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 Northeaster 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 Safffir-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. Koeppl (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).

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

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

Scale			Wind Speed			
Beaufort [7]			(Published *Calculated* [8])			
Force Number	Description (US-NWS)	Description (WMO)	MPH	Knots	km/h	m/s [9]
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 <*

=maximum sustained wind for 1 minute (Landsea 2000c); these typhoon categories are also
atory 1999b) following World Meteorology Organization scheme; average sustained speed in km/h
= U.S. National Weather Service; WMO=World Meteorological Organization. [8](Landsea 2000b;

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

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

[1](NCDC 2001a; Stormfax 2001). [2](Landsea 2000a; NWS, no date–b). [3](Landsea 2000a; NWS, no date–a). [4]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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