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SHORT COMMUNICATION

Hurricanes need not cause high mortality: the effects of Hurricane Gilbert on forests in Jamaica

P J BELLINGHAM¹, *School of Agricultural and Forest Sciences, University College of North Wales, Bangor, UK*

V KAPOS, *Botany Department, University of Cambridge, Cambridge CB2 3EA, UK*

N VARTY, *International Council for Bird Preservation, 32 Cambridge Rd, Girton, Cambs, CB3 0PJ, UK*

J R HEALEY, *School of Agricultural and Forest Sciences, University College of North Wales, Bangor, UK*

E V J TANNER, *Botany Department, University of Cambridge, Cambridge, UK*

D L KELLY, *Botany Department, Trinity College, University of Dublin, Republic of Ireland*

J W DALLING, *Botany Department, University of Cambridge, Cambridge, UK*

L S BURNS, *Department of Conservation, Private Bag, Auckland, New Zealand*

D LEE², *Natural Resources Conservation Division, Ministry of Agriculture, Kingston, Jamaica*

G SIDRAK, *Botany Department, University of the West Indies, Kingston, Jamaica*

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In recent years, increasing attention has been paid to the role of disturbance, both minor and catastrophic, in determining ecosystem structure, species diversity and relative abundance of species (Connell 1978, Grubb 1977, Hubbell & Foster 1986). Windstorms, a well-known type of natural catastrophe, can damage up to 100% of forest canopy trees (Foster 1988, Lugo *et al* 1983, Naka 1982, Weaver 1986, Webb 1958, Whitmore 1974) and favour the establishment of gap-demanding species at frequencies higher than would otherwise be found (Foster 1988, Hartshorn 1978, White 1979, Whitmore 1989). However, the effects on tree mortality have rarely been reported despite their importance for population and community structures. We report here the effects of Hurricane Gilbert, one of the most powerful hurricanes ever recorded, on several forest types in Jamaica.

¹Present address: Botany Department, University of Cambridge, Cambridge, UK

²Present address: Protected Areas Resource Conservation Project, Planning Institute of Jamaica, Suite 204, 85 Hope Road, Kingston 6, Jamaica

The Caribbean islands have relatively little remaining natural forest (Johnson 1988). The influence of hurricanes on its structure and diversity is clearly very important, although not fully understood (Crow 1980). Infrequent hurricane damage could account for the occurrence of gap-demanding species in the natural montane forests of Jamaica at greater frequencies than can be explained by normal rates of gap formation (Sugden *et al* 1985). Five hurricanes have passed within 20 km of the Blue Mountains since 1870 (Healey 1990). Hurricane Gilbert, which passed over Jamaica from SE to NW (Figure 1) on 12 September 1988, was the most powerful on record (*New Scientist* 1988), pressure at the eye of the storm was 885 mbar, maximum wind speeds were $> 255 \text{ km h}^{-1}$, and up to 400 mm of rain fell during the storm (Jamaican Meteorological Service 1988). We report here an assessment of hurricane damage to four widely separated areas of Jamaican native forest (Figure 1).

Blue Mountains A general survey of the Blue Mountains forests above 1000 m was done from subsidiary ridges and light aircraft (Dec 1988–June 1989). Damage was very patchy: some areas were devastated, others hardly affected. We estimated that 30% of the area was severely damaged (up to 20%, but more usually 10%, of the trees blown down and the remaining trees heavily damaged leaving large areas apparently leafless). Another 30% was moderately damaged (relatively few uprooted trees, but significant crown damage and defoliation visible even three months after the hurricane). The rest of the area, mostly more protected gullies on the lower slopes, showed minor damage (moderate defoliation, but recovery already evident at the time of survey). The damage was concentrated near the crests of the main and spur ridges (Figure 2). However, severe damage occurred in all kinds of topographic positions, including gully heads. Plantations of *Pinus caribaea* between 700 and 1000 m were very heavily damaged, with c 80% of the trees broken or uprooted.

