Biophysical Impacts to Trees at Protected Sites on the Island of Dominica: Implications for Biodiversity and Conservation

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Abstract

This study, framed within the concepts of biodiversity and sustainable development, focused on the occurrence of biophysical impacts to trees at two national park sites on Dominica and explored two research hypotheses. Larger tree diameters and basal areas found at Emerald Pool were anticipated because of more favorable edaphic and climatic conditions. But, the larger number of stems and species encountered at Cabrits were unexpected. Overall, the extent of impacts to trees at the sites does not seem to be a serious problem, considering that mean tree damage index (TDI) for both sites was less than two. Nevertheless, given the critical role of nature tourism to the island's socio-economic development the need for implementing sound resource conservation and management strategies to protect the resources and biodiversity of the island is critical. This exploratory study can serve as a framework for similar studies in resource poor developing tropical island nations. Such research is important not only because island-ecosystems have a strong tourism appeal, are generally biologically diverse, and reflect high levels of endemism, but also because Morne Trois National of which Emerald Pool is but a small part is a World Heritage Site, and is thus of global significance. Dominica therefore has an international obligation to ensure the effective management of these natural assets for the benefit of mankind.

Keywords: biophysical impacts, Dominica, island, nature tourism, trees.

1. Introduction

Recreational impacts at campsites and along trails have been the focus of a large number of past recreation and tourism impacts studies. The term impact, in the recreation ecology literature has been used to denote any 'undesirable visitor-related biophysical change' of the natural resource (Leung and Marion, 2000). It is used in that context in this paper. A number of studies examined the ecological impacts on vegetation (Cole, 2004; Cole & Fichtler, 1983; Cole & Marion, 1988; Farrell & Marion, 2002; Frissell,1978; Marion & Leung, 2001; Nepal & Way, 2007; Parsons & Macleod, 1980; Pickering & Hill,2007; Wood, et al., 2006), whereas some investigated the effects of outdoor recreation on vegetation growth (James, et al., 1979; Settergren & Cole, 1970; Stohlgren & Parsons,1986). These studies as well as others such as Hammitt (1987) have concluded that outdoor recreation and by extension nature-based tourism, results in impacts on the natural condition of vegetation. One such impact, as reported by James et al., (1979) was that annual stem growth of jack pines in high impacted campsites was 59% less than jack pines on undisturbed sites.

Edwards (1977) in a comparative study of relative cover and species composition along alpine trails and in undisturbed areas looked at ecological impacts to vegetation from pedestrian traffic in a non-campsite setting. An important conclusion of that quantitative study was that most of the vegetation impacts resulting from trampling were confined to a one-meter border on both sides of the trail. Pedestrians generally find it uncomfortable to walk along eroded trails. Consequently these walkers create new tracks on each side of the main trails. This process is repeated over time (Edwards, 1977) resulting in the gradual expansion of impacted zone.

Ewert (1999) noted that there was an 'uneasy alliance' between outdoor recreation and natural resource management. He highlighted four critical principles which can aid in understanding this 'uneasy alliance': (a) impacts are multidimensional (b) recreational use results in impacts (c) generally, the majority of the impacts related to recreation use occur in early stages of use and (d) the type of recreational activities influence the rate and amount of impacts. These principles are in agreement with those advanced by Hammitt and Cole (1998).

1.1 Importance and Relevance of Study

Most of the published ecological studies addressing human-induced impacts were undertaken in developed countries. In comparison to North America, other industrialized nations, and mainland countries in general only a limited number of such studies (Altinay & Hussain, 2005) have focused on island nation developing countries, hence the motivation in part for this study. It is generally accepted that an island is 'a piece of land surrounded by water' (Oxford Dictionaries, 2012). However, there is no clear official, internationally accepted definition for what constitutes an island-nation (Schimidt, 2005). In some circumstances physical size has been used as the primary defining criteria whereas in other situations population size has been used as the defining bar (Schimidt, 2005). Irrespective of the criteria used islands and island-nations generally have much appeal to and stimulate much interest to international travelers and tourists. Consequently, accessing, monitoring, and understanding the relationship between use of islands' natural habitats for recreation and tourism purposes is of global importance.

The Caribbean island-nation of Dominica, the focus of this study, has embraced nature-based tourism as a primary socio-economic developmental path. However, tourism "…depends on the quality of the environment for its success and good tourist development requires the protection and even the improvement of the environment" (UNEP, 1998). Thus, such research is important not only because islands' ecosystems are generally small, biologically diverse and reflect high levels of endemism, but also because in the case of Dominica the Morne Trois National Park of which the Emerald Pool, one of the study sites, is but a small part, was inscribed as a World Heritage Site by UNESCO in 1997 (UNESCO, 2012) and is therefore of global significance. Hence Dominica has an obligation to the international community to ensure the effective management of these natural assets for the benefit of mankind.

