Resource Recovery Plan for

Spreading globeflower
Trollius laxus Salisbury

in Pennsylvania

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Cover photo: *Trollius* laxus photographed 4/25/1989 at Getz Swamp, Northampton County PA.

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Trollius laxus Salisbury

Classification

Spreading globeflower, *Trollius laxus* Salisbury (Ranunculaceae) is a globally rare herbaceous perennial of limestone wetlands. It has a limited range in the northeastern United States from Ohio to Connecticut (FNA 1997). The species was first collected by Muhlenberg in Pennsylvania and listed as *Trollius americanus* in his catalogue of the plants of Lancaster County (Muhlenberg 1793). This record was cited by deCandolle (1846) as *Trollius americanus* Muhl. However, the earliest published account in which the plant was both named and described was by Salisbury in 1807 and is the source of the name *Trollius laxus* Salisbury (Salisbury 1807).

There is some confusion arising from the fact that *Trollius albiflorus* (A. Gray) Rydberg, which grows in alpine areas in the northern Rocky Mountains from Colorado to British Columbia, has been treated as a variety of *T. laxus* (*Trollius laxus* Salisbury var. *albiflorus* A. Gray). However, Parfitt, in the Flora of North America (FNA 1997) recognized the western alpine plant at the species level as *T. albiflorus* on the basis of ploidy level, *T. albiflorus* is a diploid (2n = 16) and *T. laxus* a tetraploid (2n = 32), and geographic isolation. We have followed this treatment, and thus *Trollius laxus* as used here, refers only to the northeastern populations (Rhoads and Block 2007).

Description

Trollius laxus is a low-growing herbaceous perennial plant 1—5 dm tall with one to many erect or spreading stems arising from a single root crown. Scanga (2009) described limited clonal growth via short, non-persistent rhizomes leading to the production of clumps. Both basal and cauline leaves are present; basal leaves are petioled with a deeply divided palmate blade with 5—7 coarsely toothed segments. The 2—5 cauline leaves are similar to the basal leaves but smaller. A characteristic whorl of sessile reduced leaves encircles the stem below the flower. The leaves and stems are completely glabrous.

Flowers are produced singly at the stem tip, and are 2.5—5 cm in diameter with 5—7 petal-like pale to bright yellow sepals; the petals are reduced and function as nectaries. Numerous (20—80) stamens surround the cluster of 5—28 separate pistils. The pistils mature into a whorled cluster of distinct follicles, each with 4—6 seeds. When the flowers are fully open, the sepals of *T. laxus* are spreading producing a shallow bowl-shaped flower.

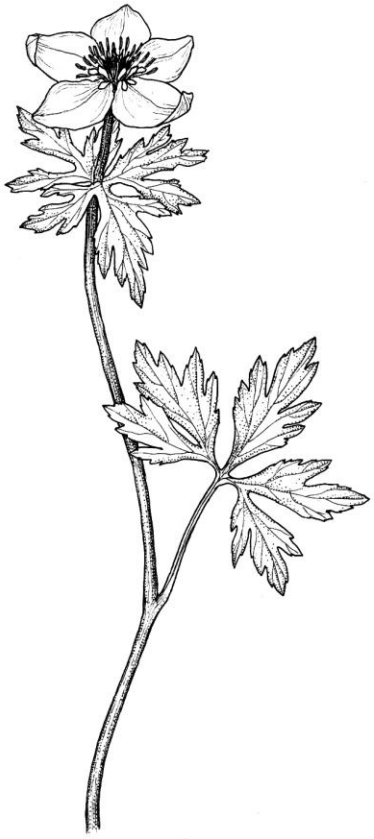


Figure 1. Flowering stem of *Trollius laxus*. Drawing by Anna Aniśko, used with permission of Univ. of Pennsylvania Press.

Reproduction

Trollius laxus plants emerge in early spring, often right after snow melt. Flowering begins in early to mid-April, peaks in early May, and continues into June. In northeastern Ohio most seed is mature and has dispersed by late June (Parsons and Yates 1984). The plants remain green until frost and may continue growth after surrounding trees and shrubs lose their leaves. *Trollius laxus* is readily identified by an experienced botanist, however, the plants become difficult to locate as other taller herbaceous species mature around them.

Pollination
Jones and Klemetti (2012) observed bees in genera *Lasioglossum* and *Nomada*, a tachinid fly, and several ants visiting *T. laxus* flowers in Connecticut. *Trollius laxus* is apparently not a host for flies in the genus *Chiastochaeta* which have evolved a mutualistic relationship, involving pollination and seed parasitism, with *Trollius europaeus* and other Eurasian species (Pellmyr 1992).

Seed dispersal
Seeds are dispersed passively by gravity, wind, water, or by passive transport in mud adhering to the exterior surfaces of animals (epizoochory).

Seed germination
Brumback (1989) reported that *T. laxus* seed germinates best when it is sowed outside immediately after ripening and allowed to cure under warm moist conditions over the summer. This is followed by *in situ* winter exposure to cold, moist conditions essential to break dormancy. Germination occurs the following April or May.

In greenhouse studies, 90 percent germination was obtained with wild-collected seed exposed to a 90 day moist cold period, whereas seeds kept in a pit greenhouse without an extended cold period germinated at significantly lower percentages, 8.0—28 percent (Brumback 1989).

Seed sown in fall typically produced blooming size plants during the second growing season. In seedling growth trials the preferred pH was 6.1—7.4, seedlings grown at pH 4.3—5 were depauperate and chlorotic, and suffered high mortality (Parsons and Yates 1984).

Seed banking potential – Using tetrazolium to test for viability, Scanga (2009) found that 0.6 percent of 840 *T. laxus* seeds enclosed in buried mesh packets were capable of germination after 16 months.

Ecology

Range

Trollius laxus occurs in five northeastern states: Connecticut, New York, New Jersey, Pennsylvania, and Ohio. Early reports from Michigan, Delaware, and northern New England are not supported by specimens and were apparently based on misidentifications (Voss 1985; Jones 2001).

Habitat

Trollius laxus is an obligate wetland plant that grows in fens, wetlands that are fed by cold, calcium-rich ground water. The ground is saturated much of the year and is frequently characterized by hummock and hollow micro-topography and a seasonally high water table. *Trollius laxus* typically grows on the sides of hummocks in open areas or under a tree or shrub canopy. Parsons and Yates (1984) found pH values ranging from 5.9 to 6.7 at a *T. laxus* site in northeastern Ohio. A surface organic layer is usually present but varies greatly in depth from site to site (WPC 1995). Most *T. laxus* sites are associated with Wisconsinan glacial deposits or glacial outwash; however, a few sites occur south of the terminal moraine on unglaciated limestone.

Plant communities and associated species – *Trollius laxus* occurs in both forested and open fen communities. In New Jersey a recently discovered large population of *T. laxus* is growing in a successional old field that has grown up in a former cow pasture (D. Snyder, personal communication).

In western Pennsylvania, fen communities are primarily herbaceous, ***Golden saxifrage - sedge rich seep*** (McPherson 2011a), or contain scattered trees and shrubs, ***Poison sumac – bayberry – red cedar fen*** (Podniesinski 2011b). In eastern Pennsylvania *T. laxus* is known historically from both open fens and forested sites corresponding to the ***Red maple – black ash palustrine forest*** community type (Eichelberger 2011).

