Supplementary Information

Data sources used in the analysis for "Microsites Promoting Seedling Regeneration in the Alpine Treeline Ecotone Worldwide" by Adelaide C. Johnson and J. Alan Yeakley

Source	Country	Annual temperature (°C)	Annual precipitation (cm)	Elevation (m)	Genus	Microsite type
Yu et al. 2019	China	-3.1	105	2050	*Betula*	Concave
Butler et al. 2004	Montana	2.2	93	2900	*Abies*	Concave
Enrico et al. 2004	Argentina	8.0	84	2100	*Polyeptis*	Concave
Autio and Coepert 2005	Finland	-1.3	50	460	*Picea*	Concave
Hemp 2005	Tanzania	8.0	14	3000	*Erica.*	Concave
Holtmeier and Broll 1992	USA, Colorado	-3.5	123	3500	*Picea*	Concave
Hughes et al. 2009	Georgia	-3.6	107	2512	*Betula*	Concave
Mellman-Brown 2005	USA, Colorado	3.7	62	2995	*Pinus*	Concave
Kimball and Weihrauch 2000	USA, New Hampshire	0.7	147	1624	*Betula*	Concave
Kullman and Oberg 2009	Sweden	-0.5	73	795	*Betula*	Concave
Li and Yang, 2004	Austria	4.5	103	2100	*Picea*	Concave
€olak 2003	Turkey	5.0	100	1800	*Pinus*	Convex
Brett and Klinka 1998	Canada, B.C.	5.0	300	1195	*Chamaecyparus*	Convex
Heikkinen 1984	USA, Washington, Mt. Baker	4.5	280	1500	*Abies*	Convex
Hiller and Müterthies 2005	Switzerland	1.3	66	2300	*Pinus*	Convex
Holtmeier 2009	USA, Colorado	1.9	93	3100	*Picea*	Convex
Lowery 1972	USA, Washington, North Cascades	1.4	279	1665	*Abies*	Convex
Mori and Hasegawa 2007	Japan	2.5	350	1910	*Abies*	Convex
Rochefort and Peterson 1996	USA, Washington, Mt. Rainier	3.6	280	1775	*Abies*	Convex
Taylor 1995	USA, California	-0.2	107	2600	*Tsuga*	Convex
Zald, personal communication	USA, Oregon, Mt. Jefferson	2.6	223	1797	*Tsuga*	Convex
Renard et al. 2016	Canada	-4.0	160	1261	*Picea*	Object
Akhalkatsi et al. 2006	Georgia	4.8	78	2512	*Betula*	Object
Bader et al. 2007	Ecuador	12.0	117	3600	*Clusia*	Object

Batllori 2009	Spain	11.0	100	2200	*Pinus*	Object
Cholar et al. 2001	France	12.0	123	2600	*Pinus*	Object
Cierjacks et al. 2007	Ecuador	8.3	143	4093	*Polyeptis*	Object
Cuevas 2000	Chile	2.7	50	700	*Nothofagus*	Object
Cunningham 2007	Switzerland	5.5	150	2040	*Picea*	Object
Source	**Country**	**Annual temperature (˚C)**	**Annual precipitation (cm)**	**Elevation (m)**	***Genus***	**Microsite type**
Daly and Shankman 1985	USA, Colorado	-3.5	93	3400	*Picea*	Object
Hättenschwiler and Smith 1999	USA, Wyoming	3.6	70	3200	*Picea*	Object
Harsch et al. 2012	New Zealand	5.4	150	1350	*Nothofagus*	Object
Johnson and Smith 2006	USA, North Carolina	7.8	148	1908	*Abies*	Object
Maher and Germino 2006	USA, Wyoming_	0.6	100	3017	*Abies*	Object
Moir et al. 1999	USA, Wyoming	1.1	108	3200	*Picea*	Object
Oosterhoorn and Kappelle 2000	Costa Rica	12.0	255	2710	*Quercus*	Object
Rehm and Feeley, 2013	Peru	8.5	220	3600	*Polyeptis*	Object
Šrůtek et al. 2002	Spain, Canary Islands	11.0	22	2000	*Pinus*	Object
Wearne and Morgan 2001	Australia	12.0	180	1640	*Eucalyptus*	Object
Marzano et al. 2013	Italy	5.6	75	1800	*Pinus*	Object
Baier et al. 2007	Germany	5.0	187	1100	*Picea*	Wood
Gratzer 1999	Bhutan	4.7	137	3700	*Abies*	Wood
Johnson, unpublished	USA, Washington, Mt. Rainier	3.6	279	1700	*Abies*	Wood
Johnson, unpublished	USA, Alaska, Mt. Roberts	0.1	345	873	*Tsuga*	Wood
Johnson, unpublished	USA, Alaska, Prince of Wales, Island	2.4	439	885	*Picea*	Wood
Johnson and Yeakley 2016	USA, Washington, North Cascades	1.6	237	1215	*Abies*	Wood
Mori et al. 2004	Japan	3.5	250	2050	*Picea*	Wood
Motta 2006	Italy	2.4	131	1900	*Picea*	Wood
Narukawa et al. 2003	Japan	2.0	200	2200	*Tsuga*	Wood
Ran 2010	China	1.5	86	3300	*Rhodo*	Wood
Veblen 1989	Chile	7.0	250	1500	*Nothofagus*	Wood