1.2 Parameters and Hypotheses to be Explored

Three specific aspects of biophysical impacts to trees namely changes in basal area, changes in forest canopy, and mechanical damage to trees were examined. Some other direct impacts of recreation and tourism activities such as extent of root damage to trees, reduced height growth and vigor, and various other forms of vandalism to trees were not investigated. It is accepted, however, that such impacts, though often less visible, recognized and reported in the literature, have implications for tree health and condition.

In addition the biophysical variables examined two research hypotheses were explored:

(1) There are no significant differences between the level of impacts (in terms of vegetation changes) which are occurring in the two ecological zones – secondary rainforest and dry shrub woodland.

(2) In secondary rainforest outdoor recreation environments on Dominica, gommier (*Dacroydes excelsa*) and bois bande (*Richeria grandis*), though among the most abundant species, are not the tree species most frequently damaged.

2. Materials and Methods

This paper is one of the products of a larger exploratory study. Thus, some of the material presented under the methodology section of the paper has been presented in some form in other publications and manuscripts (Christian, et al., 2009; Christian & Lacher Jr.). Phase 1 of the study was implemented during the months of December/January whereas Phase 2 was undertaken during the months of June/July. Data collection was usually completed at one site before the commencement of sampling at the other site simply because of the limited number of field personnel (Christian, et al., 2009; Christian & Lacher Jr.). The nature and format of data collection activities undertaken were the same during both phases and at both sites.

2.1 Study Sites

Dominica, located in the Eastern Caribbean (Figure 1) has a land area of 790 km^2 and is the most mountainous island in the Lesser Antilles (Beard, 1949). These peaks, as well as much of the island, are covered with lush-green vegetation. The island is of volcanic origin (Lang, 1967) and experiences a rainy season from mid-June to mid-January and a dry season from mid-January to mid-June (Nicolson, 1991).

The research was undertaken at the Cabrits and Morne Trois Pitons National Parks. The Cabrits peninsula, part of the Cabrits National Park (CNP) is located in the drier northwestern part of the island whereas the Emerald Pool, a popular site within the Morne Trois Pitons National Park (MTPNP) and World Heritage Site is located in the south-central part of the island. CNP has a land area of 512 ha whereas MTPNP covers 6,349 ha. In addition, CNP has a large marine component. Dry scrub woodland vegetation and the largest tract of wetlands on the island are the dominant terrestrial ecological zones at the Cabrits peninsula in contrast to the secondary rainforest vegetation found at the Emerald Pool.

The island's national parks and other natural assets are critically important given the fact that nature-based tourism is one of the 'pillars' of the island's socio-economic development strategy. The island's government is committed to pursuing a vision of "…sustainable tourism that enriches the lives of all citizens by creating economic, social and cultural opportunities, protecting the natural resources and scenic, heritage and cultural features of the country…" (Government of Dominica, 2006). Dominica's emphasis on nature-based tourism seems to be bringing some benefits to the island. John (2009) reported that in the 2003-2004 and 2004-2005 budgetary cycles the state generated EC$1,054,424 (US$390,527) and EC$1,085,060 (US$401,874) respectively in net revenues from the sale of tickets for accessing nature sites by tourists.

2.2 Research Design

Resource conditions along one-meter trail corridors and in established rectangular research plots were investigated during the study. Nine 50.02 m^2 (3.2 m by 15.63 m) plots were established at each study site. Individual plots were further subdivided into five equal sub-plots (3.2 m by 3.126 m). The distance from the trail head at which the first plot was established was randomly determined based on the use of random tables. Deliberate efforts were made however, to ensure that the first plot was located at least 10 m from the trailhead in an effort to exclude areas of excessively high use and impact. The first plots at the Emerald Pool and the Cabrits were located 16 m and 37 m respectively from the trail entrance.

To facilitate future location of plot and sub-plot boundaries their corners were demarcated through the use of six inch metal nails buried in the ground during Phase 1. A magnetic pin locator was used to locate nails during Phase 2. A schematic map, based on compass bearings and measured distances to selected fixed reference features such as mature trees and large rocks prepared during Phase 1 proved very useful in plot and sub-plot boundary location during Phase 2 of the study.