In New York *T. laxus* is found in ***rich graminoid fen***, ***rich shrub fen***, ***rich sloping fe***n, ***northern white cedar swamp***, ***hemlock-hardwood swamp***, ***rich hemlock – hardwood peat swamp***, and ***red maple – tamarack peat swamp*** community types (NYNHP 2012; Edinger et al. 2002). At one site, a population of 4,000—5,000 plants occurs in a conifer swamp complex. At this location a mosaic of new and old canopy gaps provide opportunities for growth of herbaceous species (Scanga 2009; Scanga and Leopold 2010; Scanga and Leopold 2012).

Ohio populations of *T. laxus* are described as occurring in a shrub swamp dominated by alder and a pin oak forest with a gentle flow of water running through it (Spooner et al. 1984). In Connecticut *T. laxus* grows in both forested and open fen sites (Jones and Klemetti).

Associated herbaceous species commonly found in fens include *Boehmeria cylindrica, Carex atlantica, Carex leptalea, Carex stricta, Chelone glabra, Chrysosplenium americanum, Geum rivale, Onoclea sensibilis, Osmunda regalis, Parnassia glauca, Saxifraga pensylvanica, Packera aurea, Smilacina stellata, Symplocarpus foetidus, Thelypteris palustris,* and *Viola* spp.

Effects of light and hydrology **–**Scanga studied the effects of hydrology and light levels on plant vigor in 30 sub-populations of *T. laxus* in a forested fen in New York State. Located in what was then the largest known population of *T. laxus* in the world, their subplots contained 2—438 mature plants and 0—262 seedlings under a variety of lighting conditions and water levels. She found that flower and fruit production increased with increased levels of spring and summer diffuse light transmittance. Production of fruit also increased in plots with higher spring groundwater levels. Stem, plant, and seedling abundance were not significantly related to light or hydrology variables (Scanga 2009; Scanga and Leopold 2010).

In follow-up greenhouse studies Scanga (2011) compared the growth of *T. laxus* at four light levels (6, 40, 77, and 90 percent of full light) and two simulated groundwater levels (10 and 20 cm below the soil surface). Highest plant performance, measured as root and shoot biomass, was obtained at the highest light and the lowest ground water levels. This result does not correspond with results obtained in the field, but *in situ* plant performance is affected by competition from other vegetation as well as abiotic habitat factors. In this case it suggests that reduced light and higher water levels are tolerated in a tradeoff that allows *T. laxus* to achieve reduced competition from other herbaceous plants (Scanga 2009).

In a more extensive *in situ* study of the effect of light on *T. laxus* growth, Scanga and Leopold (2012) found that stem and flower production increased in artificially created gaps during the second and third years after treatment, but subsequently decreased to near control levels as other herbaceous and understory plants grew up in the gaps. In an open fen site in Connecticut Jones and Klemetti (2012) found that clipping adjacent herbaceous vegetation increased flowering and fruit production compared to unclipped plots, providing more evidence that *T. laxus* benefits from additional light if competition is suppressed.

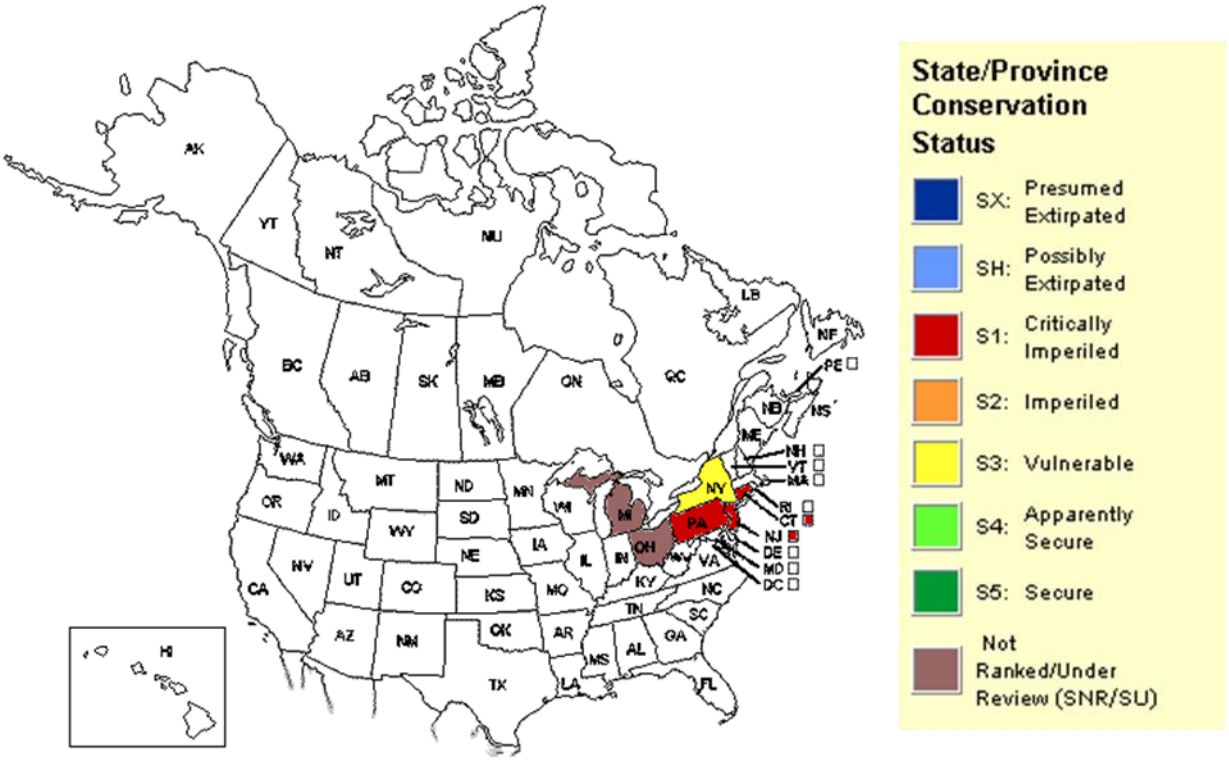
Conservation Status

Trollius laxus was a candidate for listing under Federal Endangered Species Act. In 1985 it was assigned 3C status indicating that it had been found to be more abundant than was previously believed, but could be re-evaluated should the situation change (Federal Register 1985).

NatureServe ranks *T. laxus* vulnerable globally (T3) and vulnerable at the national level (N3); at the state level it is classified as vulnerable (S3) in New York, critically imperiled (S1) in Pennsylvania, New Jersey, and Connecticut, and unranked in Ohio. (Figure 2) (NatureServe 2011).

Trollius laxus is also part of the National Collection of Endangered Plants of the Center for Plant Conservation, a coalition of 37 botanical institutions dedicated to preventing the extinction of native plants of the United States. It is assigned to the Holden Arboretum (CPC 2012).

Figure 2. Range and Conservation status of *Trollius laxus*
Source: NatureServe 2011.