Ziolonka and Niklossen 2004	Poland	3.0	180	1350	*Picea*	Wood

References cited

Akhalkatsi, M., Abdaladze, O., Nakhutsrishvili, G., & Smith, W. K. 2006. Facilitation of seedling microsites by Rhododendron caucasicum extends the Betula litwinowii alpine treeline, Caucasus Mountains, Republic of Georgia. *Arctic, Antarctic, and Alpine Research*, *38*(4), 481-488.

Autio, J., and A. Colpaert. 2005. The impact of elevation, topography and snow load damage of trees on the position of the actual timberline on the fells in central Finnish Lapland. Fennia 183(1):15-36.

Bader, M. Y., van Geloof, I., & Rietkerk, M. 2007. High solar radiation hinders tree regeneration above the alpine treeline in northern Ecuador. *Plant Ecology*, *191*(1), 33-45.

Baier, R., J. Meyer, and A. Gottein. 2007. Regeneration niches of Norway spruce (*Picea albies* [L.] karst.) saplings in small canopy gaps in mixed mountain forest of the Bavarian Limestone Alps. European Journal of Forest Research 126:11-22.

Batllori, E., Camarero, J. J., Ninot, J. M., & Gutiérrez, E. 2009. Seedling recruitment, survival and facilitation in alpine Pinus uncinata tree line ecotones. Implications and potential responses to climate warming. *Global Ecology and Biogeography*, *18*(4), 460-472.

Brett, R. B., and K. Klinka. 1998. A transition from gap to tree-island regeneration patterns in the subalpine forest of south-coastal British Columbia. Canadian Journal of Forest Research 28(12):1825-1831.

Butler, D. R., Malanson, G. P., and Resler, L. M. 2004. Turf-banked terrace treads and risers, turf exfoliation, and possible relationships with advancing treeline. Catena 58:259–274.

Choler, P., Michalet, R. and Callaway, R.M., 2001. Facilitation and competition on gradients in alpine plant communities. *Ecology*, *82*(12), pp.3295-3308.

Cierjacks, A., Iglesias, J. E., Wesche, K., and I. Hensen. 2007. Impact of sowing, canopy cover and litter on seedling dynamics of two Polylepis species at upper tree lines in central Ecuador. Journal of Tropical Ecology 23(3):309.

Çolak, A. 2003. Effects of microsite conditions on scots pine (*Pinus sylvestris* L.) Seedlings in High-Elevation Plantings. *Forstwissenschaftliches Centralblatt vereinigt mit Tharandter forstliches Jahrbuch*, *122*(1), 36-46.

Cuevas, J. G. 2000. Tree recruitment at the *Nothofagus pumilio* alpine timberline in Tierra del Fuego, Chile. *Journal of Ecology*, *88*(5), 840-855.