Figure 1 Location of Dominica and the Study Sites

The plots were positioned in groups of threes, perpendicularly to the selected trail sections. One of the shortest sides of each of the three test plots (T1s) closest to the trail touched the trail’s edge. The second test plot (T2) of each group of three plots was located five meters away from and along the same compass bearing as the corresponding T1 plot (Figure 2). The third plot (C) of each group was located 10 m away from the second test plot (T2) but along the same compass bearings as the corresponding T1 and T2 plots. Thus, the final plot of each group was approximately 46.26 m away from the trail. A distance of 50 m was maintained between adjacent groups of plots. The T1 and T2 plots of each group were regarded as test/research plots whereas the C plots furthest away from the trails were considered as control plots. C plots were generally located in minimally impacted or un-impacted areas (Figure 2). Rectangular plots were used instead of circular or square plots simply because elongated rectangular plots usually furnish data which facilitate more accurate analysis of ecological studies (Cox, 1972; Orloci, 1978).

A trail section that connects the Fort Shirley Complex-West Cabrits trail to the Douglas Bay Battery trail and measuring approximately 0.6 km was selected at CNP for monitoring and comparison to the Emerald Pool's 0.8 km loop-trail section. One-meter wide trail corridors, on both sides of the selected trail sections at each site, were also assessed and monitored during the study.

2.3 Data Collection

Several data collection methods were used. A field assistant positioned at the trail entrance kept a tally of the number of visitors to the study sites. Data on tree diameter, species composition, and tree damage were collected. The diameter at breast height (dbh) of all trees which were equal to or greater than 5 cm within the plots and in one-meter corridors was measured, for the purpose of computing basal areas.

