Polyctenium williamsiae* Rollins (1983, p. 508).

Type Specimen: NEVADA, Washoe County: Virginia Range, T17N, R20E, S16, foothills E of Little Washoe Lake, edge of a vernal pond, 5680 ft., 10 June 1982, *Tiehm & Williams 7135* (holotype: GH; isotypes: CAS, K, NY, RENO, RSA, UTC) (Rollins 1983, Tiehm 1996) (site 01).

Synonym(s): *Polyctenium fremontii* (S. Watson) E. Greene var. *confertum* Rollins (1993).

Vernacular Name(s): Williams combleaf, crowded combleaf.

Family: Brassicaceae (mustard family).

Major Groups:	Cronquist (1988)	Thorne (1992)
Class	Magnoliopsida (Dicotyledoneae)	Magnoliopsida (Angiospermae)
Subclass	Dilleniidae	Magnoliidae (Dicotyledoneae)
Superorder	———	Violanae
Order	Capparales	Brassicales

Review of Alternative Taxonomic Treatments: Greene's (1912) segregation of *Polyctenium* from *Smelowskia* encompassed the three species *P. bisulcatum, P. fremontii,* and *P. glabellum*. Jepson (1936) rejected Greene's segregation. Rollins (1938) accepted Greene's segregation from *Smelowskia* but collapsed the genus into a single species consisting of two varieties (*P. fremontii* var. *fremontii*. and *P. fremontii* var. *bisulcatum*). Abrams (1944) retained the two varieties within a single species of *Smelowskia.* More recent treatments (Munz 1959, Hitchcock and Cronquist 1973) have recognized *Polyctenium* as a distinct genus. Discovery of *Polyctenium williamsiae* as an obviously distinct congener substantially strengthened the generic status of *Polyctenium* (Rollins 1983).

Available keys notwithstanding, we found it very difficult to differentiate confidently between *Polyctenium fremontii* var. *confertum* and *P. williamsiae*. Upon finding populations comprised of individuals that keyed to both taxa, we began to suspect their taxonomic distinctness. Using a double-blind test on a series of collections, both of us misidentified at least one specimen each from the type localities of both taxa. While a thorough morphometric analysis and taxonomic evaluation was beyond the scope of this survey, we offer the following evaluation.

I (Holland) measured fruit length, fruit width, and pedicel length using an optical comparator graduated at 0.05 mm. I measured the three most mature capsules on each of three individuals from each of my collections, ultimately measuring over 200 siliques and pedicels. I had five accessions from the *Polyctenium williamsiae* type locality, and four from Larkin Lake and Nye Canyon (both cited in the *P. fremontii* var. *confertum* type description). Means and standard deviations for these specimens and for several collections of *P. fremontii* var. *fremontii* appear in Appendix 1, table 6. The same means with their 95% confidence intervals are shown in Appendix 2, figure 12. The fruit were obviously longer (6.8 vs. ~4.0 mm) and more narrow (1.2 vs. ~1.8 mm) in *P. fremontii* var. *fremontii* than in *P. fremontii* var. *confertum* and *P. williamsiae*. There was no statistically significant difference in fruit length between *P. fremontii* var. *confertum* (4.1 mm.) and *P. williamsiae* (3.9 mm., t-test, p=0.43). Ninety-five percent confidence intervals around fruit length width overlapped considerably between *P. fremontii* var. *confertum*

and *P. williamsiae,* and did not overlap at all with that of *P. fremontii* var. *fremontii*. The difference in fruit width between *P. fremontii* var. *confertum* (1.8 mm.) and *P. williamsiae* (2.0) was marginally significant ($p < 0.04$), but is of such small proportion (0.2 mm) as to be useless for field identification. Ninety-five percent confidence intervals around fruit width barely overlap between *P. fremontii* var. *confertum* and *P. williamsiae* but are completely separated from that around *P. fremontii* var. *fremontii*. Pedicel length is of no apparent value in differentiating among the three taxa.

These data suggest there are no practical differences in fruit dimension between *P. williamsiae* and *P. fremontii* var. *confertum*. Given their identical habitat requirements and broadly overlapping distributions, including some lake beds where both forms can be found, and given their strong collective separation from *P. fremontii* var. *fremontii*, it seems taxonomically prudent to lump *Polyctenium williamsiae* and *P. fremontii* var. *confertum* together as a distinct species, *Polyctenium williamsiae*. Long after this analysis had been completed, the author of *Polyctenium* for the Intermountain Flora project, Noel Holmgren, examined the full set of specimens that we reviewed and independently reached exactly the same conclusion (Holmgren, personal communication, April 2002).

Biogeography and Phylogeny: *Polyctenium* consists of three taxa distributed generally around the northern and western perimeter of the Intermountain Region. *Polyctenium williamsiae* has the most southern distribution, occurring from eastern Mono County, California, and southern Mineral County, Nevada, north to southern Washoe County, Nevada, thence scattered farther northward to the Long Valley area of northern Washoe County, Nevada, northeastern California, and southeastern Oregon (Appendix 3, map 1). *Polyctenium fremontii* is scattered nearly as far south as *P. williamsiae*, but extends much farther north across eastern Oregon and southern Idaho where it has its greatest abundance. *Polyctenium fremontii* var. *bisulcatum* remains known only from the type collection in the Silvies Valley area of far northeastern Oregon.

The closely related genus *Smelowskia* consists of about 14 taxa. Six species populate the mountains of central Asia. Three species are endemic to the arctic flora of Beringian east Asia and Alaska. Another is endemic to the Okhotsk-Kamchatka region of far eastern Siberia. The remaining four taxa are scattered in the central and southern cordillera of North America, from central British Colombia south to the head waters of the South Platte River in Colorado and along the Cascade axis south to Lassen Peak, California (Velichkin 1979, Takhtajan 1986), and in the mountains of central Nevada. Interestingly, both the Asian and North American species appear to have diversified in the mountainous belts on the poleward side of continental deserts.

These two genera in turn are closely related to *Hedinia*, *Sophiopsis*, *Capsella*, and *Hutchinsia*. All of these genera are centered on the Irano-Turanian region (Velichkin 1979, Takhtajan 1986), which happens to be the global center for diversification among Brassicaceae (Heywood 1978). Thus *Polyctenium* and *Smelowskia* have strong arcto-tertiary affinities and likely represent yet another of the genera in Brassicaceae, Asteraceae, Lamiaceae, Scrophulariaceae, Dipsacaceae, Polygonaceae, and Poaceae that have proliferated in a climatic cycle characterized by increasing aridity, increasing extent of arid and semi-arid regions, and decreases in the area of mesic forests (Stebbins 1974).

II. TAXON HISTORY

Unless otherwise cited, reports and correspondence documenting the following chronology are on file with the Nevada Natural Heritage Program.

1912: The genus *Polyctenium* was first recognized and segregated from *Smelowskia* by E. L. Greene (1912), who recognized three species (all now synonymized under *P. fremontii*).

1936: *Polyctenium* was maintained in synonymy with *Smelowskia* by W. L. Jepson (1936).

1938: *Polyctenium* was recognized by R. Rollins (1938), who revised the genus to include a single species (*P. fremontii*) with two varieties.

1944: *Polyctenium* was maintained in synonymy with *Smelowskia* by L. Abrams (1944), who also did not recognize Rollins' (1938) revision.

1946: *Polyctenium williamsiae* was first discovered and collected by A. M. Alexander and L. Kellogg (as *P. fremontii*) in the Long Valley area of northern Washoe County, Nevada (site 25), on 7 June.

1959, 1973: *Polyctenium* was recognized by P. Munz (1959, 1973) and C. L. Hitchcock and A. Cronquist (1973) as a distinct genus.

1980: *Polyctenium williamsiae* was first collected in California by D. W. Taylor (as *P. fremontii*) at Larkin Lake in Mono County (site 07, what would later become the type locality of *P. fremontii* var. *confertum*) on 15 July.

1982: Specimens that would eventually become the type material of *Polyctenium williamsiae* were recognized as an unnamed taxon and collected by A. Tiehm and M. Williams in the Virginia Range near Washoe Lake in southern Washoe County, Nevada (site 01) on 10 June.

1983: *Polyctenium williamsiae* was formally described as a new species by Rollins (1983), which he then knew only from the 1982 Virginia Range material.

1983: Specimens that would eventually become part of the type material of *Polyctenium fremontii* var. *confertum* were collected by A. Tiehm and M. Lavin at Larkin Lake in Mono County, California (site 07), and in the Pine Grove Hills of Lyon County, Nevada (site 08), both on 12 July.

1984: *Polyctenium williamsiae* was first collected in northeast California by G. Schoolcraft (labeled as *P. fremontii*) on the Madeline Plains of Lassen County (site 31).

1984: Specimens that would eventually become part of the type material of *Polyctenium fremontii* var. *confertum* were collected by A. Tiehm and B. Ertter at Double Spring Flat in Douglas County, Nevada (site 10) on 11 July.

1985: *Polyctenium williamsiae* was first and last collected in Oregon by B. Ertter (as a single plant mixed with several plants of *P. fremontii* and labeled as the latter) at Lake on the Trail in Harney County (site 32) on 28 May.

1985: *Polyctenium williamsiae* was designated a category-2 candidate for listing under the Endangered Species Act on 27 September (U. S. D. I. Fish and Wildlife Service 1985).

1987: *Polyctenium williamsiae* was added to the Nevada list of fully protected plant species under NRS 527 and NAC 527.010 on 2 November.