Trollius laxus Salisb. in Pennsylvania

Early Records

Trollius laxus was first collected in Pennsylvania in 1849 at Hellertown in Northampton County. This was followed by its discovery in Monroe County in the vicinity of the Delaware Water Gap in 1862 and in Center County in 1866 (Table 1). By 1900 additional populations had been found in Erie, Lehigh, and Bucks Counties. In the 1950s Henry and Buker (1958) concluded that *T. laxus* was extinct in western Pennsylvania, but that changed with the discovery of a small population in Lawrence County in 1964 (Henry 1965).

Unlike *T. laxus* sites in Ohio, New Jersey, New York, and Connecticut, not all the PA populations are associated with glacial deposits; Bucks and Center Co. locations are south of the Wisconsin terminal moraine. However, all are found on limestone substrates.

In 1979 Paul Wiegman of the Western Pennsylvania Conservancy undertook a survey of all historical sites to update the status of *T. laxus* in Pennsylvania (Wiegman 1980). He found that many early populations were extirpated. The only remaining populations were at Plain Grove in Lawrence County, and a cluster of sites in Upper Mount Bethel Township, Northampton County. Subsequent field searches by Pennsylvania Natural Heritage Program botanists have added two new sites in the Mount Bethel area as well as a single location in Monroe County.

Table 1. Herbarium Specimens of *Trollius laxus* from Pennsylvania

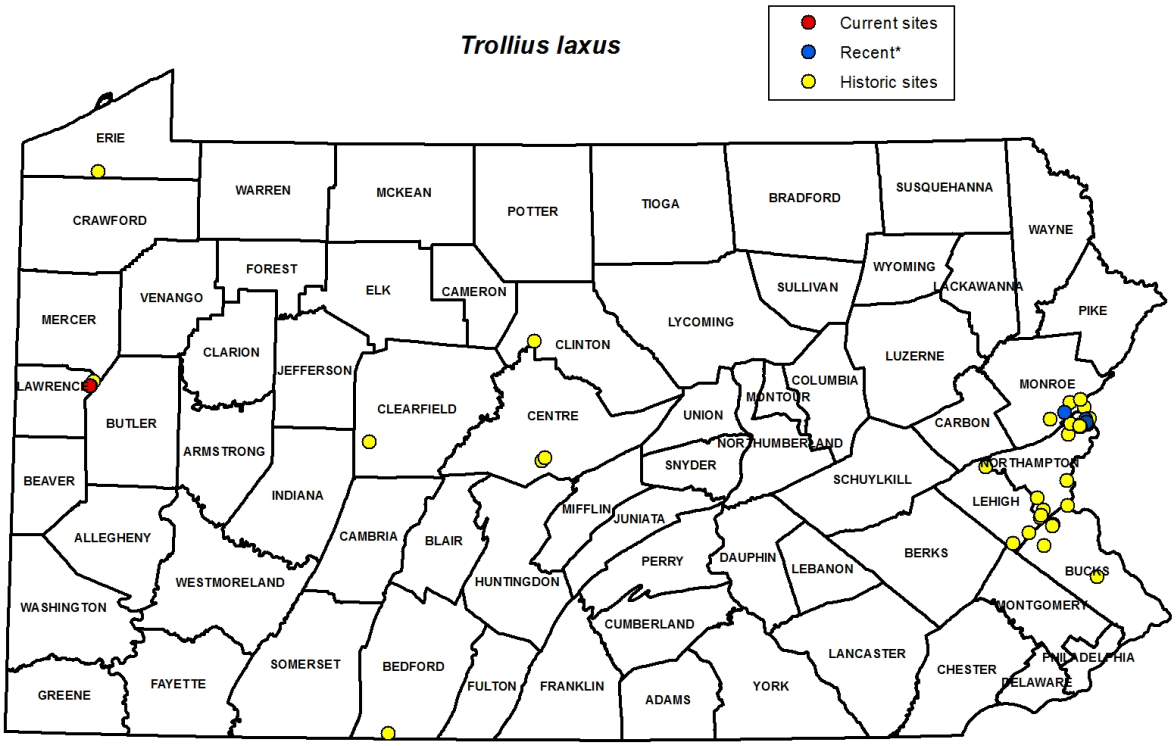
Sources: PA Flora Database (2011); Herbarium of the Academy of Natural Sciences of Philadelphia

Year	*Collector*	*County*	*Location*	*Comments*	*Herbarium*
	Buser, F.	Monroe	Minisink Hills	(locality since destroyed)	ESU
	Wolle	N'ampton	Bethlehem		PH
	Detwiller	N'ampton	Hellertown	near	PH
1838	Detwiller	N'ampton	Hellertown		PH
1849	Detwiller	N'ampton	Hellertown		PAC
1849	Detwiller	N'ampton	Hellertown		PH
1849	Detwiller	N'ampton	Hellertown		PAC
1858	Detwiller	N'ampton	Hellertown		PH
1862	Hoopes	Monroe	Delaware Water Gap	near, wet grounds	PH
1863	Negley, H.H.	Centre	State College	near	CM
1864	Garber	N'ampton	Hellertown	near	PH
1864	Porter, T.C.	N'ampton	Hellertown		PAC
1864	Porter, T.C.	N'ampton	Hellertown		PAC
1864	Fist	N'ampton	Hellertown	near	PH
1866	Green	Centre	Center Furnace	Thompsons Meadows	PAC
1866	Smith	N'ampton	Easton	below	PH
1868	Rothrock	Centre	Centre Co.	State College	PH
1868	Garber	Lehigh	Bethlehem	vicinity of	PH
1868	Garber	N'ampton	Bethlehem		PH
1868	Garber	N'ampton	Easton	vicinity of	PH
1872	Knipe	Monroe	Delaware Water Gap	near, wet meadow	PH