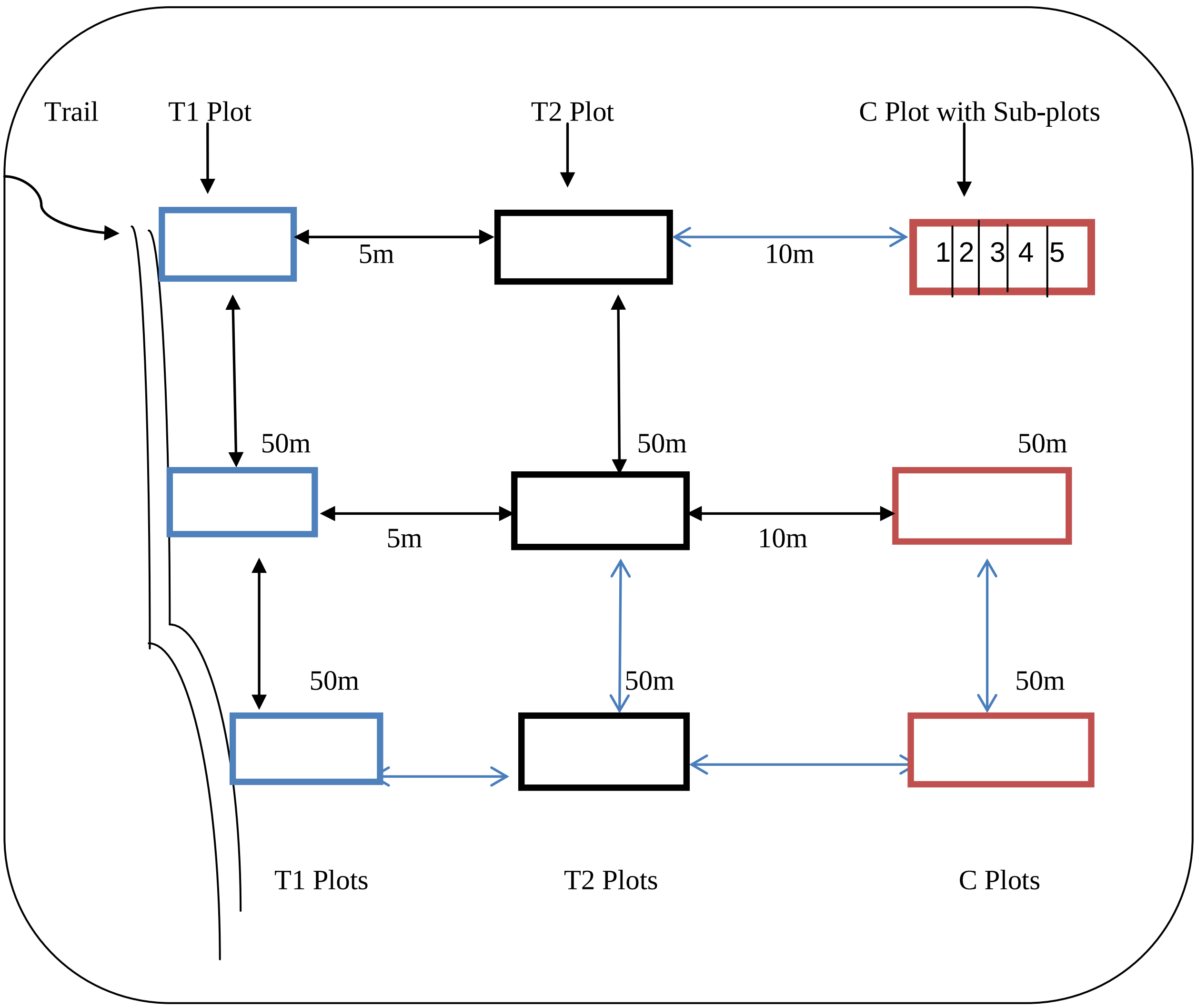

Figure 2 Schematic Layout of Plots (not drawn to scale)

Diameter tapes were used to measure dbh at roughly 1.5 m above ground (Barrett & Nutt, 1979; Mueller-Dombois & Ellenberg, 1974). Individual members of the field crew used a straight stick 1.5 m long to identify the approximate diameter at breast height point at which dbh measurements were made. Dbh points were not demarcated on individual trees.

Marion's (Marion, 1984) system, slightly modified, was used to assess damage to trees (i.e., those equal to or greater than 5 cm dbh). In accordance with that system classes of tree damage were identified and then used to calculate a tree damage index (TDI). Each standing tree within the sub-plots and one-meter corridors was identified, evaluated, and classified. The four classes of tree damage used by Marion (1984) and utilized in this study were:

1 = No tree damage other than from natural causes.

2 = Slight tree damage – nails or nail holes, small branches cut off or broken, small superficial trunk scars or mutilations.

3 = Moderate tree damage – trunk scars and mutilations may be numerous but moderate in size and totaling less than one square foot [0.09 m^2] of trunk area.

4 = Severe tree damage – trunk scars and mutilations numerous with many that are large and having a combined total of more than one square foot [0.09 m^2] trunk area, any complete girdling of tree (including bark striping all the way around tree) regardless aerial extent (Marion, 1984).

The terms small branches and large branches were not defined by Marion (1984). In this study, however, small branches were considered to be less than or equal to 2.5 cm in diameter. Unlike Marion's (Marion, 1984) system in which felled trees were neither recorded nor classified, such trees (stumps) were placed in a fifth category – felled. The tree damage index formula was amended accordingly to include this class. Dead trees were also recorded but were not included in TDI computations partly because a total of less than 10 dead trees were recorded.

The TDI normally varies between 1 and 4 (Marion, 1984). However in this study TDI ranged between 1 and 5 because of the inclusion of a fifth category, "felled". TDI was calculated "…by multiplying the number of trees in the 'none' category by 1 and the number of trees in the 'slight', 'moderate', 'severe' and [felled] categories by 2, 3, 4, and 5 respectively. The products were summed, and the sum was divided by the total number of trees" (Cole, 1989). The TDI represents the average level of damage to trees at a site, the upper end the scale being the worst scenario.

Cole (1989) noted that Marion's system, which was initially used to do a comprehensive evaluation of campsites, failed to identify camper-caused damage to trees which were outside the physical boundaries of the campsites. The layout of the plots in this study hopefully minimized the overall effect of that weakness. It should be emphasized that although no camping occurs at the study sites, some of the actions and behaviors of park users and field personnel result in impacts somewhat similar to those reported for camp-sites, hence the reason for using the TDI. Evaluation and classification of tree damage were done by the same individual throughout the study to ensure consistency.

2.4 Data Analysis

SAS statistical package (SAS Institute, 1990) was used to conduct a variety of statistical analyses. The general linear model was the primary method used for hypothesis testing. Wilcoxon rank scores and chi-square test of independence were both used to compare tree damage between sites.

Tree damage index was computed for each site in order to determine which of the two sites experienced the most tree damage. Frequencies and other descriptive statistics were also generated.

3. Results and Discussion

A mix of approaches was used to analyze the data and to evaluate the results. The results of the analyses and evaluations are presented below.