1987: Kartesz's (1987) flora of Nevada included and recognized *Polyctenium williamsiae*.

1990: *Polyctenium williamsiae* was designated a category-1 candidate for listing under the Endangered Species Act on 21 February (U. S. D. I. Fish and Wildlife Service 1990).

1990: A field survey (14-17 June) and status report for *Polyctenium williamsiae* was funded by the U. S. D. I. Fish and Wildlife Service and performed by Teri Knight (1990) of the Nevada Natural Heritage Program, focusing on the Virginia Range and southern Pine Nut Mountains, and finding no additional populations beyond the type locality.

1992: *Polyctenium williamsiae* was included in a lawsuit settlement with Fund for Animals, requiring the U. S. D. I. Fish and Wildlife Service to determine by 1996 whether about 400 Category-1 Candidate species warranted listing as threatened or endangered.

1992: Intensive surveys for *Polyctenium williamsiae* were conducted on 2 March near the type locality in the Virginia Range by K. Heise and J. Nachlinger of The Nature Conservancy, who documented two new populations nearby.

1992: New populations of *Polyctenium williamsiae* were found by J. Morefield at high elevation in the Kawich Range of central Nye County, Nevada, on 3 July, sparking renewed interest in more extensive surveys for the species.

1993: *Polyctenium fremontii* var. *confertum* was formally described as new to science by Rollins (1993) based on the 1983-1984 material from Larkin Lake, Double Springs Flat, and the Pine Grove Hills.

1993: *Polyctenium* was recognized as a distinct genus in Rollins (1993b) and Hickman (1993).

1994-1996: Status surveys for *Polyctenium williamsiae* and *P. fremontii* var. *confertum* were funded by the U. S. D. I. Fish and Wildlife Service and were conducted by R. F. Holland under contract to the Nevada Natural Heritage Program for this report and for a previous report (EP-3-8), during which several new populations and historical records were discovered, and it became clear that the two taxa should probably be united as a single species distinct from *P. fremontii*.

1995: An interim status report on rare *Polyctenium* taxa was submitted to the Nevada Natural Heritage Program and the U.S.D.I. Fish and Wildlife Service by R. F. Holland, documenting about 15 newly discovered populations.

1995: *Polyctenium williamsiae* was reclassified as a Category-2 Candidate, in part due to the several new populations that were being discovered. The U.S.D.I. Fish and Wildlife Service also began developing a Conservation Agreement with the Bureau of Land Management to further help preclude the need for listing.

1996: Category-2 candidate designations were eliminated for all species on 28 February by the U. S. D. I. Fish and Wildlife Service (1996), and all such species in Nevada were designated sensitive species by the U. S. D. I. Bureau of Land Management (1996).

1997: A Conservation Agreement for Williams combleaf was finalized between the U.S.D.I. Fish and Wildlife Service and Bureau of Land Management on 24 March.

1997: The first draft of this report was submitted by R. F. Holland on 4 August, and subsequently distributed widely to interested parties for information and review pending final editing.

1998-1999: Extensive surveys of known and potential *Polyctenium williamsiae* habitat continued, particularly by Lisa Sims (Bridgeport Ranger District, Humboldt-Toiyabe National Forest) and Arnold Tiehm (Nevada Native Plant Society), documenting four new sites and providing new information for many known sites.

2000: The LaBorde land exchange between the American Land Conservancy and the U. S. D. I. Bureau of Land Management (2000) was approved on 11 May, bringing the privately-held populations of *Polyctenium williamsiae* in the Virginia Range of southern Washoe County, Nevada, into public ownership.

2002: Noel Holmgren of the New York Botanical Garden, an author of the *Intermountain Flora* series, completed an independent study of the specimens collected for this survey and concluded that *Polyctenium fremontii* var. *confertum* should become a synonym of *P. williamsiae*, and that *P. williamsiae* is a species separate from *P. fremontii*.

2002: The U.S.D.I. Fish and Wildlife Service funded and initiated development of a Management and Conservation Strategy for Williams combleaf, ultimately awarding a contract to BMP Ecosciences.

2003: BMP Ecosciences initiated field surveys of known populations, and a 16 July helicopter survey of selected potential sites found 1 new population.

III. PRESENT LEGAL OR OTHER FORMAL STATUS

International: Using a system established by NatureServe (formerly part of The Nature Conservancy), the various state Natural Heritage Programs rank sensitive taxa at state, national, and global levels on a scale of 1 to 5, with 1 being the most vulnerable and 5 the most secure. *Polyctenium williamsiae* was most recently ranked 2 by the Nevada Natural Heritage Program (2003) at all levels. The results of this report show that 2 is still the most appropriate rank.

Federal: *Polyctenium williamsiae* was most recently designated a category-2 candidate for listing as endangered or threatened under 16 U.S.C. 1531 *et seq.*, the Endangered Species Act as amended in 1988, until the U. S. D. I. Fish and Wildlife Service (1996) eliminated that category. Category-2 included taxa for which "*proposing to list them as endangered or threatened species is possibly appropriate, but for which substantial data on biological vulnerability and threat(s) are not currently known or on file to support the immediate preparation of rules*" (U. S. D. I. Fish and Wildlife Service 1985). *Polyctenium williamsiae* remains a "species of concern" to the Fish and Wildlife Service, but this term has no formal or legal status. *Polyctenium williamsiae* is on the sensitive species lists of the U. S. D. I. Bureau of Land Management (1996) and the Inyo National Forest in Nevada and California. This report recommends that *Polyctenium williamsiae* be added to the Humboldt-Toiyabe National Forest sensitive species list, and that all other designations remain unchanged.

State: Since 1987 *Polyctenium williamsiae* has been on the State of Nevada's list of fully protected ("Critically Endangered") species established by N.R.S. 527.260-.300 and enumerated by N.A.C. 527.010. *Polyctenium williamsiae* is also on the Nevada Native Plant Society's Threatened List (Nevada Natural Heritage Program, 2003). This report recommends no changes to these designation.

IV. DESCRIPTION

Non-technical: Perennial herb from a buried taproot and somewhat woody, loosely to densely branched underground stems, grayish to dark green with small white flowers; **stems** above ground annual, mostly widely spreading, often branched, to 1.3 dm long; **leaves** alternate, to 1.3(-1.8) cm long, not or shortly stalked, not clasping at the base, fringed by 2-4 pairs of stiff, narrow comb-like lobes and by stiff, often branched hairs, the lowest leaves densely crowded; stem leaves becoming smaller and less crowded up the stems; **flowers** (May-July) in crowded rows at

stem tips, the outer flowering before the inner, becoming slightly less crowded as the stem elongates in fruit; **flower cup of 4 separate sepals,** each greenish to purplish, ± oval, 1.2-2.3(-2.8) mm long, sparsely hairy, with hard, glassy margins; **petals** 4, white to pinkish, oval to spoon-shaped, shortly ± stalked, broadest toward the tip, 2-4 mm long, the tip sometimes appearing cut off; **anthers** 6, 0.4-0.5 mm long; **fruit stalks** angled ± upward, straight, 2.5-5(-7.5) mm long, sparsely hairy; **fruits** (June-August) narrowly to broadly oval, 3-6.5(-8) mm long, 1.3-2.5 mm wide, 1.5-4x longer than wide, ± crowded, erect to ± angled upward, somewhat compressed, mostly hairless, the 2 chambers splitting apart at maturity; **style** thick, 0.1-0.6 mm long on the mature fruits; **stigmas** slightly expanded; **ovules** 15-20 per chamber; **seeds** 0.7-0.9 mm long, broadly oval to nearly round, reddish-brown, wingless [based on Knight (1990), Rollins (1983, 1993, 1993b), Holmgren (personal communication, 2002), and observations for this report].

Technical: Perennial herb, cespitose from a stout subterranean taproot, root branches occasionally bearing retoños; **caudex** subligneous, loosely to densely branched; **herbage** dark- to grayish- or glaucous-green; **stems** mostly ± decumbent, often branched, to 1.3 dm; **leaves** alternate, cauline, to 1.3(-1.8) cm, sessile to shortly and broadly petioled, non-auriculate, stiffly and pectinately imparipinnately lobed, pubescent with stiff, dendritic trichomes mixed with fewer simple or forked ones; lobes linear, 2-4 pairs, margins revolute, apex often with a large setulose trichome; proximal leaves densely congested; distal leaves gradually reduced and less congested; **inflorescence** (May-July) densely racemose, corymbose, ebracteate, somewhat elongate in fruit, pubescent; **sepals** 4, greenish to purplish, broadly lanceolate to oblong, 1.2-2.3(-2.8) mm, sparsely pubescent, margins hyaline; **petals** 4, white to pinkish, obovate to broadly spatulate, obscurely clawed, 2-4 mm, apex often ± truncate; **anthers** 6, 0.4-0.5 mm; **fruiting pedicels** ± ascending, sometimes widely so, straight, 2.5-5(-7.5) mm long, sparsely pubescent; **silicles** (June-August) oblong to ovoid, 3-6.5(-8) x 1.3-2.5 mm, 1.5-4x longer than wide, congested, erect to widely ascending, ± compressed contrary to the septum (often irregularly so), mostly glabrous, dehiscent; **style** stout, 0.1-0.6 mm; **stigmas** slightly expanded; **ovules** 15-20 per locule, funiculi slender, 0.5-1 mm; **seeds** uniseriate, 0.7-0.9 mm, broadly oblong to orbicular, reddish-brown, wingless, not mucilaginous when wet, cotyledons incumbent [based on Knight (1990), Rollins (1983, 1993, 1993b), Holmgren (personal communication, 2002), and observations made for this report].