1878	Krout	Lehigh	Lehigh Co.		PH
1878	Krout	Lehigh	Upper Saucon		PH
1882	Fretz, C.D.	Bucks	Springfield Twp.		PH
1882	Pretz, H.W.	Bucks	Springfield Twp.		PH
1884	Bennett, F.G.	Erie	Edinboro	swamp	CM
1894	Brown, S.	Bucks	Quakertown	near	PH
1894	Brown, S.	Bucks	Quakertown		CM
1895	Porter, T.C.	N'ampton	Easton	bank of Delaware River above Water Works	PH
1899	Pretz, H.W.	Bucks	Springfield Twp.		PH
1900	Porter, T.C.	N'ampton	Bingen	near	PH
1900	Locksman	N'ampton	Bingen	near	PH
1904	Williamson, C.S.	N'ampton	Bangor		PH
1904	Williamson, C.S.	N'ampton	Bingen	near	PH
1904	Williamson, C.S.	N'ampton	Bingen		PH
1904	Bachman, C.C.	N'ampton	Mount Bethel		PH
1907	Yetter	Monroe	Stroudsburg		PH
1907	Williamson, C.S.	N'ampton	Bangor	near	PH
1907	Williamson, C.S.	N'ampton	Bangor		PH
1907	Bartram, E.B.	N'ampton	Mount Bethel		PH
1907	Long, B.	N'ampton	Mount Bethel	1 mi SW, near trolley track, meadow	PH
1907	Van Pelt, S.S.	N'ampton	Mount Bethel	1 mi SW, by trolley track, meadow	PH
1908	Van Pelt, S.S.	N'ampton	Johnsonville	W of RR station, east end of great swamp	PH
1908	Williamson, C.S.	N'ampton	Mount Bethel	swampy meadows	PH
1908	Bachman, C.C.	N'ampton	Mount Bethel		PH
1909	Williamson, C.S.	N'ampton	Bangor	near	PH
1909	Long, B.	N'ampton	Johnsonville	S of RR, a little east of station	PH
1909	Williamson, C.S.	N'ampton	Johnsonville		PH
1909	Bachman, C.C.	N'ampton	Johnsonville		MUHL
1909	Van Pelt. S.S.	N'ampton	Mount Bethel	S of RR and E of Morey's Crossing, wet meadow	PH
1909	Long, B.	N'ampton	Mount Bethel	NE, near Jacoby Creek, wet meadow	PH
1909	Long, B.	N'ampton	Mount Bethel	SW, near Morey's Crossing, meadow	PH
1909	Bachman, C.C.	N'ampton	Mount Bethel	E of Morey's Crossing, near RR	PH
1913	Brown, S.	Bucks	Pleasant Valley	near	PH
1922	Pretz, H.W. 11451	Lehigh	Spring Valley P.O.	0.8-1 mi SSE, open, grassy, springy slope between woods and rivulet at base of Triassic slope	PH
1923	Long, B. 27310	Bucks	Pleasant Valley	head of tributary of Cooks Creek, 1.5 mi NW, border of boggy swale	PH
1923	Pretz, H.W. 11649	Lehigh	Spring Valley P.O.	0.8-1 mi SSE, open, grassy, springy slope between woods and rivulet at base of Triassic slope	PH
1923	Pretz, H.W. 11649	Lehigh	Spring Valley P.O.	0.8 mi SSE, open grassy, springy slope between woods and rivulet at base of Triassic slope	MUHL
1928	Pretz, H.W. 13165	Lehigh	Hosensack P.O.	2.5-2.1 mi ENE, grassy, marshy pastured place adj. to farm buildings	PH
1928	Pretz, H.W. 13165	Lehigh	Hosensack P.O.	2.5 mi ENE, open grassy-marshy meadow pasture adj. To farm buildings	MUHL
1946	Schaeffer, R.L. 22908	N'ampton	North Bangor	1.5 mi NE, swamp	PH
1946	Schaeffer, R.L.	N'ampton	Portland	1 mi W	PH

	23419				
1954	Schaeffer, R.L. 45760	N'ampton	North Bangor	1 mi NW	MUHL
1964	Buker, W.E.	Lawrence	Plain Grove	near, woods at Plain Grove Bog	CM
1965	Buker, W.E.	Lawrence	Plain Grove	near, woods at Plain Grove Bog	CM
1966	Buker, W.E.	Lawrence	Plain Grove	near, woods at Plain Grove Bog	CM
1978	Buser, F.	Monroe	Hamilton Square	in bloom in 1978 (note: This site is called Mansfield Fen in later PNHP surveys.)	ESU
1989	Bissell, J.K.; et al.	Lawrence	Plain Grove Township	Forest Fen, 316 deg and 1.65 mi from int. I-79 and Rt 108	CLM
1992	Bissell, J.K.	Lawrence	Plain Grove Fens	Forest Fen, 315 deg and 1.65 mi from int. I-79 and Rt 108	CLM
1995	Davis, A.F.	N'ampton	Upper Mt. Bethel Twp.	wooded sapling swamp on E side of RR between transmission lines ROW	PH
2012	S.P Grund, S.Schuette	Lawrence	Plain Grove, 2.5 km WNW	Mitchell Fen, open *Carex stricta* fen	CM
CM=Carnegie Museum					
CLM=Cleveland Museum of Natural History					
ESU= East Stroudsburg University					
MUHL=Muhlenberg College					
PAC=Pennsylvania State University					
PH=Academy of Natural Sciences of Philadelphia					

Figure 3. Documented occurrences of *Trollius laxus* in Pennsylvania



*Plants present within the past 20 years but not seen in 2012

Current or Recent Occurrences

Upper Mount Bethel Township, Northampton County – Records of *T. laxus* in the Mount Bethel area go back to 1904 (Table 1). In 1908 members of the Philadelphia Botanical Club made a series of field trips to further explore the flora of the area which resulted in the discovery of additional sites (Van Pelt 1908; 1909).

Eastern Pennsylvania fens provide habitat for a number of endangered, threatened, or rare plants in addition to *T. laxus* including *Carex flava, C. prairea, C. sterilis, C. tetanica, Conioselinum chinense, Cypripedium parviflorum* var. *parviflorum, Epilobium strictum, Lobelia kalmii, Parnassia glauca, Potentilla fruticosa, Rhamnus alnifolia, Rhyncospora capillacea, Salix serissima,* and *Solidago uliginosa* (Fike 1999; Eichelberger 2011; McPherson 2011b; Podniesinski 2011a, 2011b).

Located on kame deposits at the southern edge of the Wisconsin terminal moraine (Epstein 1969), the Mount Bethel area has undergone extensive sand and gravel mining in the intervening years. Despite the disturbance, some of the early sites are still reasonably intact.

Getz Swamp is located on the south side of Route 512, 1.5 mi SW of Mount Bethel. Original collections of *T. laxus* from this site date from Sept. 2, 1907 (Table 1). Getz Swamp is bounded by Rt. 512 on the north. An earlier wet meadow within the site was converted to a pond in 1954 (Wiegman 1980).

In May 1980 the remaining wetland was described as a red maple swamp with, a canopy dominated by *Acer rubrum* with *Fraxinus* spp., and *Carpinus caroliniana*; the understory consisted of *Salix* spp. and *Cornus amomum*. A large population of *T. laxus* (1,500—2,000 plants) was found in the eastern end of the site. The owners recounted that the swamp had been grazed for many years, but in the late 1950s a fence was erected and cattle excluded. Since then, in their opinion, *T. laxus* had declined throughout and been eliminated from the ungrazed portion (Wiegman 1980).

Table 2. *Trollius laxus* census data for Getz Swamp 1980—2012
(sources: Wiegman 1980; PNHP 2011)

date	number of plants	comments
5/ /1980	1800-2000	in 1-1.5 ha area at the eastern end where canopy and shrub layers are more open
4/21/1986	1800-2000	fruiting on June 30, plants spread over 5 acres
4/20/1991 (J. Kunsman)	150 (100 flowering)	brief search, some plants may have been overlooked
6/8/1993 (J. Kunsman)	no count	plants seen and doing well
5/4/1995 T. Davis)	60-65 small plants, 25% flowering	succession causing too much shading
7/1/1997 (J. Kunsman)	100 vegetative genets	at ESE end of swamp, plants small, some evidence of deer browsing
4/13,16 and 27/2012	0	site searched by Block , Rhoads, and Kunsman

Between 1986, when the count was 1,800—2,000 plants, and 1995, the population declined dramatically (Table 2). On May 4, 1995 only 60—65 plants were found, one quarter of them flowering (PNHP 2011). Block and Rhoads searched the site on three occasions in April 2012 including one visit with Pennsylvania Heritage Program botanist, John Kunsman, who had seen the plant there in 1991, 1993, and 1997 (Table 2), but found no *T. laxus*.