3.1 Basal Area

Sample plots at Emerald Pool contained almost three times as much basal area as Cabrits' plots (Table 1). Mean basal area of the trees at Cabrits showed only a small increase (1.27 cm^2) over Phase 1, but at Emerald Pool mean increase during the same period was much larger (18.33 cm^2). These results were not surprising, considering that past field studies have confirmed that the ratio of annual diameter increase of plantation species in the dry Cabrits' environment is approximately one-fourth of the annual diameter increase of similar species established in the island's rain forest and secondary forest zones.

Table 1 Summary of Basal Area Data from Research Plots at Study Sites on Dominica

Site	Phases	Total Basal Area (cm^2)	Mean Basal Area (cm^2)	Min. Basal Area (cm^2)	Max. Basal Area (cm^2)
Emerald Pool	1	23 952.48	399.21	20.43	4 185.40
	2	24 635.12	417.54	22.90	4 864.52
	Both	48 587.60	408.30	20.43	4 864.52
Cabrits	1	8 104.46	144.72	22.06	789.24
	2	9 051.44	145.99	19.64	789.24
	Both	17 155.90	145.39	19.64	789.24

The diameters of trees monitored at Emerald Pool varied widely, from 5.1 cm to 78.7 cm. Less variation was noticed at Cabrits where the range was from 5 cm to 31.7 cm.

Two-way analysis of variance of mean basal area, based on a general linear model, produced significant results ($F = 4.97$, $p = 0.002$). The difference between the mean basal areas of the two sites was significant (Table 2). However, neither the effect of phase nor the interaction between site and phase was significant (Table 2). It is assumed that the short time interval of 6 months between the phases was insufficient to detect any significant differences.

Details on the mean and standard error (S.E.) of dbh by phase at the site level are contained in Table 3. The S.E. associated with the dbh means at the Cabrits were less than one whereas the standard errors associated with the dbh means of Emerald Pool trees were closer to two suggesting that the values reported for Cabrits may be more reliable.

Table 2 Two-way ANOVA of Basal Area and dbh of Trees in Plots at Study Sites

Source	SS	df	MS	F	p-value
A. **Mean basal area**					
Site	4 093 325.63	1	4 093 325.63	14.88	0.000*
Phase	5 685.64	1	5 685.65	0.02	0.886
Site X Phase	4 309.24	1	4 309.24	0.02	0.901
Error	64 095 546.22	233	275 088.22	-	-
Corrected total	68 200 988.10	236	-	-	-
B. **Mean dbh**					
Site	1 793.87	1	1 793.87	14.77	0.000*
Phase	0.04	1	0.04	0.00	0.985
Site X Phase	0.85	1	0.85	0.01	0.934
Error	28 291.30	233	121.41	-	-
Corrected total	30 090.63	236	-	-	-

*Significant at alpha = 0.05 level.

Table 3 Means and Standard Errors (S.E.) of dbh of Trees Monitored in Research Plots at Emerald Pool and Cabrits on Dominica

Variable	Phase 1 Mean (SE)	Phase 2 Mean (SE)
Emerald Pool		
dbh (cm)	17.74 (1.81)	17.83 (1.92)
Cabrits		
dbh (cm)	12.35 (0.76)	12.20 (0.78)

3.2 Forest Canopy

The forest canopy at Emerald Pool is dominated by carapite (*Amanoa caribaea*), cre cre (*Miconia spp*.), and bois bande (*Richeria grandis*). Together these species accounted for 94.8% of the 115 stems observed in the research plots at that site. The tree species most frequently observed at Cabrits were mapou (*Pisonia fragrans*), campeche (*Haematoxylum campechianum*), savonnette (*Lonchocarpus latifolius*), bois cutlet (*Citharexylum spinosum*), and vermicelle (*Capparis flexuosa*), which together represented 80.9% of the 141 stems recorded there (Table 4).

Table 4 Tree species which made-up 3% or more of total species encountered in research plots on Dominica

Site	Tree Species	Frequency	% of Site Total[1]
Emerald Pool	Carapite (*Amanoa caribaea*)	51	44.3
	Cre cre (*Miconia spp*.)	29	25.2
	Bois bande (*Richeria grandis*)	11	9.6
	Gommier (*Dacroydes excelsa*)	6	5.2
	Caconnier (*Ormosia spp.)*	4	3.5
	Coco poule (*Cordia laevigata*)	4	3.5
	Mangle blanc (*Symphonia globulifera*)	4	3.5
	Tree fern (*Cyathea arborea*)	4	3.5
Cabrits	Campeche (*Haematoxylum campechianum*)	28	19.9
	Marpo (*Pisonia fragrans*)	28	19.9
	Savonnette (*Lonchocarpus latifolius*)	23	16.3
	Bois cutlet (*Citharexylum spinosum*)	15	10.6
	Vermicelle (*Capparis flexuosa*)	12	8.5
	Ti fieulle (?)	8	5.7

[1] Only species which contribute 3.5% or more of total number of stems (115 at Emerald Pool and 141 at Cabrits) in the plots are reflected in Table.