Field Characters: (see Appendix 2 figures) Within the mustard family, *Polyctenium williamsiae* is easily recognized by its combination of low perennial herbaceous growth form, stiff narrowly-lobed comb-like leaves with branched and unbranched hairs, whitish flowers, oval fruits flattened perpendicular to their dividing walls and generally no more than 7 mm long and 4x longer than wide, and the habitat in shore zones of seasonal ponds and playas. The following key is synthesized mainly from Hickman (1993), Rollins (1983, 1993, 1993b), Holmgren (personal communication, 2002), and observations made for this report, and should separate specimens of *Polyctenium williamsiae* from members of similar or co-occurring taxa:

1. Plants annual *or* leaves all basal *or* leaves not or shallowly lobed *or* leaves hairless *or* fruit stalked above flower *or* fruit breaking transversely *or* petals yellow or purple .... **other Brassicaceae**

1' Plants perennial, stems leafy; leaves pinnately lobed to midrib, covered with hairs all or most of which are branched; fruit not stalked above flower, breaking lengthwise; petals white to pinkish.

2. Upper leaves clearly stalked, the lobes soft, broader, blunt; root crown covered with leaf bases; fruits compressed mostly parallel to internal wall; plants of alpine fellfields .... ***Smelowskia***

2' Upper leaves obscurely or not stalked, the lobes rigid, linear, sharply pointed; root crown free of leaf bases; fruits compressed perpendicular to internal wall; plants of mid-elevation seasonal pool shores ..... ***Polyctenium***

3. Fruit linear-fusiform to narrowly oblong, 5.5-9x longer than wide, the longest usually 7-16 x 1-1.7(-2) mm; longest petals generally 4-6 mm ..... ***Polyctenium fremontii***

3' Fruit oblong to ovoid, 1.5-4x longer than wide, the longest 3-6.5(-8) x 1.5-2.5 mm; longest petals 2-4 mm ..... ***Polyctenium williamsiae***

Photographs and Line Drawings: A line drawing of *Polyctenium williamsiae* by Jeanne R. Janish was published in Rollins (1993b, p. 717), and is reproduced in Appendix 2, figure 1 of this report. A line drawing of *P. fremontii* by Linda A. Vorobik was published in Hickman (1993, p. 437), and is reproduced in Appendix 2, figure 2 for comparative purposes. Another line drawing of *P. fremontii* by Jeanne R. Janish was published in Hitchcock and Cronquist (1973, p. 174). No photographs of *Polyctenium williamsiae* are known to have been published. Photographs of *Polyctenium williamsiae* and its habitat were made for this report, are reproduced in Appendix 2, figures 3-11, are filed with the Nevada Natural Heritage Program, and are available on its public web site at http://heritage.nv.gov.

V. SIGNIFICANCE OF TAXON

Natural: *Polyctenium* is quite unusual among the mustards in its adaptation to seasonally amphibious habitats. As a family, the mustards are not typically associated with wetland habitats: Mason's (1957) treatment of the California marsh flora includes only 22 species in just 6 cruciferous genera. Nearly all of these taxa inhabit permanently flooded or permanently saturated sites. In contrast, *The Jepson Manual* (Hickman 1993) treats hundreds of species in 63 genera, making the Brassicaceae one of the largest families in the California flora. The parallels between *Polyctenium* habitat and California's vernal pools are vividly apparent and await exploration. The insular nature of the habitat makes it suitable for studies of introgression and adaptive radiation. The entirely perennial genus *Polyctenium* poses interesting population biological contrasts with the predominantly annual genera so characteristic of California vernal pools.

Human: No studies of medicinal or other qualities of potential human benefit are yet known to have been performed on any *Polyctenium* species. As a member of the mustard family, *Polyctenium williamsiae* is closely related to the cole (*Brassica oleracea*) crops (broccoli, Brussels sprouts, cabbage, cauliflower, kale, kohlrabi, etc.), a number of important ornamentals (*Erysimum, Lunaria*), and several important weeds (*Cardaria, Brassica, Lepidium*), and others. *Polyctenium* has the potential to provide novel genetic material for incorporation into existing crop varieties or in developing new varieties.

VI. GEOGRAPHIC DISTRIBUTION

Geographic Range: (Appendix 1, tables 1-3; Appendix 3 maps). Globally, *Polyctenium williamsiae* has been documented from 34 lake beds in about 15 scattered groups, concentrated mainly in the mountains and foothills of the southwestern Great Basin near the California-Nevada border from Reno southeast to Montgomery Pass in Mineral, Lyon, Douglas, and southern Washoe counties, Nevada, and adjacent Mono County, California, and also scattered north-

ward along the western edge of the Great Basin in northeastern California, northwestern Nevada, and southeastern Oregon, and disjunct on the south edge of the Great Basin in the Kawich Range of central Nye County, Nevada. The known sites are variously on Bureau of Land Management (BLM; roughly 37%), Humboldt-Toiyabe National Forest, Bridgeport Ranger District (HTNF; 33%), Inyo National Forest (INF; 16%), and private (14%) lands. The most distant two extant occurrences are separated by about 400 miles (650 km), and the number of extant occurrences is reduced to 20 if a 1 km minimum separation distance is imposed.

Precise Occurrences: Site numbers and descriptions are given in Appendix 1, table 1. The tables cross-reference each site to its related maps, figures, and Nevada Natural Heritage Program occurrence numbers, and shows its most recent year observed and source(s) of documentation. The table also shows estimated areas and maximum numbers of individuals for each site, along with elevations, apparent land management status, and types of impacts or threats.

Numbers of individuals in populations were estimated variously by direct counting or by density samples extrapolated to the habitat area observed to be occupied. The maps in Appendix 3 show estimated habitat boundaries, derived by appropriate GIS buffering of lake and playa shores as mapped on 1:24,000 topographic maps or as visualized on 1:12,000 digital orthophotomaps, combined with field observations of the extent to which the lake bottoms comprised occupied or otherwise appropriate habitat or instead showed signs of semi-permanent inundation. The areas, elevation ranges, and land management information given in table 1 were derived from the final site boundaries thus mapped. Threats and impacts were assessed from all available information, including but not limited to visual inspection on the ground, and association with mapped disturbances.

To the best of our knowledge, no privately managed sites were entered upon to obtain any of the new information documented by these surveys against the restrictions of the owners or managers. In some cases, private sites were small and easily viewed and documented from adjacent public lands or public access areas. In a few cases, sites were not surveyed due to lack of access, and the information in this report is then based solely on any previously existing information.

Historical site(s) rediscovered or recently known extant: (Appendix 1, table 1) Through the end of 1993, nine occurrences of *Polyctenium williamsiae* were known to have been documented (sites 01-08 and 10). During surveys for this report, all but two of these (03-04, known extant in 1992) were revisited and censused. Several were also visited by various Forest Service and BLM personnel who generously shared their results. Historical documentation for six additional sites (16, 25, 28-29, 31-32) became known only after surveys for this report were complete, and two of these (16 and 29) were visited and further documented during or subsequent to surveys for this report. Of the 15 total sites here considered to comprise the historical records for this species, 11 were rediscovered or recently known extant, and the other four are of unknown status (see below). All other sites are considered new and are discussed below.

New site(s) discovered: (Appendix 1, table 1) During surveys for this report, 12 new populations (sites 09, 11-15, and 17-22) were discovered and documented in western Mineral and Lyon counties, Nevada. Concurrent and subsequent surveys and collections by other agencies and individuals discovered and documented another seven populations (sites 23-24, 26-27, 30, and 33-34).

Historical site(s) searched for but not rediscovered: None.

Other site(s) searched where not discovered: (Appendix 3 maps) Sites U01-U40, comprising 68 individual lake beds, were surveyed for this report without encountering any *Polyctenium* taxa. Another 26 lake beds comprising 24 sites (F01-F24) surveyed for this report, or subsequently found to be documented by specimens, were found to harbor only *Polyctenium fremontii*. And an additional 14 identified potential lake beds (now sites U41-U54) were visited in July 2003 by Alison Stanton of BMP Ecosciences via helicopter and found to be unoccupied. To date, a total of 108 appropriate seasonal pools have been visited in western Nevada and found to be unoccupied by *Polyctenium williamsiae*.

Historical site(s) known or suspected to be erroneous reports: No erroneous reports of *Polyctenium williamsiae* were detected in the historical record. During surveys for this report, material collected from the west side of the Black Butte Hills of northern Washoe County seemed to key readily to *Polyctenium fremontii* var. *bisulcatum*. This taxon is otherwise known only from the nineteenth century type collection from the Blue Mountains of north east Oregon. This material was subsequently determined to be var. *fremontii*, and initial reports of var. *bisulcatum* for Nevada were therefore erroneous.

Historical site(s) known or assumed extirpated: None. Zero population counts have been recorded at a few sites in certain years, but these may represent normal population fluctuations, and no conclusive cases of extirpation have yet been documented.

The lake bed west of Double Spring Flat (site 10) is cited as a paratype locality for *Polyctenium fremontii* var. *confertum* by Rollins (1993), and the Tiehm collection documenting it is widely distributed. Tiehm's collections characteristically are reliably located, so when plants could not be relocated there in 1995, this population was thought to be extirpated. The site had recently been fenced, ditched, and drained, and was not entered because it was private property, but no plants were visible over the fence. *Polyctenium* probably has been extirpated over the vast majority of this 350 acre lake bed, but Tiehm was able to relocate plants in 1998 at his collecting site, documenting that this site has not yet been extirpated.