Succession and deer browse were suggested as possible factors in the decline of *T. laxus* by Anthony Davis, Heritage Program Ecologist, and Kunsman (Table 2). In 1998 Getz Swamp was described as forested with full canopy cover; *Acer rubrum* was the dominant tree species (WPC and TNC 1998). In 2012, Rhoads and Block observed signs of site degradation including invasive species (*Lysimachia nummularia, Duchesnia indica, Viburnum opulus, Anthriscus sylvestris*) and runoff from adjacent agricultural fields.

Other rare plants at the site include a population of over 100 *Trillium cernuum* documented by Rhoads and Block and approximately 20 shoots of *Cypripedium parviflorum* var. *parviflorum* seen by Rhoads, Block and Kunsman in 2012. Historical records exist for *Arethusa bulbosa* and *Conioselinum chinense*. This site is privately owned and is not protected.

Lohman Fen is on the north side of Township Road 701, 0.3 mi southeast of Stier (Johnsonville). In 1980 this site was described as a shrub community with small openings dominated by tussock-forming sedges. In May 1979 Wiegman found 32 *T. laxus* plants, eight in flower and one in fruit in an eight meter diameter opening. A year later in May 1980 he counted 38 plants, four in bloom, none in fruit. Associated species included *Parnassia glauca, Maianthemum stellatum, Lobelia kalmii, Gentiana crinita,* and *Arenaria lateriflora* (Wiegman 1980).

Twenty-eight plants were counted in1982, of which 24 were in flower; most were found growing on the sides of *Carex stricta* tussocks in open to filtered light. On April 20, 1991 15 plants were noted in a brief visit, and on June 1, 1995 only a single plant was found (PNHP 2011) (Table 3).

Table 3. *Trollius laxus* census data for Lohman Fen 1979—2012
sources: Wiegman 1980; PNHP 2011)

date	number of plants	comments
5/ /1979 (Wiegman)	32 (8 in flower, 1 in fruit)	all in an 8 meter diameter opening
5/14/1980 (Wiegman)	38 (4 in flower, none in fruit)	all in an 8 meter diameter opening
4/18/1982 (Davis)	5	
4/22/1986	28 (24 in flower)	in open to filtered light in open area of fen, mostly growing on the top or sides of *Carex stricta* hummocks
4/20/1991 (Kunsman)	15	brief search
6/1/1995(Davis)	1	brief search at poor time of year
4/13/2012 and 4/27/2012	0	site searched by Block, Rhoads, and Kunsman

No *T. laxus* plants were found in a search conducted by Block and Rhoads on April 13, 2012. A return visit with John Kunsman on April 27, 2012 also failed to reveal any *T. laxus*. The site had

become a successional forest of *Acer rubrum* with an understory of *Cornus racemosa* growing on the remains of *Carex stricta* tussocks. There was no sign of *Parnassia glauca* or *Maianthemum stellatum*, which were noted previously.

Lohman Fen was previously described as a shrub fen unlike the forested sites at Getz Swamp and Rasely Woods. This site is privately owned and is not protected.

Rasely Woods is on the north side of Audubon Drive, 0.9 mi. N of Mount Bethel. *Trollius laxus* was discovered at this site in 1984 growing in successional forest that has developed in a former pasture. The site was visited on April 26, 1984 at which time 100 plants were counted, 30% were in flower (A. Rhoads, field notes, 4/26/1984). Some damage to petals by slugs was noted. On May 2, 1985 additional plants were found in a 1—3 acre area. A brief visit on April 20, 1991 revealed 19 plants and in May 4, 1995 approximately 20 plants were noted in 3 sub-populations: one plant was along the road, three were near the farm pond, and approximately 15 plants were found 30 yards into the woods across from the garage. On April 10, 1997 nine individuals were seen in a forested seep (pH 6.8, temperature 50 deg.) (PNHP 2011) (Table 4).

Associated herbaceous species included *Anemone quinquefolia, Carex umbellata, Erythronium americanum, Geranium maculatum, Lysimachia ciliata, Maianthemum canadense, Mitchella repens,* and *Symplocarpus foetidus*. Water flow was diffuse and present only in the spring (WPC and TNC 1998).

From 1984 to 1997 the trend at this site has been declining population size and increasing canopy density. No *T. laxus* plants were found by Rhoads and Block during a search of the site on April 13, 2012 or by Rhoads, Block and Kunsman on April 27, 2012.

Table 4. *Trollius laxus* census data for Rasely Woods 1984—2012
Source: PNHP 2011

date	*number of plants*	*comments*
4/26/1984 (Rhoads et al.)	100 (30% in flower)	40% open canopy slugs feeding on petals
4/27-28/1984 (SMI)	150+	spread over 3 acres. mostly in canopy openings
5/2/1985 (SMI)	additional plants in flower and fruit	1-3 acre area
4/20/1991 (Kunsman)	19	brief visit, many overlooked?
5/4/1995 (Davis)	approx. 20	in 3 sub-populations
4/10/1997 (LEI)	9	growing in forested seep
4/13 and 27/2012	0	searched by Rhoads, Block, & Kunsman

Rasely Woods Seep lies at the base of a long gentle slope covered with Wisconsinan ground moraine deposits. The former pasture has a full tree canopy dominated by *Acer rubrum* and *Fraxinus pennsylvanica* and a shrub layer consisting of *Lindera benzoin* with thickets of *Rosa multiflora*. The site is privately owned and is not protected.

Savadge Fen is located 0.5 mi northwest of Mount Bethel along the east side of the railroad tracks north of the Railroad Avenue crossing. In 1983 there were 10—12 blooming clumps of *T. laxus*. On May 4, 1995 one hundred mature plants in fruit and flower were described as growing vigorously in a successional sapling swamp with *Fraxinus nigra, Carpinus caroliniana, Ostrya virginiana, Solidago rugosa, Caltha palustris* and *Symplocarpus foetidus* (PNHP 2011).

During a site visit on April 27, 2012 Rhoads, Block, and Kunsman were unable to find any *T. laxus* plants despite the presence of what appeared to be suitable habitat. This site is owned by The Nature Conservancy.

Mansfield Fen, Monroe County – This site was first reported by Frank Buser in 1978 as Hamilton Square when he noted the presence of blooming plants of *T. laxus* (Table 1). A subsequent visit was made in 1982 when approximately 25 plants were observed in an area described as "a rocky sloping hillside with seeps and streamlets" (A. Rhoads, field notes, 8/27/1982). In 1986, 27 plants were counted in 1.5 acre area, eight flowering and 19 in vegetative condition (PNHP 2011). On April 20, 1991, 21 plants were observed, 15 in flower and six vegetative (PNHP 2011) (Table 5).

Mansfield Fen is on a small kame deposit associated with the Wisconsinan glaciation. Located at the base of a forested slope, it experiences groundwater flow throughout most of the year.