From January to June 1989 (3–8 months after the hurricane), we evaluated in detail the impact of the hurricane on 2600 permanently marked trees in 49

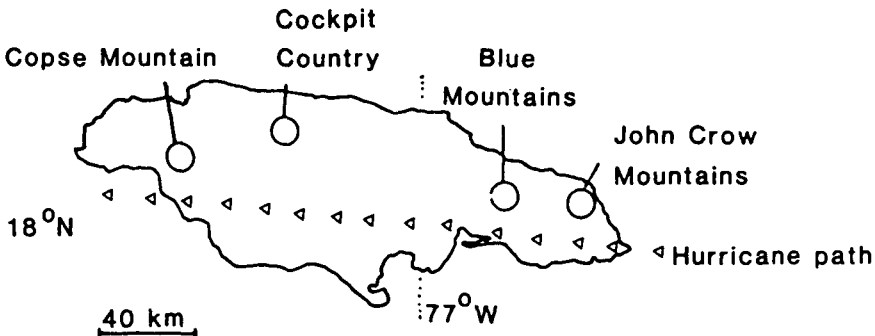
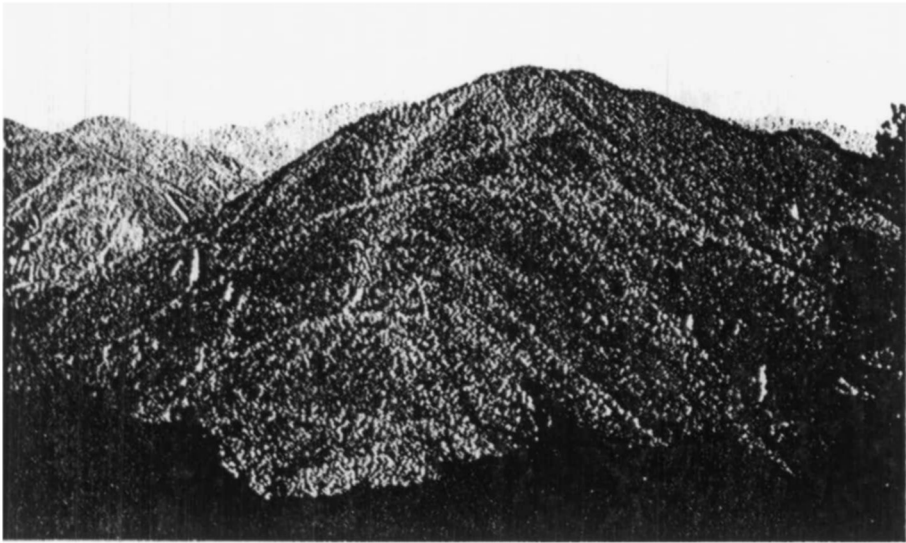
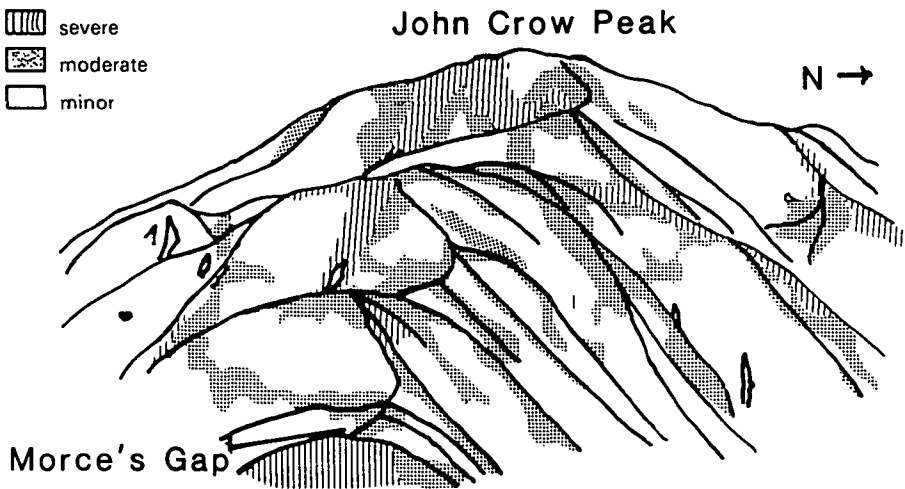


Figure 1 The approximate path of Hurricane Gilbert over Jamaica on 12 September 1988. Pressure at the eye of the storm was 885 mbar. Average windspeeds at the Kingston airport exceeded 205 km h^{-1} for more than 3 hours and maximum winds of $> 255 \text{ km h}^{-1}$ were recorded at various locations. Up to 400 mm of rain fell on 12 September, and large areas of the island received more than 250 mm (Jamaican Meteorological Service 1988). The sites of the various detailed studies reported here are indicated.



