

**Technical Note****TREES AND WIND: WIND SCALES AND SPEEDS**by **Scott Cullen**

**Key Words.** Trees and wind; wind; wind scales; wind speeds.

**NEED AND PURPOSE**

Arborists and urban foresters frequently refer to “wind loads,” “sail areas,” and so forth when discussing the risk of tree failure. Whether the discussion is generally descriptive or specifically quantitative, wind speed is an essential consideration. Wind load is a function of wind speed. Acceptable levels of risk must be associated with wind speeds and their probability of recurrence (Cullen 2002a).

It is conventional in scholarly literature to cite wind speed in SI (*Systeme International*) units of m/s (NIST, no date). It is customary, however, for meteorological agencies to report wind speeds in miles per hour, knots, or kilometers per hour. The preferred units vary by both agency and country. In addition, various classification scales are used to describe weather events by wind speed ranges. Some of the tree-risk literature employs these scale numbers (e.g., Sinn and Wessolly 1989; Wessolly 1995; Peterson and Rebertus 1997; Wessolly and Erb 1998; Hayes 1999; Peterson 2000; Brudi 2002).

These various usages may be an obstacle to proper understanding of the tree-wind literature (Cullen 2002b), to practical tree-risk management, and to dissemination of knowledge and methods across national and cultural boundaries. The tables in this article should facilitate simple and accurate comparison.

**COMPARING SCALES AND SPEEDS**

A comparison of wind speed scales and wind speeds in various units of measure is presented in Table 1. The table is not intended to catalog all wind speed scales, but includes several common systems. The World Meteorological Organization provides a list of weather reporting agencies around the world (WMO, no date) that employ various systems.

Some scales incorporate other elements of storm severity in addition to wind speed. For example, the Fujita Scale (Fujita 1987; NCDC 2001a; TTU 2002)—or Fujita-Pearson Scale—(Stormfax 2001) considers the width and length of tornado damage paths; and the

Dolan-Davis Northeast Storm Scale (Dolan and Davis 1992) considers the “storm surge” in coastal water bodies. A variety of scales are catalogued by the Natural Hazards Research Centre (2001). These scales may be useful in assessing risks of tree damage in particular locales.

**TREES AS WIND SPEED INDICATORS**

A number of scales have been developed to use tree movement or deformation as an indication of current or experienced wind speed.

**Tree Movement and Damage**

Historically, the Beaufort Scale was developed to scale wind speeds over water and describe wind effects that could be observed by mariners. The scale has been adjusted for use on land, including description of wind effects on trees. The Fujita Tornado Scale and Saffir-Simpson Hurricane Scale (NWS, no date-b; Simpson and Riehl 1981; NCDC 2001b) use tree damage as an index of wind speeds. These effects are presented in Table 2. Rating damage using the Fujita Scale has been characterized as “highly subjective and variable” (Edwards and Harmon, no date; Doswell and Burgess 1988).

**Deformation of Trees**

In chronically windy locations, wind can also affect tree growth resulting in permanent deformation. Robertson (1987) notes that a number of investigators have developed indices of deformation related to wind speeds. These indices include the Griggs-Putnam index (Putnam 1948) for North American conifers; the Barsch index (Barsch 1963) for European broadleaves; and Yoshino (1975) and Yoshino et al. (1976) for European and Japanese trees. Koepl (1982) reports that the Griggs-Putnam index was further developed to scale deformation against wind characteristics including mean annual wind speed, mean growing season wind speed, mean nongrowing season wind speed, and percentage of winds from prevailing direction. The predictive reliability of these indices is not without critics (Hennessey 1980).

Other studies of tree deformation by chronic wind include those by Cordero (1999), Musselman et al. (1990), and Noguchi (1979, 1992).

Table 1. Wind scales and speeds (copyright Scott Cullen 2002).

Fujita Tornado <sup>1</sup>		Scale			
		Saffir / Simpson		Tropical Cyclone	
Description	Category	Atlantic <sup>2</sup> NE. Pacific	NW Pacific Typhoon <sup>3</sup> Indian Cyclone	AUS <sup>5</sup>	Hong Kong <sup>6</sup>
		Hurricane	(MSW) <sup>4</sup>	km/h	km/h
$V_{WIND} = 14.1 \cdot (F + 2)^{1.5}$					
Gale Tornado	F0		Tropical Depression A Weak Tropical Storm		Tropical Depression
Moderate Tornado	F1		B Severe Tropical Storm		Tropical Storm
Significant Tornado	F2	1	1 Minimal Typhoon	1	Typhoon
		2	2 Moderate Typhoon	2	
		3	3 Strong Typhoon	3	
Severe Tornado	F3	4	4 Very Strong Typhoon Super Typhoon	4	
		5	5 Devastating Typhoon	5	
Devastating Tornado	F4				
Incredible Tornado	F5				
None Expected	F6....				
	....F12 Mach 1				

<sup>1</sup>(NCDC 2001a). <sup>2</sup>(Landsea 2000a; NWS, no date-a). <sup>3</sup>(Landsea 2000c; Navy, no date; NWS 1999). <sup>4</sup>MSW classified by higher peak gusts (Navy-no date). <sup>5</sup>(BoM-AU 2001); strongest gust. <sup>6</sup>(Hong Kong Observatory near center over 10 minutes. <sup>7</sup>(Hong Kong Observatory 1999a; Landsea 2000a; NWS, no date-b) NWS-NCDC 2000; NIST, no date). <sup>9</sup>Calculated speeds > 4 m/s rounded to nearest whole number.