The total number of stems and species observed at Cabrits plots were greater than the numbers found in the secondary rainforest community at Emerald Pool. Nineteen tree species with a projected density of 9 462.9 stems/hectare were recorded at Cabrits in comparison to 15 species with a projected density of 8 330.0 stems/hectare encountered at the Emerald Pool. The diameters of trees at Emerald Pool were larger than those at Cabrits, and the mean diameters were significantly different ($F = 4.9$, $p = 0.002$) based on an analysis of variance.

The species which were most abundant in the plots were also dominant in the one-meter corridors. Carapite 44 (37.0%) and bois bande 7 (5.9%) were the tree species encountered most frequently in the one-meter corridors at Emerald Pool. At Cabrits the most common one-meter corridor species were campeche 30 (35.7%), mapou 17 (20.2%), and two species of mahogany 11 (13.1%). Large-leaf mahogany (*Swientenia macrophylla*) and small-leaf mahogany (*Swientenia mahogani*) are two exotic, plantation species at Cabrits. The relatively high frequency of those species as a group in the one-meter corridor was due to the fact that the selected trail section partially traversed the boundaries of a mahogany plantation.

3.3 Mechanical Damage to Trees

A total of 83 (72.2%) of the 115 stems evaluated and classified in the plots at Emerald Pool during both phases of the study showed no evidence of human induced damage. Six (5.3%) of stems showed signs of moderate or severe damage whereas 17 (14.8%) were slightly damaged. Four (3.5%) dead trees were noticed, however, possible causes of death could not be ascertained from field observations. Mechanical damage to trees was more evident at Cabrits where 21 (14.9%) of the 141 trees evaluated had suffered either moderate or severe levels of damage. In addition, 24 (17.0%) of Cabrits' trees had been felled as evidenced by the presence of stumps in contrast to only five (4.3%) at Emerald Pool (Table 5).

Table 5 Tree Damage Encountered in Research Plots at two National Parks Sites on Dominica

	Frequency (% of sites total*)		
Site/Tree Damage	**Phase 1**	**Phase 2**	**Both Phases**
Emerald Pool			
None	46 (82.1)	37 (62.7)	83 (72.2)
Slight	4 (7.1)	13 (22.0)	17 (14.8)
Felled	2 (3.6)	3 (5.1)	5 (4.3)
Dead	2 (3.6)	2 (3.4)	4 (3.5)
Severe	1 (1.8)	2 (3.4)	3 (2.6)
Moderate	1 (1.8)	2 (3.4)	3 (2.6)
Totals	**56 (100)**	**59 (100)**	**115 (100)**
Cabrits			
None	26 (38.8)	25 (33.8)	51 (36.2)
Slight	18 (26.9)	22 (29.7)	40 (28.4)
Felled	11 (16.4)	13 (17.6)	24 (17.0)
Moderate	10 (14.9)	7 (9.5)	17 (16.1)
Severe	1 (1.5)	3 (4.1)	4 (2.8)
Dead	1 (1.5)	4 (5.4)	5 (3.5)
Totals	**67 (100)**	**74 (100)**	**141 (100)**

*No statistical test was performed because an unacceptable number of cells have expected frequency counts of less than 5.

Data from the one-meter corridors also indicated that mechanical damage to trees was more serious at Cabrits. Fifty-six (67.5%) of the 83 corridor trees at Cabrits had been felled and 11 (13.2%) others had suffered either moderate or severe damage. Only 8 (6.7%) of the 119 corridor trees at Emerald Pool had been removed, but 71 (59.6%) had either been moderately or severely damaged (Table 6).

The statistical significance of the difference between sites on the research plot data could not be explored with the chi-square test of independence because many cells had less than the expected frequency counts. However, after "moderate" and "severe" classes were pooled chi-square test showed a significant statistical relationship between tree damage and study site (χ^2 = 35.54, df = 4, p = 0.000).