Historical site(s) where present status unknown: (Appendix 1, table 1) Four sites (25, 28, 31-32) area documented solely by historical specimens collected between 1946 and 1988, and were neither searched for nor relocated for this report. *Polyctenium williamsiae* could now be extirpated at some of these sites, or may remain extant at all of them.

The one record for Oregon (site 32) is documented by a single plant on a single herbarium sheet that otherwise contains several plants of *P. fremontii* var. *fremontii*, and is the only known instance of the two taxa occurring together in the same population.

After completing field surveys, the first author (Holland) found the 1946 Alexander and Kellogg collection from northern Washoe County, Nevada, filed among *Polyctenium fremontii* specimens at the California Academy of Sciences. The locality is vague ("Long Valley, vernal pond shore") and could correspond to any one of the scores of playas scattered over the 25 miles from Central Lake north to Calcutta and Mosquito lakes. Two of the most likely playas for this occurrence are identified among the potential sites mapped in Appendix 3, but have not yet been visited. Otherwise only *Polyctenium fremontii* was found in northwestern Nevada.

Potential site(s) meriting future field surveys: Lake beds exploited by *Polyctenium* typically are mapped as playas or intermittent lakes on 1:24,000 topographic maps. This facilitates site selection for focused field surveys. In preparation for this status survey, the second author (Morefield) paged through every 7.5' topographic quadrangle in the western half of Nevada, ultimately compiling several hundred potential locations. Many of these were low-elevation playas supporting *Sarcobatus* or *Atriplex*, or were otherwise obviously alkaline, and were eliminated from further consideration. After the surveys detailed above, 265 of these lake beds comprising 163 sites (25?, P002-P035, P037-P053, P055-P061, P064-P065, P067-P070, P072, P075, P077-P081, P083-P084, P086-P087, P089, P091, P093-P094, P096-P178) remained identified as potential habitat and are shown on the maps in Appendix 3. Surveys for this report focused on potential sites deemed to have the highest probabilities of supporting *Polyctenium williamsiae*, and on those that could reasonably be accessed within the constraints of time and budget. Most of the remaining potential sites are therefore considered to have low probabilities of supporting *Polyctenium williamsiae* (especially the large majority in northwestern Nevada, where *P. fremontii* is the most likely occupant), but nevertheless a few new populations of *P. williamsiae* likely await discovery among them.

VII. HABITAT CHARACTERISTICS

Environment and Habitat Summary: (Appendix 2, figures 6-11) *Polyctenium williamsiae* inhabits relatively barren sandy to sandy-clay or mud margins and bottoms of non-alkaline seasonal lakes and playas perched over siliceous volcanic bedrock in the sagebrush, pinyon-juniper, and mountain sagebrush zones between 4215 and 8935 feet (1285-2725 meters) elevation. Very rarely it is also found in seasonally wet drainages near such lakes. The lakes may be turbid or clear, and they vary widely in the depth and duration of standing water from year to year based on seasonal precipitation, resulting in wide fluctuations in the associated combleaf populations.

The lake beds generally support a sparse cover of other plant species that tolerate seasonal inundation such as *Carex douglasii, Muhlenbergia richardsonis, Camissonia tanacetifolia* var. *tanacetifolia, Iva axillaris, Myosurus minimus, Potentilla newberryi, Psilocarphus brevissimus, Downingia* sp., *Eleocharis* sp., *Juncus balticus, Artemisia cana, A. tridentata,* etc. Total plant cover typically is low, usually less than 5 per cent and frequently well below 1 per cent.

The elevations at which populations occur decrease fairly uniformly from south to north, although this pattern is also constrained by the elevations at which appropriate lake beds are found. In the main range of the species, elevations range from 5660 feet (1725 m) near Reno in the north, up to 8270 feet (2520 ft m) toward the south in the Bodie Hills. The lowest elevations occur at the northwest limits of the species in southeast Oregon and northeast California, and the highest occur at the southeast limit in central Nye County, Nevada.

Physical Characteristics:

Physiography: Most known locations of *Polyctenium williamsiae (sensu lato)* are within Holmgren's (1972) Reno Section of the Great Basin Division of the *Intermountain Flora* region. The Reno Section is a strip of generally high mountain ranges adjacent immediately east of and parallel to the Sierra Nevada and west of the shores of glacial Lake Lahontan, and is characterized by the "climatic influences of high mountains within and adjacent to the section, and the high, sagebrush covered valleys" (Holmgren 1972). The

Great Basin Division consists of a series of mostly north-south-oriented ranges and basins that age toward the southeast, block-faulted from rocks that age progressively toward the northwest and that have been arched upward in the middle. The Reno Section correlates well with the northern half of the Walker Belt as mapped by Stewart (1980)."

Climate: Hidy and Klieforth (1990) aptly describe the climate of the Great Basin as ". . . one of the most extreme and variable climates on earth." This high variation occurs along horizontal and elevational gradients and at all time scales: hourly, diurnally, seasonally, annually, and over the tens of thousands of years of glacial cycles. The region's latitude, interior continental position, and high mountainous borders combine to create a generally arid climate. As in most arid regions, evapotranspiration greatly exceeds precipitation at all elevations, producing an average net loss of surface moisture (Hidy and Klieforth 1990). Most annual precipitation falls from about November through April in Pacific storm systems from the west. The Great Basin also lies within the influence of sub-tropical summer moisture, which originates in the Gulfs of Mexico and California and spreads over most of Arizona during July and August. This "monsoonal" influence produces a secondary peak of precipitation particularly toward the eastern and southern parts of the region, averaging about a quarter to half of the annual total, and capable of delivering a substantial majority of annual precipitation to limited areas in any given year. Both summer and winter precipitation are highly variable from year to year, ranging between about 25% and 250% of the local long-term averages. This variability decreases somewhat toward the northeast and at higher elevations.

Temperature regimes in the Great Basin are markedly continental, with fluctuations up to 40-50°F (22-28°C) diurnally, in average differences between warmest and coldest months, and in departures of extreme highs and lows from seasonal averages (Hidy and Klieforth 1990, Holmgren 1972, Morefield personal observations). This can result in differences up to 120-140°F (67-78°C) between the extremes experienced at any one site during a year. In general, temperature ranges at all the above scales tend to increase toward lower elevations and toward the northeast (more continental) part of the region. Daily variations further tend to be greatest at the lowest humidities during the spring and fall seasons. The average daily temperature range throughout the year is about 25-30°F (14-17°C). Climatic conditions in the adjacent eastern Sierra Nevada tend to be somewhat less extreme and variable, with higher and more consistent annual precipitation.

The sites where *Polyctenium williamsiae* populations occur presently experience a mid-latitude steppe climate (Houghton, Sakamoto, and Gifford 1975), with warm dry summers, cold moist winters, and semi-arid moisture regime. Based on data from the PRISM precipitation models developed at Oregon State University, annual precipitation at the sites averages between about 8.71 and 24.98 inches (221-634 mm) water equivalent, with a mean of 16.40 inches (417 mm). About 15-50% or more of these amounts fall as snow, depending on the elevation. *Polyctenium williamsiae* is apparently affected less by direct precipitation, however, than by the seasonal water levels in their lake bed habitats, which can also be influenced by temperatures, cloud cover, and other natural and man-made factors. Mean annual temperatures are about 44-50°F (7-10°C), with mean January lows approaching 15°F (-9°C) and mean July highs approaching 90°F (32°C). Because the populations occupy topographic lows, they are also subject to local cold air accumulation at night and during winter.

Geomorphology, aspect, and slope: All documented population of *Polyctenium williamsiae* occupied intermittent lake beds in bolson bottoms. As such, they had no slope or aspect. Several of the lake beds were paradoxically situated atop broad passes. Others were more obviously influenced by local faulting. None of the lake bed surfaces had been distorted by wind or water erosion. All the sites were on older (Wisconsin or older) landforms with well developed clayey argillic horizons, silica-cemented duripans, and other characteristics of stable, old landforms (Archer 1984, Baumer 1983, Blake 1991).

Geology: Local bedrock geology is uniformly volcanic at known *Polyctenium williamsiae* sites. Oldest among these rocks are the rhyodacites of the Kawich Ranges, which have been dated isotopically at 26.4 $\pm$ 1.3 million years (Kleinhampl and Ziony 1985). Most of the remaining sites are on potassium-rich andesites erupted in late Miocene to earliest Pliocene time. These rocks have been isotopically dated in the Virginia Range at about 13 m.y. (Bonham, 1969).

Soils: Surprisingly many *Polyctenium williamsiae* locations are covered by published soil surveys. These surveys map "soil associations," broad categories consisting of two or more geographically associated soils mapped as a single map unit. This mapping convention is used because of the impracticality of mapping the intimately-intermingled component soils, but in almost every case the lake beds are not differentiated from surrounding upland soils. Only in the Virginia Range are the lake beds specifically identified: they are mapped as "playas" (Baumer 1983). Surrounding soils have strongly developed argillic horizons and extensive silica-cemented duripans typical of landforms of considerable age (Baumer 1983; Archer 1984; Blake 1991). These duripans and the underlying unweathered bedrock presumably act as aquatards, much like they do for the vernal pools of California's Great Valley (Holland and Dains 1990).