Scale			Wind Speed			
Beaufort <sup>7</sup>			( Published <i>Calculated</i> <sup>8</sup> )			
Force Number	Description		MPH	Knots	km/h	m/s <sup>9</sup>
	(US-NWS)	(WMO)				
0	Calm	Calm	0 - 1	< 1	< 1	0 - 0.4
1	Light	Light Air	1 - 3	1 - 3	1 - 6	0.4 - 1.3
2	Light	Light Breeze	4 - 7	4 - 6	7 - 12	1.8 - 3.1
3	Gentle	Gentle Breeze	8 - 12	7 - 10	13 - 19	4 - 5
4	Moderate	Moderate Breeze	13 - 18	11 - 16	20 - 30	6 - 8
5	Fresh	Fresh Breeze	19 - 24	17 - 21	31 - 39	8 - 11
6	Strong	Strong Breeze	25 - 31	22 - 27	40 - 50	11 - 14
7	Strong	Near Gale	32 - 38	28 - 33	51 - 62	14 - 17
			< 39	< 34	< 63	< 17
			39 - 49	26 - 43	63 - 79	17 - 22
8	Gale	Gale	39 - 46	34 - 40	63 - 74	17 - 21
			40 - 72	35 - 62	64 - 116	18 - 32
9	Gale	Strong Gale	47 - 54	41 - 47	75 - 87	21 - 24
10	Whole Gale	Storm	55 - 63	48 - 55	88 - 102	25 - 28
11	Whole Gale	Violent Storm	64 - 72	56 - 63	103 - 117	29 - 32
			50 - 73	44 - 63	80 - 117	22 - 33
12	Hurricane	Hurricane	73 <	64 <	118 <	33 <
			73 - 112	63 - 97	117 - 180	33 - 50
			74 - 95	64 - 82	119 - 153	33 - 42
			< 78	< 67	< 125	< 35
			78 - 106	67 - 92	125 - 170	35 - 47
			96 - 110	83 - 95	154 - 177	43 - 49
			106 - 140	92 - 121	170 - 225	47 - 63
			< 112	< 97	< 180	< 50
			111 - 130	96 - 113	179 - 209	50 - 58
			113 - 157	98 - 136	182 - 253	51 - 70
			131 - 155	114 - 135	211 - 249	59 - 69
			150 <	130 <	241 <	65 <
			140 - 175	121 - 151	225 - 280	63 - 78
			156 <	136 <	251 <	70 <
			156 - 194	136 - 170	251 - 312	70 - 87
			158 - 206	137 - 179	254 - 331	71 - 92
			175 <	151 <	280 <	78 <
			< 206	< 178	< 331	< 92
			207 - 260	180 - 226	333 - 418	93 - 116
			261 - 318	227 - 276	420 - 512	117 - 142
			319 <	277 <	513 <	143 <
			< 738	< 638	< 1187	< 330
			738 <	638 <	1187 <	330 <

<sup>7</sup>=maximum sustained wind for 1 minute (Landsea 2000c); these typhoon categories are also (Landsea 2000b) following World Meteorology Organization scheme; average sustained speed in km/h (Landsea 2000b); <sup>8</sup>= U.S. National Weather Service; WMO=World Meteorological Organization. <sup>9</sup>(Landsea 2000b);

Table 2. Wind speeds and trees (compiled by Scott Cullen 2002).

		Scale		Wind Speed MPH <sup>4</sup>	
Fujita Tornado <sup>1</sup>		Beaufort <sup>2</sup>			
Description	Category	Force Number	Tree Effect		
<i>Tree Effect</i>					
		0		0 - 1	
		1		1 - 3	
		2	<i>Leaves Rustle</i>	4 - 7	
		3	<i>Leaves &amp; Small Twigs in Constant Motion</i>	8 - 12	
		4	<i>Small Branches in Motion</i>	13 - 18	
		5	<i>Small Trees in Leaf Begin to Sway</i>	19 - 24	
		6	<i>Large Branches in Motion</i>	25 - 31	
		7	<i>Whole Trees in Motion</i>	32 - 38	
Gale Tornado	F0	}	8	<i>Twigs Break</i>	39 - 46
			9		47 - 54
			10	<i>Trees Broken or Uprooted</i>	55 - 63
			11		64 - 72
		12		73 <	
Moderate Tornado	F1	}	<b>Saffir / Simpson<sup>3</sup></b>		
			1	<i>Some Damage to Trees and Shrubby</i>	74 - 95
			2	<i>Considerable Damage to Trees and Shrubby</i>	96 - 110
Significant Tornado	F2	}			< 112
				<i>Large Trees Broken or Uprooted</i>	113 <
Severe Tornado	F3	}			< 157
				<i>Most trees in Forest Uprooted</i>	158 <
Devastating Tornado	F4	}			< 206
				<i>Trees in Forest Uprooted and Carried some Distance</i>	207 <
Incredible Tornado	F5	}			< 260
				<i>Trees Debarked</i>	261 <
				< 318	

<sup>1</sup>(NCDC 2001a; Stormfax 2001). <sup>2</sup>(Landsea 2000a; NWS, no date-b). <sup>3</sup>(Landsea 2000a; NWS, no date-a). <sup>4</sup>See Table 1 to convert mph to other units.

These indices and studies may be useful in assessing wind exposure of trees and biomechanical effects of winds of varying speeds.

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