Table 6 Tree damage encountered in one-meter trail corridors on Dominica

	Frequency and % of Site Total		
Site/Tree Damage	**Phase 1**	**Phase 2**	**Both Phases**
Emerald Pool			
None	8 (13.8)	4 (6.6)	12 (10.1)
Sight	11 (19.0)	16 (26.2)	27 (22.7)
Moderate	22 (37.9)	28 (45.9)	50 (42.0)
Severe	14 (24.1)	7 (11.5)	21 (17.6)
Felled	3 (5.2)	5 (8.2)	8 (6.7)
Dead	0 (0.0)	1 (1.6)	1 (0.8)
Totals	**58 (100)**	**61 (100)**	**119 (100)**
Cabrits			
None	1 (2.6)	1 (2.3)	2 (2.4)
Slight	8 (20.5)	6 (13.6)	14 (16.9)
Moderate	3 (7.7)	4 (9.1)	7 (8.4)
Severe	1 (2.6)	3 (6.8)	4 (4.8)
Felled	26 (66.7)	30 (68.2)	56 (67.5)
Totals	**39 (100)**	**44 (100)**	**83 (100)**

*No statistical test was performed because an unacceptable number of cells had expected frequency counts of less than 5.

The non-parametric Wilcoxon Scores (Rank Sums) Test was also used to compare the extent of tree damage, as indicated by tree class, between the two sites. The difference between the sites was statistically significant in Phase 1, Phase 2, and for both phases combined (Table 7). These results do not support the hypothesis: 'There are no significant differences between the level of impacts (in terms of tree damage) which are occurring in the two ecological zones – secondary rainforest and dry scrub woodland'.

Table 7 Statistical Comparison of Rank Mean Scores of Tree Damage Classes Based on Data from Study Sites at Emerald Pool and Cabrits on Dominica

Phases	**Variable**	**Emerald Pool**	**Cabrits**	**Z**	**p>|z|**
1	Tree Class	48.06	73.65	- 4.45	0.000*
2	Tree Class	55.03	76.54	- 3.41	0.000*
Both	Tree Class	102.57	149.65	- 5.51	0.000*

*Significant at alpha = 0.05 level based on the Wilcoxon Scores (Rank Sums) Test.

Furthermore, the evidence indicates that contrary to the initial assumption that the dry scrub woodland zone experienced the least amount of impact. Cabrits does experience more tree damage than Emerald Pool. Comparison of TDI was another approach used to evaluate the extent of tree damage between sites, plots, and individual species. Computed TDI for Cabrits was consistently greater than those for Emerald Pool (Table 8). This provides further evidence for the conclusion that the problem of tree damage is more serious at Cabrits.

Table 8 Computed TDI of Trees found in Research Plots at two Research Sites, Emerald Pool and Cabrits, on Dominica

Phases	Site/Tree Damage Index Emerald Pool	Cabrits	Difference
1	1.31	2.29	0.98
2	1.61	2.39	0.78
Both	1.44	2.34	0.90

Further examination of TDI results indicates that the difference between the two phases was greater at Emerald Pool (0.3) than at Cabrits (0.1). This suggests that whereas the total amount of tree damage may be greater at Cabrits the rate of damage may be higher at Emerald Pool.

Owing to the small number of stems recorded by species at Emerald Pool, most likely in part because of the small sample area, it was not possible to test the hypothesis: 'In secondary rain forest, outdoor recreation environments on Dominica, gommier (*Dacryodes excelsa*) and bois bande (*Richeria grandis*) are not the tree species most frequently damaged' in the generally accepted statistical methods. However, to gain some perception of this hypothesis the ratio of damaged stems to total number of stems per species, as well as TDI for individual tree species found at Emerald Pool was computed and compared (Table 9).

Table 9 Summary of Number of Trees (Damaged and Undamaged), Ratio of Damaged to Total Number of Trees per Species, and TDI per Species at Emerald Pool Plots

Site/Tree Species[1]	Total[2]	Damaged	Undamaged	Ratio	TDI
Emerald Pool					
Balate	2	0	2	0.00	1.00
Bois bande	11	4	7	0.36	1.70
Bois diable	1	1	0	1.00	2.00
Carapite	44	11	33	0.25	1.45
Caconnier	4	0	4	0.00	1.00
Coco poule	4	3	1	0.75	1.75
Cre cre	27	5	22	0.19	1.30
Gommier	6	1	5	0.17	1.17
Laurier de rose	2	2	0	1.00	5.00
Mangle blanc	3	0	3	0.00	1.00
Mauricif	2	0	2	0.00	1.00
Palmiste	1	0	1	0.00	1.00
Ti citron	2	1	1	0.50	1.50
Tree fern	0	-	-	-	-
Yeux crab	2	0	2	0.00	1.00

[1] Scientific names are captured in text.
[2] Dead trees are not reflected.