Limited field examination of soils at known *Polyctenium williamsiae* sites revealed obvious hydromorphic properties including low chromas, extensive mottling, root haloes and occasional manganese shot typically associated with seasonally standing water.

Hydrology: Besides incident precipitation, *Polyctenium williamsiae* sites receive and retain sufficient run on from surrounding uplands to create seasonally standing water. Typically, this would be associated with mid-winter precipitation, much of which may fall as snow. These lakes may not form every winter; Heise and Nachlinger collected mature to senescent *Polyctenium williamsiae* in March of 1992, suggesting that the site had not been flooded over the preceding winter. The lakes also may fill during summer, as was observed in 1995 at the Kawich Range sites, resulting in the extirpation or non-emergence of the current year's cohort.

Air and water quality requirements: No specific requirements or unusual tolerances are known. Lakes with *Polyctenium williamsiae* growing around their margin may be either turbid or clear. None of the lakes had overt signs of salinity or alkalinity. All of the lakes were shallow enough to warm and cool diurnally. Keeley (1990) has shown that warm vernal pool water in late afternoon is essentially without dissolved CO_2, stimulating the development of crassulacean acid metabolism in several prominent vernal pool genera. *Polyctenium* would seem a likely candidate for such metabolic elaborations.

Biologic Characteristics:

Community physiognomy: *Polyctenium williamsiae* is a component, sometimes locally dominant or codominant, of the typically sparse herbaceous vegetation of the lake beds it inhabits. Frequently, the *Polyctenium* is found in a narrow to broad concentric band obviously related to inundation regimes within the lake beds. Woody plants are conspicuously absent from all sites. Canopies typically are under 20 cm tall, and may be as short as 2-5 cm. Total cover typically is less than 25 per cent, and may be below 2 per cent. The upland vegetation surrounding the lake beds typically consists of sagebrush shrublands or pinyon-juniper woodlands.

Vegetation type: The lake beds exploited by *Polyctenium* clearly are azonal. They may be distantly associated with Sawyer and Keeler-Wolf's (1995) low sagebrush (*Artemisia arbuscula*) series, but would more appropriately be part of a silver sage (*Artemisia cana*) series if one existed. In the National Vegetation Classification System of Anderson *et al*. (1998), *Polyctenium williamsiae* habitat would best fit under "non-tidal mid flat seasonally / temporarily flooded sparse vegetation" (VII.C.4.N.c.).

Associated plant species: (Appendix 1, table 4) *Carex douglasii* and *Muhlenbergia richardsonis* were observed at every site inhabited by *Polyctenium williamsiae*. *Camissonia tanacetifolia* var. *tanacetifolia* was recorded at 9 of the 22 sites documented by this report. *Iva axillaris* and *Myosurus minimus* co-occurred with *Polyctenium williamsiae* at 6 and 5 lake beds respectively. Typically, *P. williamsiae* grew in otherwise barren areas rather than with canopies intertwined with other plants. Other relatively frequent associates included *Potentilla newberryi, Psilocarphus brevissimus, Downingia* sp., *Eleocharis, Juncus balticus, Artemisia cana,* and *A. tridentata*.

Other endangered, threatened, and sensitive species: Only the sensitive plant species *Cusickiella quadricostata* (Bodie Hills draba) and *Penstemon pudicus* (bashful beardtongue) are known to occur within 0.5 mile (0.8 km) of *Polyctenium williamsiae* populations in Nevada. Another 29 sensitive plant and animal species have been found within 6 miles of the Nevada populations. None of the above species occurs in habitats similar to that of *Polyctenium williamsiae*. *Ivesia pityocharis,* the Pine Nut Mountains mousetails, occurs in seasonal lake shore habitats very similar to those of *Polyctenium williamsiae* in the southern Pine Nut Mountains of Douglas County, Nevada. These lakes are at high elevations and somewhat more heavily vegetated, however, and the only *Polyctenium* that has been found in or near the *Ivesia* populations is *P. fremontii*. In northwestern Nevada another sensitive plant species, *Phacelia inundata* (playa phacelia), also occurs in potential *Polyctenium williamsiae* habitat, but again only *P. fremontii* has been found with the *Phacelia*. Contact the Nevada Natural Heritage Program for current information all rare and sensitive species found in the vicinity of *Polyctenium williamsiae* or elsewhere in the state.

Land Management: (Appendix 1, table 1) At most sites, domestic livestock and feral horses were seen or otherwise were evident. For all sites, management status was determined based on the best maps, GIS data, and other information available, but generally was not further verified. Ownership status of associated minerals and water rights was not determined for any site, nor was the presence or absence of any easements or other encumbrances.

Bureau of Land Management (BLM), U. S. Dept. of Interior: About 37% of the global *Polyctenium williamsiae* population occurs on public lands managed by BLM in

the Bishop Resource Area, Carson City District, Battle Mountain District, and possibly the Surprise Resource Area or other divisions. Most of these lands are currently open to multiple uses, including livestock and feral horse use, mineral entry, non-motorized recreation, and sometimes off-road vehicle use, and/or are identified as available for disposal or exchange.

An area of Critical Environmental Concern has been designated by the Carson City District to include the Virginia Range populations, where the recent LaBorde land exchange brought all four lake beds into public ownership, but no other protective withdrawals affecting *Polyctenium williamsiae* are currently known on BLM lands.

Humboldt-Toiyabe National Forest (HTNF), Carson City Ranger District, U. S. Dept. of Agriculture: Roughly 33% of the global *Polyctenium williamsiae* population occurs on public lands managed by HTNF. Most of these lands are currently open to multiple uses, and overall management is similar to that for the BLM lands discussed above.

Inyo National Forest (INF), U. S. Dept. of Agriculture: Roughly 16% of the global *Polyctenium williamsiae* population occurs on public lands managed by INF. Most of these lands are currently open to multiple uses, and overall management is similar to that for the BLM lands discussed above.

Private lands: Roughly 14% of the global *Polyctenium williamsiae* population occurs on lands identified as privately managed, which may include some county or municipal lands. Land use and/or management plans and actions on these lands are not known to or likely to consider the presence of *Polyctenium williamsiae* or its habitat. The region occupied by *Polyctenium williamsiae* includes the urban interface areas around Reno, Carson City, Virginia City, and Garnerville in western Nevada, and some lake beds have already been impacted directly or indirectly by urban and residential development.

VIII. BIOLOGY AND ECOLOGY

Population Summary: Available population estimates for each site are given in Appendix 1. Because of the wide annual fluctuations in apparent population sizes observed at most of the known sites, population totals given here and throughout this report are based on the maximum numbers reported at each site, unless observed habitat losses or degradation appear to justify a lower number.

Based on the information gathered for this report, the maximum total known global population of *Polyctenium williamsiae* was estimated to be about 452,000 individuals, and to occupy about 542 acres (219 ha) of habitat divided among 34 sites in 15 scattered areas, concentrated mainly in the mountains and foothills of the southwestern Great Basin in west-central Nevada and adjacent California, but scattered also in northeastern California, southeastern Oregon, and south-central Nevada, between 4215 and 8935 feet (1285-2725 meters) elevation. The most distant two occurrences are separated by about 400 miles (650 km), and the number of extant occurrences is reduced to 20 if a 1 km minimum separation distance is imposed. Based on the probable extent and occupancy rate of unsurveyed potential habitat, the true total population of *Polyctenium williamsiae* is estimated up to about 150%, though more likely less than 50%, greater than that now documented.

In 1995, an estimated 420,000 or 93% of the known individuals covered the large bed of Larkin Lake, but this may have been an exceptional year for the species, as more recent surveys were only able to locate about 1000 individuals at the same site (Anne S. Halford, personal communication, July 2003).

Demography: Systematic long term monitoring has not been conducted for most Nevada *Polyctenium* populations. Absence of the species from numerous apparently suitable sites provides circumstantial evidence that the species may have undergone population declines at least during prehistoric times, and/or that it may have limited ability to disperse and to establish new populations in unoccupied habitat.

At least qualitative population estimates are available at odd intervals for the 4 Virginia Range sites (sites 1, 2, 5 and 6). In 1987, Knight reported between 11 and 50 plants at 2 of the 4 lakes. In 1990 she reported 3000-5000 plants at sites 1 and 2 (combined) and none from sites 5 and 6. (Her Field Survey Form also notes "more sporadic than in 1988", but we have no additional data for that year.) Heise and Nachlinger (1992) estimated over a thousand plants at each of the 4 lakes. More recently the numbers are down sharply. Precipitous drops are evident also at the Bellehelen Lakes (sites 3 and 4), where Morefield estimated 1000 plants grew in 1992. The lakes were brim full when revisited in 1995, and no plants were found. These data collectively imply substantial year to year fluctuation in population size.

Because of the dramatic fluctuations observed, there is every reason to expect that in different years different lake beds than Larkin Lake would have held the majority of the world's population. *Polyctenium williamsiae* probably responds more like an annual than like a long-lived woody species. Conceivably, in some years growing conditions could be simultaneously optimal at every location, presumably resulting in a large seed crop. This should offset the equally conceivable chance of simultaneously unsuitable conditions everywhere, at least for as many years as the seeds or roots survive under continuous inundation or desiccation. There are several records of *Polyctenium williamsiae* from California in the region from the Bodie Hills to the Madeline Plains, but the species has not been systematically sought in that broad area. Unless and until simultaneous monitoring can be conducted in both states, the proportions of the reproductive populations occurring in California versus Nevada cannot accurately be estimated.