a



b

Figure 2 (a) Photograph taken looking west along the main ridge of the Blue Mountains from Belle Vue Peak towards John Crow Peak showing patchiness of the damage and defoliated areas (Damage was more severe further east on the main ridge) (b) Sketch of the same view indicating which areas of the photo correspond to each of the three damage classes: Note heavy damage parallel to and south of the main ridge

plots of 10 m × 10 m along the crest of the main ridge between Morce's Gap and John Crow Peak (1540–1770 m altitude), inventoried in previous studies (Healey 1990, Tanner 1977, Tanner *et al* 1990) Overall, 37% of the trees were either killed or seriously damaged. Mortality since the last census (7.1% in 5 years) was only slightly higher than would have been expected from the long-term

average (Table 1), though the hurricane probably doubled annual mortality for 1988. Species-specific mortality ranged from 0 to 32%. On the whole, severe crown breakage was a more common cause of death from the hurricane than uprooting. This may have been because the relatively low rainfall before and during the storm did not saturate the soils, leaving them relatively strong and stable. Contrary to previous findings (Lugo *et al* 1983, Putz *et al* 1983, Healey 1990), snapped trees did not have smaller dbhs than uprooted trees (Kolmogorov-Smirnov 2-sample test, $P < 0.05$, $n_1 = 359$, $n_2 = 130$). This contrast may be due to the stunted character of the ridge-top forest, where trees are short (canopy height 8–15 m) and mostly small in diameter (mean dbh c. 14 cm for trees > 3 cm dbh, Healey 1990). A significant majority of the fallen trees fell towards the NE ($X^2 P < 0.05$, 64% fell in directions between 10° and 100°), which suggests that most fell during the first part of the storm.

Fewer trees were killed by the hurricane than were damaged without being killed, although some of the damaged trees may yet die, and apparently dead trees may resprout (56% of all stems in the plots had fresh epicormic resprouts). Relatively few individuals were fully defoliated, most retained leaves in the lower crown, but stripping of twigs as well as leaves contributed to the openness of the canopy. In areas with substantial canopy damage, many seedlings of gap-demanding species germinated within three months of the storm. There were up to 2000 seedlings m^{-2} of the most abundant species (*Alchornea latifolia*) compared with 0.24 m^{-2} in undisturbed forest (Healey 1990), and *Bocconia frutescens* was also common.

Other Jamaican forests Other forested areas in Jamaica also suffered significant damage from Hurricane Gilbert (Table 2), though it is clear that damage was very variable. The Blue Mountains (BM) forests were the least damaged, and the difference between the two BM data sets is due to the inclusion of severely

Table 1 Mortality and damage patterns in the Blue Mountains forests after Hurricane Gilbert. Data are from 49 pre-existing plots covering 0.49 ha and comprising 2600 permanently marked trees

| | | |
|--|-------------------------------|------------------|
| Mortality over 5 year period including Hurricane Gilbert (1984–89, %) | | 7.1 |
| Previous long-term average annual mortality in a period with no serious hurricane impact (% y^{-1}) | | 1.1 ¹ |
| Visible damage to dead trees or apparent cause of death | toppled ² | (%) 1.0 |
| | trunk or crown broken | (%) 3.8 |
| | unknown | (%) 2.1 |
| Non-fatal damage ³ | toppled ² | (%) 3.8 |
| | trunk or crown totally broken | (%) 3.3 |
| | crown partly broken | (%) 4.8 |
| | crown fully defoliated | (%) 18.2 |
| (range among plots: 0–75%) | | |

¹Tanner, unpublished data

²Blown over $\geq 40^\circ$ from vertical, trunk not broken

³Most of the remaining 63% of trees suffered slight damage, mostly partial defoliation

Table 2 Hurricane Gilbert-related mortality and damage of trees at selected sites in Jamaica (locations of sites shown in Figure 1; damage definitions as in Table 1)

| | Mortality | Breakage | Uprooting |
|---------------------|--|---|---|
| | Mortality of previously enumerated stems during period including Hurricane Gilbert [% (SEM)] | Stems with trunks or crowns completely or partly broken (both alive and dead) [% (SEM)] | Stems toppled ($\geq 40^\circ$) or fallen (both alive and dead) [% (SEM)] |
| Blue Mountains | | | |
| 1 | 7.1 (0.7) over 5 years | 12.3 (1.0) | 4.3 (0.6) |
| 2 | N/A | 23.1 (1.4) | 9.2 (1.0) |
| John Crow Mountains | | | |
| 3 | 13.5 over 4 years | 21.8 | 15.0 |
| 4 | N/A | 14.7 (1.1) | 28.1 (1.7) |
| Cockpit Country | | | |
| 5 | N/A | 17.7 (2.1) | 19.9 (2.7) |
| Westmoreland | | | |
| 6 | 17.7 over 3.3 years | 20.6 | 18.9 |