Cunningham, C., Zimmermann, N. E., Stoeckli, V., and H. Bugmann. 2006. Growth of Norway spruce (*Picea abies*) saplings in subalpine forests in Switzerland: Does spring climate matter? *Forest ecology and management* 228(1):19-32.

Daly, C. and D. Shankman. 1985. Seedling establishment by conifers above tree limit on Niwot Ridge, Front Range, Colorado, USA. *Arctic and Alpine Research* 17:389-400.

Enrico, L., Funes, G., and M. Cabido. 2004. Regeneration of *Polylepis australis* Bitt. in the mountains of central Argentina. *Forest Ecology and Management* 190(2): 301-309.

Gratzer, G., P. B. Rai, and G. Glatzel. 1999. The influence of the bamboo *Yushaniamicrophylla* on regeneration of *Abies densa* in central Bhutan. Canadian Journal of Forest Research 29:1518-1527.

Harsch, M.A., Buxton, R., Duncan, R.P., Hulme, P.E., Wardle, P. and Wilmshurst, J., 2012. Causes of tree line stability: stem growth, recruitment and mortality rates over 15 years at New Zealand Nothofagus tree lines. *Journal of Biogeography*, *39*(11), pp.2061-2071.

Hättenschwiler, S., and C. Körner. 1995. Responses to recent climate warming of *Pinus sylvestris* and *Pinus cembra* within their montane transition zone in the Swiss Alps. *Journal of Vegetation Science* 6:357-368.

Hunziker, U. and P. Brang. 2005. Microsite patterns of conifer seedling establishment and growth in a mixed stand in the southern Alps. *Forest Ecology and Management* 210:67-79.

Heikkinen, O. 1984. Dendrochronological evidence of variation of Coleman Glacier, Mt. Baker, Washington, U.S.A. *Arctic and Alpine Research* 53-64.

Hemp, A. 2005. Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. *Global Change Biology*, *11*(7), 1013-1023.

Hiller, B. and A. Müterthies. 2005. Humus forms and reforestation of an abandoned pasture at the alpine timberline (Upper Engadine, Central Alps Switzerland). *Mountain Ecosystems: Studies in Treeline Ecology* 2:203-218.

Holtmeier, F., and G. Broll. 1992. The influence of tree islands and microtopography on pedoecological conditions in the forest-alpine tundra ecotone on Niwot Ridge, Colorado Front Range, USA. Arctic and Alpine Research 24:216-228.

Hughes, N. M., Johnson, D. M., Akhalkatsi, M., and O. Abdaladze. 2009. Characterizing *Betula litwinowii* seedling microsites at the alpine-treeline ecotone, central Greater Caucasus Mountains, Georgia. Arctic, Antarctic, and Alpine Research 41(1):112-118.

Johnson, A.C., Yeakley. 2016, Seedling regeneration in the alpine treeline ecotone: comparison of wood microsites and adjacent soil substrates, *Journal of Mountain Research and Development*. 36(3):443-452.

Johnson, D. M., & Smith, W. K. 2005. Refugial forests of the southern Appalachians: photosynthesis and survival in current-year Abies fraseri seedlings. *Tree physiology*, *25*(11), 1379-1387.

Kimball, K. D., and D. M. Weihrauch. 2000. Alpine vegetation communities and the alpine-treeline ecotone boundary in New England as biomonitors for climate change. *In* USDA Forest Service Proceedings 15(3):93-101.

Kullman, L. and L. Öberg. 2009. Post-Little Ice Age tree line rise and climate warming in the Swedish Scandes: a landscape ecological perspective. Journal of Ecology, *97*(3):415-429.

Li, M. H. and J. Yang. 2004. Effects of microsite on growth of Pinus cembra in the subalpine zone of the Austrian Alps. Annals of Forest Science, 61(4):319-325.

Lowery, R. F. 1972. Ecology of subalpine zone tree clumps in the north Cascade Mountains of Washington. Ph.D. Dissertation. University of Washington, Seattle.