From estimates of the total individuals within total occupied habitat (see population summary, above), a maximum average density of 834 plants per acre (2060/ha) can be estimated. This is greatly skewed, however, by the large and dense population found at Larkin Lake in 1995, and removal of this population from the data results in a maximum average density of 72 plants per acre (/ha) for the remaining sites. Individual site estimates were quite variable, ranging from 1 or fewer plants per acre or hectare to about 650 plants per acre (1600/ha) at site 18 (excluding the Larkin Lake site; see Appendix 1, table 1). In reality, the plants are much more aggregated than the average densities would suggest, and local densities of more than 50 plants/m^2 were observed at some sites. Some of the population fluctuations reported at the Virginia Range sites may reflect unjustified extrapolation of locally observed densities over large areas.

Phenology: Flowering and fruiting times in *Polyctenium williamsiae* likely vary widely with the timing of seasonal precipitation and temperature changes, and the consequent filling and drying of the lake beds it inhabits. Heise observed newly emerged tufts of leaves in early March, 1992, at the Virginia Range sites. Available specimens generally date from June or early July, with more mature fruit on the later collections. In 1995, flowering was well under way by mid May

and extended well into July. Fruit were fully developed as early as mid June. Valves began to separate from the replum in late June, and most seed had been released by late July.

Genetics: No studies of the genetic structure in *Polyctenium williamsiae* are known. The species' scattered, insular distribution should promote local differentiation among the various populations, such as seen in several genera common in California vernal pools (Holland and Jain 1976). *Polyctenium williamsiae* provides an intriguing contrast with most of the vernal pool species, however, by virtue of its perennial habit. If the species produces seed via insect-mediated pollen exchange, this could further augment genetic diversity in *Polyctenium williamsiae*.

Reproduction and Dispersal: No studies or observations of reproduction or dispersal are known for *Polyctenium williamsiae*. Most Brassicaceae offer nectar rewards to pollinators. A variety of insects was observed visiting *Polyctenium williamsiae* flowers, but it was not apparent which, if any, of these insects actually were effecting pollination. Each locule of a *Polyctenium williamsiae* fruit can produce 15-20 ovules (Rollins 1983). Each inflorescence contains about 10-50 flowers, and each plant may produce 4-10 such groups. Thus, a plant could produce between 1200 and 20000 seed each year, assuming 100% pollination and survival to dispersal.

Long-distance dispersal of seeds (which become mucilaginous and sticky when wet) in the mud picked up by shore-bird species, while almost impossible to document, is the most likely and effective dispersal method between suitable lake-bed habitats. This could explain the scattered populations found to the north and east of the main range of *Polyctenium williamsiae*. Dispersal by any other means is presumably quite limited, and if more than a few tens of meters would much more likely land the propagule in inhospitable sagebrush scrub than in the appropriate lake bed habitat. Local dispersal within ponds probably occurs by wind blowing or water floating seeds, capsules, or entire plant parts. Intact plants were observed floating at several locations, presumably dislodged by animal or wave action.

Hybridization: No evidence of hybridization or intergradation between *Polyctenium williamsiae* and any other taxon has been observed or reported. *Polyctenium williamsiae* has not been found growing with *P. fremontii* except at the one Oregon site, and no plants on the herbarium specimen from this site showed any signs of intermediacy.

Pathology: The first author occasionally observed plants that were infected with an unidentified orange rust. Infected plants seemed to be flowering and maturing a normal seed crop. Only scattered infected individuals have been observed, never an entire population.

Predation: Rabbits and other native wildlife probably graze the plants on an occasional basis without significant impacts. Livestock use was evident at every site, and in some cases was severe. In 1995, heavy sheep use for forage and water was evident at Nye Canyon (sites 08 and 09). The normally meager canopy of *Carex douglasii* and *Muhlenbergia richardsonis* had been replaced by a thin layer of sheep feces over about 2/3 of the lake beds. Only the deepest part of the northeastern lake was spared, as water still stood in that part of the lake during the grazing season. Heavy sheep and cattle use are also implicated in the population drops seen at the Virginia Range sites (sites 1, 2, 5, 6). Bair and Ramakka (1996 field survey form filed at Nevada Natural Heritage Program, Carson City) reported salt blocks present at 2 of the 4 lakes with attendant trampling and manure. Plants were found growing in wild horse stud piles at Mt. Hicks and Bald Mountain. Most mustard family members are considered unpalatable to livestock, and presumably this extends to *Polyctenium* as well. Damage to the species is much more likely due to trampling or wallowing than to herbivory.

Competition: *Polyctenium williamsiae* appears to be a poor competitor that depends on winter flooding and summer desiccation to keep the zonal vegetation in check. When Tiehm discovered the species in 1983 at site 01, he found it growing below the lowermost band of big sagebrush which was growing at that time. Very heavy rains in February 1986 flooded many acres of big sagebrush around site 01, and *Polyctenium williamsiae* was growing among the drowned shrubs when Knight visited the site in 1987. The dead shrubs still are visible today, but the *Polyctenium* has retreated to generally below the former sagebrush zone. The large populations reported in the late 1980s and early 1990s may reflect a spike afforded by transiently available habitat.

Response to Disturbance: The preceding section relates a competitive response to one kind of disturbance. Hiese (1992) reported observations by Tiehm of large populations of *Polyctenium fremontii* that entirely vanished following a particularly rainy winter that kept the plants flooded. This also has been observed in *P. williamsiae* at sites 3 and 4 (Kawich Range) and may explain why the species went undiscovered at 2 of the 4 Virginia Range sites for so long. Fire is an unlikely disturbance because the habitat is either under water or has such a vanishingly low fuel load as to preclude ignition. *Polyctenium fremontii* has been found in intermittent stream beds, on seasonally moist banks, and even in old gravel pits, suggesting some tolerance for physical soil disturbance, but *P. williamsiae* virtually never grows in such settings. Plants were observed to be nearly eliminated from several sites after heavy grazing and trampling, but did appear to recover somewhat in subsequent years. Overall it appears that *Polyctenium williamsiae* does not tolerate disturbance well, but is capable of recovering is such disturbance is not too severe or prolonged.

Other Interactions: No other interactions have been noted.

IX. EVIDENCE OF THREATS TO SURVIVAL

Causes of impacts and threats observed or reported for the known sites are summarized in Appendix 1, table 1. Several sites appear to have been significantly impacted by one or more of the following threats.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range:

Water development or diversion: Because of the close relationship observed between water levels and population extent in lake beds occupied by *Polyctenium williamsiae*, this may represent the greatest long-term threat to the species. Shallow excavations reminiscent of mid 1950s wildlife improvement projects were noted in all but two lake beds. No plants were seen in these depressions, although they did grow on some of the spoil piles. At many otherwise suitable but unoccupied lake beds, these or more substantial excavations had occurred. Such excavations or other water diversions can substantially alter the hydrology of these small lake beds, changing the level to which they would otherwise fill, and quite possibly eliminating suitable habitat for *Polyctenium williamsiae*.

Animal grazing or trampling: Use of the habitat by domestic livestock and feral horse populations was evident at every population visited, was particularly notable at the Virginia Range (cattle, sites 01-02 and 05-06), Nye Canyon south (sheep, site 09) and Mount Hicks (wild horses, site 12) populations, and had created substantial impacts at several other sites. Salt blocks were seen near or in many of the lakes. The combination of water and salt is especially attractive to cattle, which loaf around the salt by day, and disperse into the surrounding brush to forage when temperatures moderate. This focuses many

animals on a small area for a large part of each day. Most impacts are probably due to trampling and wallowing rather that to direct herbivory.

At the Double Springs Flat population (site 10), if the plants were evenly distributed over the entire lake bed (as at Larkin Lake but nowhere else observed) then this would have been the most expansive known population. The entire area, however, had been drained, fenced and stocked with many cattle. Because the area is privately owned, I (Holland) did not leave the road right of way, but no plants could be seen from over the fence. There is reasonable expectation that *Polyctenium williamsiae* may soon be extirpated at this site.

In 1995, heavy sheep use for forage and water was evident at Nye Canyon (sites 08 and 09). The normally meager canopy of *Carex douglasii* and *Muhlenbergia richardsonis* had been replaced by a thin layer of sheep feces over about 2/3 of the lake beds. Only the deepest part of the northeastern lake was spared, as water still stood in that part of the lake during the grazing season. Heavy sheep and cattle use are also implicated in the population drops seen at the Virginia Range sites (sites 1, 2, 5, 6). Bair and Ramakka (1996 field survey form filed at Nevada Natural Heritage Program, Carson City) reported salt blocks present at 2 of the 4 lakes with attendant trampling and manure. Plants were found growing in wild horse stud piles at Mt. Hicks and Bald Mountain.

Road development and maintenance and off-road vehicle use: Roads skirt or bisect many of the known populations, providing easy access to off-road vehicle (ORV) use. Substantial ORV impacts were evident at all 4 Virginia Range sites (1,2,5,6), at Sweetwater Summit (16), and at several of the other sites. Located within the triangle between Reno, Carson City, and Virginia City, the Virginia Ranges sites doubtless will see an increase in ORV activity as these two urban centers grow toward each other. The Sweetwater Summit site is very close to a busy paved highway and was an obviously popular ORV area.

