

Contents

1 High elevation treelines	1
1.1 The task	1
1.2 Previous works	4
2 Definitions and conventions	11
2.1 The life form 'tree'	11
2.2 Lines and transitions	13
2.3 Limitation, stress and disturbance	15
2.4 Altitude-related and other environmental drivers	16
2.5 Treeline nomenclature	18
3 Treeline patterns	21
3.1 Treeline taxa	21
3.2 The summit syndrome and other treeline depressions	23
3.3 Mass elevation effect	24
3.4 Treeline elevation	25
3.5 Time matters	29
3.6 Forest structure near treeline	30
4 Treeline climate	33
4.1 Specific aspects of treeline climatology	33
4.2 Criteria to define temperature regimes at treeline	34
4.3 Treeline temperatures in different bioclimatic regions	38
4.3.1 Subarctic and boreal zone (45–68° N)	38
4.3.2 Cool temperate zone (45–47° N, 44° S)	40
4.3.3 Warm temperate zone (28–42° N, 36° S)	43
4.3.4 Subtropical zone (19° S, 19° N)	43
4.3.5 Equatorial tropics (6° N to 3° S)	43
4.3.6 Mediterranean 'treelines' (38–42° N)	44
4.3.7 The <i>Nothofagus</i> and <i>Metrosideros</i> case	46
4.3.8 Treeline temperatures across bioclimatic zones	47
4.4 Seedbed and branch temperatures	51
4.5 Whole forest temperatures	55

5 Global mountain statistics based on treeline elevation	57
5.1 Mountain geostatistics	57
5.2 Elevational belts	59
5.3 Global treeline ecotones	60
6 Structure and stature of treeline trees	63
6.1 Foliage properties	63
6.2 Wood properties	70
6.3 Bark properties	74
6.4 Root traits	75
6.5 Tree stature	78
6.6 Dry matter allocation in treeline trees	80
7 Growth and development	85
7.1 Tree growth near the treeline	86
7.1.1 <i>In situ</i> growth of seedlings	86
7.1.2 <i>In situ</i> growth of saplings and adult trees	88
7.2 Xylogenesis at the treeline	91
7.2.1 <i>In situ</i> cambial activity	94
7.2.2 Apical growth dynamics	97
7.3 Root growth	99
7.4 Phenology at the treeline	101
8 Evolutionary adjustments to life at the treeline	105
8.1 Phylogenetic selection	105
8.2 Genotypic responses of growth and development	106
8.3 Genotypic responses of physiological traits	110
9 Reproduction, early life stages and tree demography	113
9.1 Amount and quality of seeds at high elevation	113
9.2 Germination, seedling and sapling stage	119
9.3 Tree demography at the treeline	126
10 Freezing and other forms of stress	131
10.1 Stress at the treeline in a fitness context	131
10.2 Mechanisms and principles of freezing resistance	132
10.3 Freezing resistance in treeline trees	137
10.4 Other forms of stress at the treeline	145
10.4.1 Freeze-thaw cycles and hydraulic failure	147
10.4.2 Winter desiccation	148

11 Water, nutrient and carbon relations	151
11.1 Tree water relations during the growing season	151
11.2 Nutrient relations	156
11.3 Carbon relations	161
 12 Treeline formation - currently, in the past and in the future	 169
12.1 Causes of current treelines	169
12.2 Treelines in the recent past	175
12.3 Treelines in the distant past (Holocene)	180
12.4 Treelines in the future	185
 References	 191
 Subject Index	 211
 Taxonomic Index	 219