1) Bellingham: $n = 49 \times 100 \text{ m}^2$ plots in Tanner (1977), Tanner *et al.* (1990) & Healey (1990) sites, along western crest of range, c. 1550 m altitude. Tree density c. 5300 stems ha^{-1} ($\geq 3 \text{ cm dbh}$); canopy height 5–18 m. Resurveyed Jan–June 1989.

2) Varty: $n = 64 \times 78.5 \text{ m}^2$ plots in transects along crest and to N and S of western end of the range, 1300–1600 m. Tree density c. 4400 stems ha^{-1} ($\geq 5 \text{ cm dbh}$). Surveyed April–June 1989.

3) Kelly: $n = 1 \times 900 \text{ m}^2$ plot in Hog House Hill site, 400–500 m (Kelly *et al.* 1988). Tree density c. 1500 stems ha^{-1} ($\geq 4 \text{ cm dbh}$); canopy height c. 26 m. Resurveyed July 1989.

4) Varty: $n = 70 \times 78.5 \text{ m}^2$ plots in transects at Hog House Hill & Ecclesdown, 300–500 m. Tree density c. 3200 stems ha^{-1} ($\geq 5 \text{ cm dbh}$). Surveyed June–July 1989.

5) Varty: $n = 56 \times 78.5 \text{ m}^2$ plots in transects at Barbecue Bottom, Pantrepant and Windsor, 150–350 m. Tree density c. 1700 stems ha^{-1} ($\geq 5 \text{ cm dbh}$); canopy height c. 20 m. Surveyed July 1989.

6) Kelly: 1100 m^2 in 2 plots at Cope Mountain, c. 300 m. Tree density c. 1600 stems ha^{-1} ($\geq 3 \text{ cm dbh}$); canopy height 17–30 m. Resurveyed June 1989.

damaged plots in the Varty data set while none of the previously enumerated (Bellingham) plots was in the most damaged areas. The ridge-top forest suffered the least crown breakage of any site and low tree uprooting. One explanation for its apparent resistance is that its exposed topographic position may have caused the ridge top forest to develop its characteristic more aerodynamically streamlined, even canopy and may also have selected species and individuals resistant to high winds (Lawton 1982). The importance of this degree of disturbance for slow-growing (average diameter increment $< 0.2 \text{ mm y}^{-1}$, Tanner *et al.* 1990) montane forest is not yet clear. Because of low mortality, Hurricane Gilbert has changed BM forest composition little in the short term.

The John Crow Mountains (JCM) plot evaluated by Kelly is in a sheltered hollow and at the low end of the damage range in JCM plots evaluated by Varty. The trees in the JCM were more susceptible to uprooting than in other sites, which may reflect the stronger impact of the hurricane in this region as well as the greater average height of the trees (26–28 m, Kelly *et al.* 1988), and

indicates that the limestone substrate did not provide the greater anchoring predicted by other authors (Howard & Proctor 1957). Within-region variability was particularly high in the Cockpit country, where the topographic differences between the ridge tops and slopes and the very sheltered 'cockpit' bottoms account for the larger standard errors. Westmoreland was quite strongly affected with the highest mortality of any site.

The highest incidence of serious damage to trees in the Jamaican forests was comparable to the average found by Lugo *et al* (1983) in Dominican forests after Hurricane David. Their results and reports from other authors (Boucher 1990, Foster 1988, Whitmore 1974, 1989) imply much higher mortality than we have recorded. The low mortality has significant implications for the long term effect of the hurricane, which will depend on the relative success of seedlings of gap demanding species that have germinated and the regrowth of damaged adult trees. Where substantial numbers of seedlings become established the hurricane will have measurable effects for several centuries, where resprouting is more important the effect will disappear in a few years or decades. All the forests probably consist of patches where one or the other means of recovery is stronger, the overall effect of each hurricane depending on the proportions of patches.