Canopy species included *Fraxinus pennsylvanica, Acer rubrum, Liriodendron tulipifera,* and *Ulmus americana*. *Carpinus caroliniana, Hamamelis virginiana,* and *Toxicodendron vernix* were present in the understory. The shrub layer was dominated by *Lindera benzoin, Viburnum dentatum, and Vaccinium corymbosum.* Associated herbaceous plants included *Amphicarpa bracteata, Apios americana, Arisaema triphyllum, Caltha palustris, Carex prasina, C. stricta, Equisetum hyemale, E. sylvaticum, E. arvense, Mitchella repens, Onoclea sensibilis, Osmunda cinnamomea,* and *O. regalis, Symplocarpus foetidus, Tiarella cordifolia, Uvularia sessilifolia, and Viola blanda* (A. Rhoads, field notes, 8/27/1982; WPC and TNC 1998).

Table 5. *Trollius laxus* census data for Mansfield Fen 1978—2012

Sources: East Stroudsburg University Herbarium; Rhoads et al. PNDI field survey report; PNHP 2011

date	*number of plants*	*comments*
1978 (Buser)	not stated	blooming
8/27/1982 (Rhoads, Buser, et al.)	25+	
4/21/1986 (SMI)	27 (8 in flower, 19 vegetative)	in 0.5 acre area
4/20/1991 (Kunsman)	21 (15 in flower, 6 vegetative	brief survey, more may be present
4/16/2012 (Rhoads & Block)	0	site bisected by landslide

During a visit on April 16, 2012 Rhoads and Block found that a massive landslide had occurred through the middle of the seepage area, tearing out the vegetation and leaving an expanse of exposed sand and gravel. No evidence of *T. laxus* was found in the remaining intact seepage areas on both sides of the landslide. This site is privately owned and is not protected

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Lawrence County Fens

Lying on till plains and outwash of the Wisconsinan glaciation, Lawrence County, Pennsylvania fens have more in common with Midwestern prairie fens than the calcareous wetlands in eastern Pennsylvania. They are classified as open or shrub-type fens; natural community types include: ***Sedge – mixed forb fen*** (McPherson 2011) and ***Alder-leaved buckthorn – inland sedge – golden ragwort shrub fen*** (Podniesinski 2011a).

Plain Grove Fen was a popular site for botanizing long before *T. laxus* was discovered there in 1964 (Table 1). When *Trollius* was first discovered, only a few plants were noted and there was speculation as to whether they had been overlooked previously or were recent arrivals (Henry 1965). Subsequent monitoring has revealed the presence of several sub-populations and fluctuating numbers of individuals (Table 6). The highest reported annual total was 100—150 plants in three sub-populations in 1982—1984 (PNHP 2011). Since then, numbers appear to have declined (Table 6).

Plain Grove Fen is the best example of a prairie fen in Pennsylvania (S. Grund, personal communication, 3/9/2012). It lies along Taylor Run just west of the village of Plain Grove in Lawrence County. The site is described as a wetland with shrub-dominated areas interspersed with herbaceous openings. The underlying soil is sandy clay overlain by 0.5—1 meter-thick layer of peat; pH is 7—7.2 (WPC 1995).

Table 6. *Trollius laxus* census data for Plain Grove Fen 1979—2009
(sources: Wiegman 1980; PNHP 2011; S. Grund)

year (observer)	quantity of plants	comments
1979 (P.Wiegman)	13	2 colonies
1980 (J. Brown)	>100	
1982-1984 (P.Wiegman)	100—150	3 locations: 1.NE corner *Carex-Juncus* community, 2. N portion of *Physocarpus* thicket, 3. swampy woods N of *Physocarpus* thicket
4/17/1986 (PWiegman)	31 clumps	at 3 sites
5/2/1988 (P.Wiegman)	12	3 sub-populations
4/25/1990 (P.Wiegman)	15—20 genets	25% in flower
4/29/1992 (J.Bissell)	<60	local, a few dozen plants in one section
2009 (S.Grund)	10—20	may not have seen them all

Other PNHP-classified plants at Plain Grove Fen include *Carex buxbaumii, C. meadii, C. tetanica, C. prairea, Dichanthelium boreale, Eleocharis elliptica, Epilobium strictum, Filipendula rubra, Parnassia glauca, Pedicularis lanceolata, Prenanthes crepidinea, Rhamnus alnifolia, Salix serissima, Schoenoplectus acutus, Solidago uliginosa, Stenanthium gramineum,* and *Symphyotrichum firmum* (S. Grund, personal communication 3/12/2012). The 380-acre Plain Grove Fen Natural Area was acquired by the Western Pennsylvania Conservancy in 1989.

Mitchell Fen is a sloping fen with seeps that flow down a hillside to a basin wetland dominated by sedges with islands of shrubs and trees (PNHP 2011). In September 1985 woody vegetation was cut, and the site was mowed and burned. The following spring, on April 18, 1986, the *T. laxus* population consisted of 286 flowering individuals plus 450—500 additional non-blooming

plants in an area 75 x 20 meters. In 1987, 500+ plants were observed, almost all in full bloom on May 5. The plants were described as 10—20 inches in height (PNHP 2011).

The site was surveyed again in May 2012 at which time 700—1200 *Trollius laxus* plants were observed, of which 25—30 percent were in bloom. Mitchell Fen is a large wetland complex; however, an anaylsis using LIDAR revealed only one area underlain by a kame deposit with an peat build-up and open canopy and which creates ideal growing conditions for *T. laxus* (S. Grund, personal communication 10/25/2012).

Surrounded by agricultural fields, Mitchell Fen is privately owned. The landowner, who had been unwilling to permit access since 1987, allowed heritage program botanists access in 2012. There is no active management of the site. The property was recently leased to a gas company (S. Grund, personal communication, 3/9/2012).

Table 7. *Trollius laxus* census data for Mitchell Fen 1986—2012
(sources: PNHP 2011; S. Grund)

year (observer)	quantity of plants	comments
4/18/1986	786—836 plants in 75x20 m area	286 plants blooming
5/5/1987	500+	almost all blooming
5/ /2012	700-1200 plants	25—30% of plants blooming

Status of *Trollius laxus* in other States

Connecticut

Trollius laxus reaches its northern limit in Connecticut, where it is confined to six sites in the Northern Marble Valley region in Litchfield County in the northwestern corner of the state (Dowhan and Craig 1976). *Trollius laxus* is included in the New England Plant Conservation Program's List of Plants in need of Conservation (Brumback and Mehrhoff 1996). It has declined in Connecticut, as is true for every state from which it is known. In addition to the six sites mentioned above, three additional sites are now extirpated (Jones 2001). Threats include land development, agricultural runoff, flooding due to beaver dams, competition from other plants, and herbivory (Jones 2001; Jones and Klemetti 2012).

The cluster of six small extant populations in Litchfield County appears to be functioning as a metapopulation. A preliminary study of genetic variation within and among four locations provided no evidence of inbreeding, but rather suggested gene flow among them due to substantial genetic variation within, but not between, populations (Zielinski 1993; Jones 2001).