Invasion of exotic plant species: Exotic species were noted at only three lake beds. *Bromus tectorum* and *Marrubium vulgare* were noted at site 02, the brome grew with *Erodium cicutarium* at site 12, and all three weeds were noted around site 05. The amphibious habitat makes it unlikely that any of these taxa ever will establish or maintain significant populations. On the other hand, tall whitetop (*Lepidium latifolium*), a noxious and aggressive weed, has rapidly invaded seasonally moist areas in western Nevada, and will likely begin affecting *Polyctenium williamsiae* habitat in the near future.

Urban and residential development: Residential development has occurred, or is likely to occur, near several of the known and potential sites in the Reno / Carson City / Virginia City area, the Double Springs Flat area, and in the Larkin Lake area. On Double Springs Flat, a significant portion of the lake bed has been converted to residential and ancillary uses. Though direct use of the habitat for building or infrastructure is highly unlikely at most other sites, indirect impacts from such developments (including most of the other items listed in this section) could affect some populations in the future.

Fire and fire suppression activities: *Polyctenium williamsiae* grows in a relatively fireproof microsite, as discussed above. This couple with the open and relatively level surfaces provided by some of the drier lake beds could make them attractive as staging or landing areas.

Recreational use: So far, significant impacts from non-vehicular recreational use of *Polyctenium williamsiae* habitat have been observed only at one site (08) where camping and hunting are popular uses. The species' habitat is obviously attractive for water fowl hunting, and spent shotgun shells were noted at every population visited.

Mineral exploration and development: None of the known populations are ever likely to be directly threatened by mineral exploration or development. Extensive mining operations are ongoing just south of the Mt. Hicks population (site 12), however, and the lake bed could conceivably be an attractive location for a cyanide leach field. Because of provisions of the mining law of 1872 (30 U.S.C. 21 *et seq*.; see further below), mining-related impacts are nearly impossible to prevent without cooperation of the developers.

Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes: The few scientific collections taken to document populations (Appendix 1, table 5) are neither known nor likely to have had significant impacts on any population of the species. No other uses of the species for such purposes is known, but see under recreational uses above.

Disease or Predation: Other than the livestock activity discussed above, no significant disease or herbivore impacts or threats have been noted at any of the sites. The very occasional rust infections observed did not appear to be affecting viability or productivity of the affected plants.

Inadequacy of Existing Regulatory Mechanisms: No adequate, enforceable, and range-wide conservation agreements or management plans yet exist for *Polyctenium williamsiae* or its habitat. Unless it is listed as endangered or threatened (50 CFR 17.61, 17.71) and occurs within federal jurisdiction, a plant has no formal protection under the federal Endangered Species Act (ESA), except for regulatory determinations by some federal land management agencies (U. S. Forest Service, Bureau of Land Management) that candidate and other sensitive species will be managed in order to avoid the need for listing. No federal protection currently extends to plants under non-federal jurisdiction unless they are listed as endangered and removing, cutting, digging up, damaging, or destroying them would be "*in knowing violation of any law or regulation of any state or . . . of a state criminal trespass law*" [ESA Sect. 9(a)2(B)], and that law extended to non-federal jurisdictions. The Endangered Species Act and the various agency regulations implementing it are also in direct conflict with provisions of the mining law of 1872 (30 U.S.C. 21 *et seq*.), and are therefore of uncertain protective value when mineral-related projects are involved.

Polyctenium williamsiae is on the sensitive species list of the Inyo National Forest, and is recommended for Sensitive Species status on the Humboldt-Toiyabe National Forest where it already appears to be managed as such. U. S. D. A. regulation 9500-4 directs the Forest Service to manage "*habitats for all existing native and desired nonnative plants, fish, and wildlife species in order to maintain at least viable populations of such species*," and to avoid actions "*which may cause a species to become threatened or endangered*." Forest Service objectives further state that viable populations of all species must be maintained "*in habitats distributed throughout their geographic range on National Forest System lands*" (Forest Service Manual [FSM] 2670.22). Placement of *Polyctenium williamsiae* on a National Forest sensitive species list identifies it as a species "*for which population viability is a concern as evidenced by . . . significant current or predicted downward trends in population numbers or density or . . . in habitat capability that would reduce a species' existing distribution*" (FSM 2670.5). Current Forest Service policy on species designated sensitive is to "*review programs and activities, through a biological evaluation, to determine their potential effect on sensitive species*" as part of the NEPA process, to "*avoid or minimize impacts*" from such activities or, if impacts cannot be

avoided, to "*analyze the significance*" of those impacts for the species as a whole. Any decision to allow impacts "*must not result in loss of species viability or create significant trends toward Federal listing*" (FSM 2670.32). Department regulation 9500-4 has the force of law at least until changed; specific provisions of written Forest Service policy implementing that regulation are of uncertain legal standing in specific cases.

U. S. D. I. Bureau of Land Management (BLM) policy provides that the agency "*shall carry out management, consistent with the principles of multiple use, for the conservation of candidate species and their habitats and shall ensure that actions authorized, funded, or carried out do not contribute to the need to list any of these species as Threatened or Endangered.*" If a candidate species occurs entirely on federal lands, BLM policy further requires that it be included as a priority species in land use plans, and that range-wide or site-specific management plans be prepared "*that identify specific habitat and population management objectives designed for recovery, as well as the management strategies necessary to meet those objectives*" (BLM Manual Section 6840). Although *Polyctenium williamsiae* is not presently a candidate for Federal listing, the Nevada State Office of BLM continues to track former candidates as sensitive species for planning purposes (U. S. D. I. Bureau of Land Management 1996). The effectiveness of any management plans developed specifically for *Polyctenium williamsiae* would still depend upon sufficient resources for adequate implementation and enforcement.

Polyctenium williamsiae is listed as "critically endangered" under Nevada Revised Statutes (NRS) 527.270. Such listing provides that ". . . *no member of its kind may be removed or destroyed at any time by any means except under special permit issued by the state forester firewarden*" on any lands in Nevada. The adequacy of this law, however, depends on informed and cooperative land managers, or on some form of deterrent enforcement, adequate resources for which the current law does not provide. It also depends on the Nevada State Forester's discretion in issuing or withholding permits, and in placing protective conditions on permits that are issued. Recently enacted regulations in Nevada Administrative Code (NAC) Chapter 527 greatly expanded and clarified the requirements and procedures for obtaining such permits.

Other Natural or Man-made Factors: Because of its usually small, isolated populations and stringent habitat requirements, *Polyctenium williamsiae* may be vulnerable to natural events such as climatic shifts or unprecedented extremes of heat, cold, drought, or flooding, and to possible human-caused climate changes. Sudden warming or drying could desiccate the lake beds, allowing zonal vegetation to supplant the species. Likewise, sudden cooling or increased precipitation could render the lakes perennial, replacing an amphibious environment with an entirely aquatic one. Either scenario would likely result in extinction or massive decline of *Polyctenium williamsiae*. Indeed, the climatic contractions of the present interglacial period may have contributed to the species' highly fragmented distribution. It could have been a wide-spread strand species that grew around Lake Lahontan and the other Pleistocene lakes of the southwestern Great Basin, but that now is restricted to scattered small lake beds, like the pupfish of desert hot springs.

To the extent that *Polyctenium williamsiae* may depend upon insect pollinators for successful reproduction, any natural or man-made factors affecting the viability of such insects would also affect the viability of *Polyctenium williamsiae*.

X. GENERAL ASSESSMENT AND RECOMMENDATIONS

General Assessment: As now known, the global population of *Polyctenium williamsiae* consists of a maximum of about 452,000 individuals restricted to about 542 acres (219 ha) of public and private lands divided among 34 sites in 15 scattered areas, concentrated mainly in the mountains and foothills of the southwestern Great Basin in west-central Nevada and adjacent California, but scattered also in northeastern California, southeastern Oregon, and south-central Nevada, between 4215 and 8935 feet (1285-2725 meters) elevation. The most distant two occurrences are separated by about 400 miles (650 km), and the number of extant occurrences is reduced to 20 if a 1 km minimum separation distance is imposed. Analysis of specimens for this report, and of the same specimens independently by another taxonomist, concluded that *Polyctenium williamsiae* includes *P. fremontii* var. *confertum* as a synonym and that the remainder of *P. fremontii* is a separate species. The species was almost entirely restricted to the relatively barren sandy to sandy-clay or mud margins and bottoms of non-alkaline seasonal lakes and playas perched over siliceous volcanic bedrock in the sagebrush, pinyon-juniper, and mountain sagebrush zones. Over 8800 acres (3560 ha) of relatively low-probability potential habitat remain unsurveyed, and the true total population of *Polyctenium williamsiae* may be up to 150%, though more likely less than 50%, greater than that now documented.

If not for the significant existing, ongoing, and threatened impacts to many of its known populations, and the inherent vulnerability of its seasonal lake-bed habitat, *Polyctenium williamsiae* would now be too abundant and widespread to warrant special conservation concern. For now the species remains vulnerable to human-caused declines and possible extinction, and significant impacts from one or more sources are known at most of the populations. No sites were yet known to be extirpated, but this determination is complicated by wide swings in population numbers from year to year. Most impacts had resulted from dredging and other water diversions, off-road vehicle use, and impacts from livestock and feral horse use and management. Threats from all these sources will exist indefinitely under present circumstances, and the existing protective designations for the species have not prevented continued impacts.