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LITERATURE CITED

- BOUCHER D H 1990 Growing back after hurricanes; catastrophes may be critical to rain forest dynamics *Bioscience* 40:163-166
- CONNELL, J H 1978 Diversity in tropical rain forests and coral reefs *Science* 199:1302-1310
- CROW, T R 1980 A rainforest chronicle: A 30 year record of change in structure and composition at El Verde Puerto Rico *Biotropica* 12:42-55
- FOSTER, D R 1988 Species and stand response to catastrophic wind in central New England, USA *Journal of Ecology* 76:135-151
- GRUBB, P J 1977 The maintenance of species richness in plant communities: the importance of the regeneration niche *Biological Reviews* 52:107-135
- HARTSHORN G S 1978 Tree falls and tropical forest dynamics Pp 617-638 in Tomlinson, P B & Zimmermann, M H (eds) *Tropical trees as living systems* Cambridge University Press Cambridge
- HEALEY, J R 1990 Regeneration in a Jamaican montane tropical rainforest PhD Dissertation, University of Cambridge
- HOWARD, R A & PROCTOR, G R 1957 The vegetation on bauxitic soils in Jamaica Part I *Journal of the Arnold Arboretum* 38:1-50
- HUBBELL, S P & FOSTER, R B 1986 Biology, chance, and history and the structure of tropical rain forest tree communities Pp 314-329 in Diamond, J & Case, T J (eds) *Community Ecology* Harper & Row, Publishers, New York
- JOHNSON T H 1988 *Biodiversity and conservation in the Caribbean Profiles of selected islands* ICBP Monograph 1 International Council for Bird Preservation, Cambridge
- JAMAICAN METEOROLOGICAL SERVICE 1988 Report, Dec 1988
- KELLY, D L, TANNER, E V J, KAPOS, V, DICKINSON, T A, GOODFRIEND, G A &

- FAIRBAIRN, P 1988 Jamaican limestone forests: floristics, structure and environment of three examples along a rainfall gradient *Journal of Tropical Ecology* 4:121-156
- LAWTON, R O 1982 Wind stress and elfin stature in a montane rain forest tree: an adaptive explanation *American Journal of Botany* 69:1224-1230
- LUGO, A E, APPLEFIELD, M, POOL, D J & MACDONALD, R B 1983 The impact of Hurricane David on the forests of Dominica *Canadian Journal of Forest Research* 13:201-211
- NAKA, K 1982 Community dynamics of evergreen broadleaf forests in southwestern Japan I Wind damaged trees and canopy gaps in an evergreen oak forest *Botanical Magazine Tokyo* 95:386-399
- NEW SCIENTIST* no 1631 22 Sept 1988
- PUTZ, F E, COLEY, P D, LU, K, MONTALVO, A & AIELLO, A 1983 Uprooting and snapping of trees: structural determinants and ecological consequences *Canadian Journal of Forest Research* 13:1011-1020
- SUGDEN, A M, TANNER, E V J & KAPOS, V 1985 Regeneration following clearing in a Jamaican montane forest: Results of a ten year study *Journal of Tropical Ecology* 1:329-351
- TANNER, E V J 1977 Four montane rain forests of Jamaica: a quantitative characterization of the floristics, the soils, and the foliar mineral levels, and a discussion of the interrelations *Journal of Ecology* 65:883-918
- TANNER, E V J, KAPOS, V, FRESKOS, S, HEALEY, J R & THEOBALD, A M 1990 Nitrogen and phosphorus fertilization of Jamaican montane forest trees *Journal of Tropical Ecology* 6:231-238
- WEAVER, P L 1986 Hurricane damage and recovery in the montane forests of the Luquillo Mountains of Puerto Rico *Caribbean Journal of Science* 22:53-70
- WEBB, L J 1958 Cyclones as an ecological factor in tropical lowland rainforest, North Queensland *Australian Journal of Botany* 6:220-228
- WHITE, P S 1979 Pattern, process, and natural disturbance in vegetation *Botanical Review* 45:229-299
- WHITMORE, T C 1974 Change with time and the role of cyclones in tropical rain forest on Kolombangara, Solomon Islands Commonwealth Forestry Institute, Paper 46, Oxford
- WHITMORE, T C 1989 Changes over 21 years in the Kolombangara rain forests *Journal of Ecology* 77:469-483

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