New Jersey

Trollius laxus is ranked critically imperiled (S1) in New Jersey and also falls under the protection of the Highlands Water Protection and Planning Act (NJ Natural Heritage Program 2012). Historically *T. laxus* is known from 42 sites in six counties in northern New Jersey; currently there are 19 extant sites in two counties, Warren and Sussex (D. Snyder, personal communication 3/1/2012).

Habitat consists of brushy calcareous fens, often along the transition zone with adjoining swampy woods. Occasionally *T. laxus* occurs in closed canopy wooded calcareous swamps where it may be an artifact of early succession conditions. However, some of these populations have persisted for 25 years or more.

Figure 4. View of the largest known population of *Trollius laxus* estimated at 15,000 plants growing in a successional old field/former pasture in Sussex County, NJ. Photographed by Kathleen Strakosch Walz, 4/22/2010.

Typically the plants are rooted in black, mucky saturated soils but on occasion, they grow on *Carex stricta* hummocks and are elevated above the saturated soils of the fens (D. Snyder, personal

communication, 3/1/2012).

Populations tend to be small to moderate in size 50—200 plants. However, one exceptional Sussex County population contained an estimated 15,000 plants when discovered in 2010 in a former cow pasture, making it the largest known population in the world (Murray 2010). The habitat is clearly an example of an early successional plant community with scattered woody plants including *Juniperus virginiana, Viburnum prunifolium, Cornus amomum, Salix* spp., *Ribes* sp., and *Rosa multiflora* (Figure 3). Herbaceous plants included *Carex* spp., *Solidago* spp., *Symphyotrichum* spp., *Geum* spp., *Packera aurea, Geranium maculatum, Thalictrum dioicum, Onoclea sensibilis*, and *Lythrum salicaria* (K.S. Waltz, personal communication, 3/5/2012).

Historically, the major cause of loss of *T. laxus* populations in urban counties has been draining, filling, and paving of former wetlands to create building sites and highways. Today threats are primarily succession, flooding of habitat by beaver, and browsing by deer. Invasion by non-native, invasive plants is also implicated in decline at some sites (D. Snyder, personal communication, 3/1/2012).

New York

Trollius laxus is classified as vulnerable (S3) in New York by NatureServe (2011); it is ranked as rare (R) by the NY Natural Heritage Program (NYNHP 2012). New York has 30 extant populations of *T. laxus* spread over 26 counties located in the southern, central, and western regions of the state; population sizes range from less than 50 plants to 4,000—5,000 (NY Flora Assn. 2012). Thirty-one additional historic populations, many of which were in the Hudson River Valley, are believed to be extirpated (NYNHP 2011; Mitchell and Dean 1982).

Habitat of *T. laxus* in New York includes a range of community types: ***rich graminoid fen***, ***rich sloping fe***n, ***rich shrub fen***, ***northern white cedar swamp***, ***hemlock-hardwood swamp***, ***rich hemlock – hardwood peat swamp***, and ***red maple – tamarack peat swamp*** (NYNHP 2010).

Despite its apparent preference for early successional habitats, *T. laxus* exists in populations of up to several thousand plants in several northern conifer swamps in New York State. One such site is the Nelson Swamp Unique Area where Sara Scanga studied the effects of light and hydrology on the *T. laxus* population which numbers 4,000—5,000 plants over 800—850 ha. Scanga noted that high vigor *T. laxus* sub-populations at her study site had experienced canopy gap disturbance more recently than low vigor sub-populations. Measures of vigor included plant and seedling abundance, stem production, and reproductive output (Scanga 2009).

In a follow-up study, eleven experimental 10 meter-diameter canopy gaps were created and paired with nearby control areas of similar size. *Trollius laxus* plants in the gaps and control sites were monitored for 5 years. Results indicated that *T. laxus* responded to gap formation by increasing the number of stems and flowers during the second and third years after plots were established. However, in the fourth and fifth years of the experiment, stem and flower number declined in the gaps to levels comparable with those in the control plots. An analysis of total biomass of other herbaceous and woody species that grew up in the gaps versus the control plots

suggested competition from other species that may have benefitted from additional light, suppressed the growth of *T. laxus* in time (Scanga and Leopold 2012).

Scanga and Leopold concluded that the robust population of *T. laxus* at Nelson Swamp was the result of natural gap formation plus a long history of human disturbance from logging, grazing, and other agricultural practices (Scanga and Leopold 2012).

Another population of several thousand *T. laxus* plants exists at Jacobs Fen, a rich, open canopy fen north of Ithaca (D. Leopold, personal communication 3/15/2012). A recent survey of 12 *T. laxus* sites in central and western NY revealed several with small populations (50 or fewer plants) and two sites where *T. laxus* was not found. Flooding due to a recent beaver dam was assumed to be the cause of the species disappearance at one site (P. Raney, personal communication 3/15/2012).

Statewide, threats to the persistence of *T. laxus* populations include draining and conversion of wetlands, flooding due to beaver activity, and succession (NYNHP 2012).

Ohio

Trollius laxus is listed as endangered (E) in Ohio (Ohio DNR 2012a). There are post-1980 records from Ashtabula and Mahoning Counties in northeastern Ohio. The Mahoning County site was described as a swamp forest dominated by *Acer saccharum, Quercus bicolor, Fraxinus americana, and Juglans nigra* on soils derived from Wisconsinan glacial material and having a seasonally high water table. In 1982 the site contained eight sub-populations with a total of 427 plants (Parsons and Yates 1984). However by 2010 the population was reduced to a single, weak plant bearing one flowering stem (J. Bissell, personal communication, 3/1/2012).

When first discovered in 1984, the Ashtabula County site, known as McCoy Fen, was described as an open canopy swamp forest on a lower valley slope and adjacent floodplain terrace along Pymatuning Creek. It contained 435 *T. laxus* plants in two subpopulations separated by a former beaver pond. The site had a canopy of *Alnus incana* ssp. *rugosa* and numerous perennial springheads and channels arising from glacial sand and gravel deposits (Bissell et al. 1985). Rhinehalt (1990) estimated that the population consisted of 550 plants in May 1986.

Currently, the number of *T. laxus* plants is closer to 100—150 in two subpopulations separated by an active beaver pond. Flooding was responsible for some of the losses. Additional habitat alteration followed the drilling of a gas well 800 feet southeast of the largest sub-population in 1989. Immediately after the well was drilled, the volume of flow from the springs declined, and the springheads receded down-slope. The *T. laxus* population subsequently declined by 50 percent. After the gas well was capped in 1995, water flow returned to previous levels and the population of *T. laxus* and a nearby population of *Spiranthes romanzoffiana,* which had also declined, showed signs of recovery (J. Bissell, personal communication, 3/1/2012).

On June 7, 2011 the condition of *T. laxus* within the fens was checked and several plants appeared to be suffering from dense shade. Within the area of the formerly large population (100-plus plants) only 38 were found, just five of which had produced fruit. Shrub growth,

consisting mainly of the non-native, invasive glossy buckthorn, was removed and a 50 x 50 ft. deer exclosure was constructed around 36 of the plants (J. Bissell, personal communication, 3/1/2012).