Maher, E. L., & Germino, M. J. 2006. Microsite differentiation among conifer species during seedling establishment at alpine treeline. *Ecoscience*, *13*(3), 334-341.

Mellmann-Brown, S. 2005. Regeneration of whitebark pine in the timberline ecotone of the Beartooth Plateau, USA: spatial distribution and responsible agents. *In* G. Broll and B. Keplin (editors), Mountain Ecosystems: Studies in Treeline Ecology. Springer, New York, N.Y.

Moir, W. H., Rochelle, S. G., and A. W. Schoettle. 1999. Microscale patterns of tree establishment near upper treeline, Snowy Range, Wyoming, USA. Arctic, Antarctic, and Alpine Research 379-388.

Mori, A., and S. F. Hasegawa. 2007. Structural characteristics of Abies mariesii saplings in a snowy subalpine parkland in central Japan. Tree physiology 27(1):141-148.

Mori A., E. Mizumachi, T. Osono, and Y. Doi. 2004. Substrate-associated seedling recruitment and establishment of major conifer species in an old-growth subalpine forest in central Japan. Forest Ecology and Management 196:287–297.

Motta, R., R. Berretti, E. Lingua, and P. Piussi. 2006. Coarse woody debris, forest structure and regeneration in the Valbona Forest Reserve, Paneveggio, Italian Alps. Forest Ecology and Management 235:155-163.

Narukawa, Y., S. Iida, H. Tanouchi, S. Abe, and S. Yamamoto. 2003. State of fallen logs and the occurrence of conifer seedlings and saplings in boreal and subalpine old-growth forests in Japan. Ecological Research 18:267-277.

Oosterhoorn, M., and M. Kappelle. 2000. Vegetation structure and composition along an interior-edge-exterior gradient in a Costa Rican montane cloud forest. Forest Ecology and Management 126(3):291-307.

Ran, F., Wu, C., Peng, G., Korpelainen, H., and C. Li. 2010. Physiological differences in Rhododendron calophytum seedlings regenerated in mineral soil or on fallen dead wood of different decaying stages. Plant and soil 337(1):205-215.

Rehm, E. M., & Feeley, K. J. 2013. Forest patches and the upward migration of timberline in the southern Peruvian Andes. *Forest Ecology and Management*, *305*, 204-211.
Rehm and Feeley, 2013

Renard, S.M., McIntire, E.J. and Fajardo, A., 2016. Winter conditions–not summer temperature–influence establishment of seedlings at white spruce alpine treeline in Eastern Quebec. *Journal of Vegetation Science*, *27*(1), pp.29-39.

Rochefort, R. M., and D. L. Peterson. 1996. Temporal and spatial distribution of trees in subalpine meadows of Mount Rainier National Park, Washington, USA. Arctic and Alpine Research 28: 52-59.

Šrůtek, M., Doležal, J., & Hara, T. 2002. Spatial structure and associations in a *Pinus canariensis* population at the treeline, Pico del Teide, Tenerife, Canary Islands. *Arctic, Antarctic, and Alpine Research*, 201-210.

Taylor, A. H. 1995. Forest expansion and climate change in the mountain hemlock (Tsuga metensiana) zone. Lassen Volcanic National Park. California, U.S.A. Arctic and Alpine Research 27:207-216.

Veblen, T. T. 1989. Tree regeneration responses to gaps along a transandean gradient. Ecology 70:541-543.

Wearne, L. J., and J. W. Morgan. 2001. Recent forest encroachment into subalpine grasslands near Mount Hotham, Victoria, Australia. Arctic, Antarctic, and Alpine Research 33:369-377.

Yu, D., Wang, Q, Wang, X., Dai, L. and M. Li. 2019. Microsite Effects on Physiological Performance of Betula ermanii at and Beyond an Alpine Treeline Site on Changbai Mountain in Northeast China, Forests

Zald_unpublished_Mt_Jefferson_OR , personal communication.

Zielonka T., and M. Niklossen. 2001. Dynamics of dead wood and regeneration pattern in natural spruce forest in the Tatra Mountains, Poland. Ecological Bulletins 49:159-163.