Status Recommendations: *Polyctenium williamsiae* was most recently classified as a category-2 candidate for listing by the U. S. D. I. Fish and Wildlife Service until that category was eliminated on 28 February 1996 (U. S. D. I. Fish and Wildlife Service 1996). Based on the best available scientific evidence, the species currently meets the definition of a candidate for listing as threatened under the Endangered Species Act. If present trends continue, *Polyctenium williamsiae* will eventually meet the definition of an endangered species as its viability becomes compromised. With active, long-term, cooperative management to reduce or eliminate further habitat destruction, and appropriate long-term monitoring, this trend can be stopped, and human-caused extirpation or extinction can be avoided. Absent such management, the long-term possibility of extinction or major declines will remain, and federal listing as endangered could become justified if more than about 10% of the known populations were lost to preventable causes.

Polyctenium williamsiae is on the list of "critically endangered" plant species fully protected under Nevada Revised Statutes 527.270. The species is also a BLM special status species in Nevada and California, is on the sensitive species list of the Inyo National Forest, is ranked 2 (imperiled) and the global and state levels by the Nevada Natural Heritage Program, and is on the Threatened list of the Nevada Native Plant Society (NNPS). Because of its relatively large geographic range but inherent and continued high vulnerability of the habitat to impacts and losses, 2 remains the most appropriate heritage rank for *Polyctenium williamsiae*. Because of its

documented occurrences and degradation on Humboldt-Toiyabe National Forest (HTNF) lands, the HTNF should add *Polyctenium williamsiae* to its sensitive species list and manage it as such. If populations continue to be degraded or lost, the U. S. Fish and Wildlife Service should pursue federal listing of *Polyctenium williamsiae* as threatened or endangered under the Endangered Species Act. No other changes in status are recommended.

Critical Habitat Recommendations: If critical habitat were ever designated through the provisions of the Endangered Species Act or any other law or regulation, it should include all populations then known, including the entire lake bed over which each population was scattered, and if feasible the entire water shed area upgradient from each site. Critical habitat should not be formally designated in cases where it might subject *Polyctenium williamsiae* to increase threats to its survival, would interfere with habitat management, or would subject managers of the habitat to problems of trespass by curiosity seekers.

Conservation and Recovery Recommendations: The following recommendations, roughly in descending order of priority, are offered as the best opportunities to maintain the long-term viability of *Polyctenium williamsiae*, to avoid any future need to list it as threatened or endangered, and to reduce the overall long-term management costs for the species. They generally do not take into account political will, limited agency resources, or other conservation priorities, which may preclude implementation of some recommendations. Some of the recommendations may already have been implemented. If monitoring indicates that preventable declines in viability of the species are occurring, then more aggressive conservation and recovery measures should be identified and pursued.

1. The U. S. Fish and Wildlife Service (USFWS), The Bureau of Land Management (BLM), the Humboldt-Toiyabe National Forest (HTNF), the Inyo National Forest (INF), the Nevada Division of Forestry (NDF), the Nevada Natural Heritage Program (NNHP), and other appropriate cooperators should continue to pursue development, adequate funding, and implementation of a long-term species management plan and conservation strategy for *Polyctenium williamsiae*, to address at a minimum all the other recommendations below. The strategy should also include a public education component to increase awareness of the significance of *Polyctenium williamsiae* and its habitat, and of the consequences that federal listing would have. Participants should share implementation costs proportionately to their management responsibilities.

2. BLM), HTNF, and INF should immediately proceed to fill dredged watering ponds and all other water diversions on publicly owned *Polyctenium williamsiae* lake beds, and to restore the natural contours of the lake beds at those sites. At the same time these agencies should implement a strict prohibition on any future modification of these lake beds, and should provide sufficient resources for effective enforcement of this prohibition in cooperation with NDF.

3. BLM, HTNF, and INF should ensure that the shores and beds of all publicly owned lake beds where *Polyctenium williamsiae* occurs are closed to off-road vehicle use, and should provide sufficient resources for effective enforcement of such closures in cooperation with NDF, including placement of effective barriers to off-road travel where needed.

4. BLM, HTNF, and INF should work with grazing permittees to ensure that livestock feed and water supplements are placed no less than 0.25 mile (0.4 km) from the nearest edge of any seasonal lake bed where *Polyctenium williamsiae* occurs, that only dispersed grazing

activity occurs in and near the known populations, and should enforce these limitations through the terms and conditions of grazing permits.

5. BLM, HTNF, and INF should aggressively manage wild and feral horse populations to avoid or reduce trampling impacts in *Polyctenium williamsiae* habitat.

6. Where overuse of *Polyctenium williamsiae* habitat by populations of large animals is a persistent problem, the managing agency(ies) should consider creating fenced corridors for large-animal access to divert traffic away from the most sensitive portions of the habitat.

7. BLM, HTNF, INF, and other cooperating agencies should implement careful preventative monitoring of the known sites for potential noxious weed invasions, particularly for tall whitetop (*Lepidium latifolium*) which has a high potential to invade *Polyctenium williamsiae* habitat, and should aggressively control and eradicate any such invasions found. These same agencies should aggressively manage and control invasions of exotic weeds within the broader range of *Polyctenium williamsiae*, in cooperation with adjacent land holders and managers, to reduce the potential for invasion of *Polyctenium williamsiae* habitat.

8. Any future artificial revegetation actions in and near the range of *Polyctenium williamsiae* should only use plant species native to the local area. BLM, HTNF, INF, NDF, and other agencies anticipating the need for artificial revegetation should plan for reasonably foreseeable needs to ensure sufficient sources and/or supplies of 100% native-species seeds. In appropriate cases, other species documented not to persist under local conditions could be added at non-competitive levels for temporary stabilization until the native species can establish.

9. HTNF should immediately add *Polyctenium williamsiae* to its list of sensitive species, and manage it accordingly for all future project planning and implementation.

10. The State of California should pursue protection of *Polyctenium williamsiae* under its endangered species laws.

11. For the privately held sites in particular, NDF should act to encourage and support implementation of the recommendations contained in this report through contact and coordination with land owners and managers, through its permitting process, through acquisition and management of conservation easements, or if necessary through law enforcement actions.

12. BLM, HTNF, and INF should pursue all available opportunities to bring additional privately held *Polyctenium williamsiae* sites into public ownership and management. Any publicly held sites conveyed into private ownership should include deed restrictions sufficient to prevent destruction of *Polyctenium williamsiae* and its habitat on those lands. Existing and newly acquired public sites should be considered for protective withdrawal as ACECs, RNAs, or other categories providing a conservation management and research emphasis.

13. BLM, HTNF, INF, and any other appropriate agencies should conduct or require additional surveys, following recognized professional standards (Nelson 1994), for undocumented *Polyctenium williamsiae* populations prior to implementation of projects within, or with the potential to indirectly affect, potential habitat of the species, and any new populations found should be thoroughly documented. Impacts to new and previously known populations should be avoided or minimized during project planning implementation. When-

ever funding and personnel permit, similar surveys should be continued outside of the project evaluation process as well, particularly in eastern California and southeastern Oregon, where significant new populations could reduce the need for federal listing.

14. BLM, HTNF, INF, USFWS, NNHP, and any other parties interested in participating, should cooperatively field-check as many *Polyctenium williamsiae* sites as possible at least every 3 years, and annually where significant impacts have previously occurred or are reasonably foreseeable, to detect any new or intensified impacts, and should take immediate steps to eliminate and correct any such impacts on lands under their management. Field checks should include field tours for appropriate personnel to familiarize them with the plant and its habitat. If extirpations or new significant impacts become likely for more than 10% of the known populations, yearly monitoring efforts should be initiated at all known sites.

15. Studies of pollinator populations, and their effectiveness in the reproductive success of *Polyctenium williamsiae*, should be encouraged and supported. If found to play a significant role, pollinators should be monitored on the same schedule as *Polyctenium williamsiae* to detect any downward trends that could contribute to reproductive failure in *Polyctenium williamsiae*, and the cause(s) and possible remedies of any such declines should be assessed.

16. Life history patterns and demographics of *Polyctenium williamsiae* should be explored in relation to inundation regime on annual and longer time scales. The relative importance of soil seed bank and over-wintering caudices should be assessed.

17. BLM, HTNF, INF, NDF, and any other appropriate fire management agencies should plan future fire-suppression actions and strategies, including identifying potential sites for fire breaks, access roads, landing pads, staging areas, etc., to avoid or minimize impacts to known *Polyctenium williamsiae* populations and other sensitive resources.

18. If implementation of, or available resources for, the above recommendations prove insufficient to prevent further decline and degradation of *Polyctenium williamsiae* and its habitat, and viability of the species as a whole is in jeopardy, the U. S. Fish and Wildlife Service should pursue formal listing of *Polyctenium williamsiae* as a threatened or endangered species under the Endangered Species Act, and the Nevada Division of Forestry should step up enforcement of existing protections for *Polyctenium williamsiae* under Nevada Revised Statutes (NRS) 527.270. A recovery plan containing more aggressive and effective conservation measures should be developed and be provided sufficient resources for effective implementation.

XI. INFORMATION SOURCES

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Field Research: Field surveys for this report were conducted on 18-19 May, 7 June, 22-27 June, and 9-10 August 1995, and on 22 and 29 June 1998, by Robert F. Holland, James D. Morefield, or Carrie Carreño for the Nevada Natural Heritage Program. Holland's field work of 14 July and 21-22 July 1994 is also incorporated into this report.

Specimens: All specimens known to document *Polyctenium williamsiae* sites are listed by site in Appendix 1, table 5. The list was compiled from all available published and unpublished sources, but is not necessarily complete. Although new collections from previously documented sites are discouraged, the Nevada Natural Heritage Program welcomes further additions or corrections to this table as they become known.

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