Spooner at al. (1983) reported historical records in three additional counties. They identified altered drainage as the greatest threat. The Ohio Natural Heritage Program suggests that *T. laxus* may be under-collected in the state due to its early blooming date, wetland habitat, and superficial similarity to other Ranunculaceae species (Ohio DNR 2012b).

Critical Management Issues

Habitat loss

Draining and filling of wetlands, and conversion to other uses are a major cause of habitat loss in northern New Jersey (D. Snyder, personal communication 3/1/2012) and the Lower Hudson River Valley in New York (NY Flora Association 2012.)

Habitat alteration

Succession – *Trollius laxus* is an early to mid-successional plant; it can persist for many years in increasing shade (D. Snyder, personal communication 3/1/2012), but flowering declines and eventually population size decreases**.** This effect can be seen in several of the Pennsylvania populations; Getz Swamp in Northampton County supported 1,800—2,000 plants in 1980 in an area described as having a thin canopy and open shrub layer due to its former use as a pasture (Wiegman 1980). Thirty-two years later the canopy had filled in and the *T. laxus* population had disappeared (Table 2).

The largest population currently known, estimated at 15,000 plants, is in a successional old field that has developed in a former pasture in Sussex County, NJ (Figure 4).

Scanga, who studied *T. laxus* in a northern conifer forested fen in New York State, found that stem, plant, and seedling abundance were not significantly related to light or hydrology variables. However, flower and follicle production increased with increased levels of spring and summer diffuse light transmittance. Northern conifer fen habitat is characterized by clumps of evergreen trees interspersed with wet openings dominated by herbaceous species. Despite the overall findings, the largest canopy gaps supported the most vigorous *Trollius* populations (Scanga 2009). Greenhouse studies confirmed the importance of higher light levels to plant vigor (Scanga 2011). In yet another study Scanga and Leopold (2012) found that stem and flower production in *T. laxus* increased in artificially created gaps, but subsequently declined as other herbaceous and understory plants grew up around them. *In situ*, it appears that although *T. laxus* benefits from higher light levels, it can occupy less than optimal growing conditions in a tradeoff that avoids competition from other taller-growing herbaceous species.

Beaver activity – Flooding caused by beaver dams, which sets succession back by killing woody plants, is part of a natural cycle which results in the perpetuation of early successional wet meadow habitat. In a landscape where *T. laxus* populations exist at several locations in a watershed this could be a viable situation. But in an isolated site, it can be destructive unless a seedbank persists to initiate new growth when suitable conditions recur.

Changes in soil nutrients – Fens can be threatened by agricultural runoff with elevated levels of nitrogen which may promote colonization of invasive, non-native species such as *Lythrum salicaria***,** *Rhamnus frangula*, and *Phragmites australis.* Creation of adequate buffer areas is necessary to protect fens from direct nutrient enrichment. Sites close to roads are also vulnerable to invasion due to runoff and seed corridor effects (Kiviat et al. 2010).

Herbivory
Virginia white-tailed deer have been recorded as causing limited damage to *T. laxus* populations. Deer exclosures have been constructed at sites in Ohio (Bissell, personal communication) and Connecticut (Jones and Klemetti 2012).

Slugs have also been observed feeding on *Trollius* leaves and petals. Jones and Klemetti (2012) suggested that seedlings might be more vulnerable to severe injury than mature plants. Severe damage to seedlings could limit reproductive success.

Loss of Genetic Diversity
Data are needed to evaluate whether loss of genetic diversity is a problem in any of the small Pennsylvania *T. laxus* populations.

Conclusions

Stabilization of Existing Populations

In fragmented landscapes, action to set back succession by opening up the tree canopy and/or shrub layer through regular management is the only alternative to restore vigor in the herbaceous layer. Jones and Klemetti (2012) suggest hand clipping of competing herbaceous vegetation in open fen communities to increase vigor in marginal *T. laxus* populations. Others have documented the importance of artificially created canopy gaps in forested fens (Anderson and Leopold 2002; Scanga and Leopold 2012). Of the Pennsylvania sites, only Plain Grove Fen and Savage Fen are owned by a conservation organization and therefore immediately available for active management. All other sites would require working with private land owners.

Trollius laxus may also benefit from landscape scale land preservation. This approach would allow natural disturbance regimes to perpetuate suitable early successional sites. For example: *T. laxus* could follow beaver through a watershed, inhabiting beaver meadows that formed when dams were abandoned. Seed dispersal at times of high water would facilitate this migration.

***Land protection* –** Efforts to protect Mitchell Fen should be pursued vigorously. The site would also benefit from continued management to control woody growth.

Protection should be sought for some or all of the Northampton County sites coupled with appropriate management. Although no plants were found at the three sites searched in April 2012, a seed bank or scattered plants may still emerge.

Establishment of New Populations

In 2007 Upper Mount Bethel Township, Northampton County acquired a 243-acre property where sand and gravel mining had left a very disturbed landscape. This site would be well suited to establishing a *T. laxus* population because it is very close to several current or historic *T. laxus* populations, and occurs on the same kame deposit as several historic sites (Epstein 1969).

A Natural Lands Trust stewardship report, prepared at the request of the township, (Steckel and Stevens 2011) identified several existing plant communities including ***graminoid marsh with tussock sedge*** and ***graminoid marsh on seepage slope*** that might be suitable for establishing *T. laxus*. This possibility should be explored.

Measures of Success

- Protection of the Mitchell Fen *T. laxus* site in Lawrence County by fee acquisition or conservation easement followed by the establishment of appropriate management

- Establishment of a new population of *T. laxus* in Upper Mount Bethel Township, Northampton County

Research Needs

- Conduct additional searches for *T. laxus* at historical sites in Northampton County.
- Characterize known populations and identify candidate sites using spatial analysis of soils, surficial geology, hydrology, and aerial photography.
- Investigate seed bank viability, and determine optimal germination requirements.
- Investigate pollination ecology.
- Conduct a range-wide genetic diversity study.

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Appendix A. Site Visits Conducted During Preparation of this Report

April 13, 2012 – Northampton Co., Getz Swamp; A. Rhoads, T. Block, J. Henckel, B. Transue

April 13, 2012 – Northampton Co., Rasely Woods; A. Rhoads, T. Block, J. Henckel, B. Transue

April 13, 2012 – Northampton Co., Lohman Fen; A. Rhoads, T. Block, J. Henckel, B. Trnasue

April 16, 2012 – Monroe County, Mansfield Fen; A. Rhoads, T. Block

April 16, 2012 – Northampton Co., Getz Swamp; A. Rhoads, T. Block

April 27, 2012 – Northampton Co., Savage Fen; A. Rhoads, T. Block, J. Kunsman, J. Henckel

April 27, 2012 – Northampton Co., Rasely Woods; A. Rhoads, T. Block, J. Kunsman, J. Henckel, B. Transue

April 27, 2012 – Northampton Co., Lohman Fen; A. Rhoads, T. Block, J. Kunsman, J. Henckel, B. Transue

April 27, 2012 – Northampton Co., Getz Swamp; A. Rhoads, T. Block, J. Kunsman, J. Henckel, B. Transue