Comparison of the number of damaged stems of a given species to the total number of stems for that species indicated that three species namely laurier de rose [*Phoebe elongata*] (100% damage, TDI=5.0), bois diable [*Licania ternatensis*] (100% damage, TDI=2.0), and coco poule [*Cordia laevigata*] (75% damage, TDI=1.75) received proportionately more damage than bois bande

(36.4%, TDI=1.70) and gommier (16.6% damage, TDI=1.17). Additionally, three other species – ti citron [*Ilex macfadyenii*] (50% damage, TDI=1.50), carapite [*Amanoa caribaea*] (25.0% damage, TDI=1.45; and cre cre (18.5% damage, TDI=1.30) – suffered more damage than gommier. Based on the results of comparison of TDI and ratio of number of damaged to undamaged stems it was concluded that the hypothesis should be rejected.

Three of the damaged bois bande trees (two moderately and one slightly damaged) occurred in T1 plots adjacent to the trail. None occurred in T2 plots and one severely damaged bois bande tree was found in a control plot. The only damaged (slightly) gommier tree occurred in a T2 plot.

All of the bois bande and gommier trees found in the one-meter corridors at Emerald Pool were damaged in some form. Five of the seven bois bande trees were severely damaged and two had been moderately damaged. Two of the four gommier stems in the corridors were severely damaged whereas the others were moderately damaged. A total of 11 (73.3%) of the 15 tree species in the one-meter corridors at Emerald Pool had suffered damage of varying degrees. Overall only 12 (10.1%) of the stems in the corridors did not show any signs of human-induced damage (Table 6). Six (40.0%) of the 15 species found in the research plots at Emerald Pool suffered no damage (Table 9).

TDI computations of research plot data also indicated that laurier de rose (TDI=5.00), bois diable (TDI=2.00), and coco poule (TDI=1.75), all experienced higher levels of damage than bois bande (TDI=1.70) and gommier (TDI=1.17).

3.4 Factors which Influence Tree Damage

Results of the forward selection stepwise regression model revealed that tree damage is strongly influenced by landform (slope) and number of visitors to the site (Table 10). The prediction model: Tree damage = 3.3438 – (0.0189 x number of users) – (0.5071 x landform), had an R^2 = 0.1707, indicating that other undetermined factors or combination of factors are responsible for 82.9% of the variability in tree damage. The results can also be interpreted to mean that the relationship between tree damage (tree class) and the dependent variables may not be linear.

Table 10 Summary of Forward Selection Regression Procedures in respect of Tree Damage, based on Data Collected at Emerald Pool and Cabrits on Dominica

Dependent Variable	Partial R^2	Model R^2	F	p-value
Tree damage				
Landform	0.1146	0.1146	16.45	0.000*
Number of users	0.5600	17.07	8.51	0.004*

*All met the 0.10 selection/entry level for inclusion in model.

4. Conclusion

Species diversity is generally expected to be higher in rain forest and secondary rain forest environments than in drier habitats of similar size and geographic location, partly because of more favorable soil and climatic conditions generally encountered in the former zones (Brown, 1988). These edaphic and climatic factors are more conducive to plant growth and so the larger tree diameters and greater total basal areas found at Emerald Pool were not surprising. Similarly, because of the presence of thorns on many tree species at Cabrits, it was initially speculated that overall, trees at that locality generally experienced lower levels of human-induced biophysical damage. This was not supported by the data. However, the larger total number of stems and tree species encountered at Cabrits was unexpected.

Overall, the extent of human induced damage to trees at these two national park sites on Dominica is not a serious problem, mean TDI for the sites being less than two in both cases. In this particular study the range of TDI was between one and five because of the inclusion of a fifth category, “felled”, in the model.

It is recognized that there are obvious limitations to some of the results of this study. For example TDI has only been used to compare tree damage between different sites in the past (Marion, 1984) and so its use to compare individual species at a given site as well as a basis for making conclusions about hypotheses may not be entirely reliable. However, this approach does permit some form of comparison. Furthermore, results of a few of the analyses undertaken seem to suggest that a period greater than six months may be required before any statistically significant differences in total basal areas and level of human-induced tree damage between study phases can be detected. Among other things the study results point to are: (a) the need for future island recreation ecology research to address monitoring and measurement of selected parameters over the long-term, (b) need for inclusion of a larger number of plots and longer trail corridor sections in sample frame, and (c) need for some focus in trying to identify the contributing causes to tree mortality in the island’s national parks. The methodology and results of this exploratory study can serve as a framework for similar studies in resource poor developing tropical island nations in the future.

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