The impacts of a selective logging operation on germination, growth and insect herbivory of *Spondias mombin* seedlings in Belize

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INTRODUCTION

Sustainable selective logging is currently regarded as a potential tool in the conservation of large areas of tropical broadleaf forest outside of protected areas. It is hoped that economically productive management of forests will ensure sufficient forest cover to remain in the tropics to minimise the loss of biodiversity through habitat loss and fragmentation. However, the impacts of selective logging on forest ecology are not well understood. This paper analyses the data collected for a single tree species, *Spondias mombin* (Anacardiaceae, commonly known in Belize as Hog plum), within an experiment investigating the impacts of a selective logging operation on the seedling and insect herbivore communities of a broadleaf forest in Belize, Central America. By analysing individual species separately, it is hoped that indepth insight into the impacts of the logging operation on the forest ecosystem can be gained that is much greater than the sum of the analysis of the individual species.

DATA COLLECTION

Study area

The field-work was carried out during 1995 and 1996 in the Chiquibul Forest Reserve, Cayo District, Belize, Central America. Hartshorn et al. (1984) consider the Chiquibul to be near the transition between the 'Subtropical lower montane moist' and the 'Subtropical moist' life zones of the Holdridge System, with annual rainfall in the region of 1500mm. The area is of Cretaceous limestone, consequently surface water is rare.

The Chiquibul has a history of frequent and often severe disturbance, from intensive agriculture by the ancient Maya until around 900AD to logging through most of the 20th century, principally for mahogany (*Swietenia macrophylla*) and some cedar (*Cedrela odorata*), interspersed with hurricanes and fires (Bird 1994). Hurricane Hattie caused severe damage in the area in 1961, flattening 60% of the trees in some areas (Wolffsohn 1967).

Study plot and methods

The field-work was carried out within four pairs of silvicultural permanent sample plots (PSPs) established by the Forest Planning and Management Project of the Belize Forest Department and situated near Las Cuevas, San Pastor, Grano d'Oro and New Maria. Access was by track from the Las Cuevas Research Station of the Belize Forest Department and the Natural History Museum (London). Each paired plot covered 18ha of forest, and was split into two PSPs of 300m x 300m each, one of which was selectively logged (at 6 trees per hectare) in May 1995 and one of which was left undisturbed as a control.

Within the central hectare of each PSP, 25 seedling quadrats were established prior to the logging, on a stratified random basis. Each quadrat was $1m^2$, and within each one all plants of 3cm height or more were tagged, identified, measured to the highest living point above the ground (to the nearest cm), and any 10cm high or more were assessed for insect damage on the top ten leaves. Enumerations of each quadrat were carried out at intervals of about 6-8 weeks, with any newly germinated seedlings of 3cm or more tagged and measured.

Disturbance assessment

Following the logging, each quadrat was assessed for disturbance. It was considered unsuitable to try to classify disturbance as simply gap or non-gap, as defining gaps can be problematic (Brokaw 1985), measuring and classifying them even more so (Brown 1993, Whitmore et al. 1993), and even non-gaps within a forest are highly variable (Lieberman et al. 1989). Therefore different classes of gap were defined based on the extent of the vegetation loss directly above each quadrat. The definitions used for each gap type were as follows:

Gap type 1 - No vegetation directly above.
Gap type 2 - Open canopy but other vegetation above.
Gap type 3 - Closed canopy but lack of midstory above.
Gap type 4 - Disturbed but with dense overhanging debris/vegetation above.
Gap type 5 - Vegetation openness unattributable to the current logging operation.
Undisturbed - Undisturbed forest.

RESULTS AND DISCUSSION

Seedling density

Germination and death

Figure 1 shows that germination of the 1995-cohort of *Spondias mombin* seedlings occurred between May 1995 and January 1996, with a peak of germination from June to August. The 1996-cohort began germinating the following May. The duration of the germination period for the 1995-cohort was longer in the logged plots than in the unlogged plots.

Figure 2 shows that seedling death was similar in the logged and unlogged plots.

Initial seedling height following germination

The mean height of *S. mombin* seedlings of the 1995-cohort at the first enumeration after germination was 9.4 cm for those in logged plots (s=3.48, n=61) and 10.5 cm for those in unlogged plots (s=2.60, n=51), a non-significant difference. Figure 3 indicates that the range of initial heights was larger for seedlings in the logged plots than those in the unlogged plots.

Seedling growth

Figure 4 illustrates that the growth of the 1995-cohort seedlings was similar in the logged and unlogged plots, with most growth occuring bewteen May and October 1995. This was followed by very little growth until May 1996. By the final enumeration, the mean height of seedlings of the 1995-cohort in the logged plots was 16.5 cm (s=5.98, n=44), compared to 14.2 cm (s=3.06, n=31) for those in the unlogged plots, a statistically significant difference ($z=2.18$, $p<0.05$).

Figure 5 illustrates the effects of local disturbance on seedling height for the 1995-cohort. It can be seen that disturbance had little effect on initial height following germination, but by the final enumeration it is clear that most growth had occurred in seedlings in areas disturbed during the logging operation (gap types 1,2 and 3).

Leaf number

Figure 6 illustrates how the mean number of leaves assessed changed over time. In both logged and unlogged plots, mean leaf number increased until December 1995, then decreased sharply during the period December 1995 to April 1996, before increasing again during May 1996. Seedlings in the logged plots had more leaves than those in the unlogged plots throughout the study period.

Insect herbivory

Table 2: The effects of disturbance on the occurance of insect herbivores in quadrats with *S. mombin* (1995 or pre-1995 cohorts) over the duration of the study (in percentage of quadrats attacked).

	Herbivore	*Sites*	*Logged*			*Unlogged*	
			Gap type 1	Gap type 2 or 3	Undisturbed	Gap type 5	Undisturbed
cLep2	Lepidoptera sp.	SP, NM	25	100	20	67	0
sAle07	Aleurothrixus sp.	SP, NM	100	100	50	67	18
sAle12,13	other Aleyrodidae	SP, GD, NM	0	29	0	33	9
sDia2,3	Diaspididae	SP, NM	25	25	10	33	9
sPse0	Pseudococcidae	GD, NM	0	40	11	0	0
hCic1	Cicadellidae	SP, GD, NM	25	43	0	33	0

Herbivory by *Aleurothrixus*

The major insect herbivore of *S. mombin* seedlings during this study was the whitefly *Aleurothrixus* sp. (Homoptera: Aleyrodidae), large colonies of which often built up on the leaves under the protection of bright white wax. Figure 8 shows that seedlings were attacked about five months earlier in the logged plots than in the unlogged plots, although by the final enumeration the percentage of plants attacked in the two sets of plots was similar.

Attack by *Aleurothrixus* was only recorded at two of the sites, San Pastor and New Maria. The effect of local disturbance on *Aleurothrixus* attack at these sites is illustrated in figure 9. Every quadrat containing *S. mombin* that was disturbed during the logging operation (gap types1, 2 and 3) suffered from attack, and over 60% of the quadrats in both the logged and unlogged plots that were in disturbed areas not attributable to the logging operation (gap type 5) also suffered attack. A much higher percentage of quadrats in undisturbed areas of the logged plots were attacked than those in undisturbed areas of the unlogged plots. However, the severity of attack (mean percentage of plants attacked and mean maximum percentage of leaves attacked) within the quadrats attacked was relatively similar, regardless of the level of disturbance. These results suggest that colony establishment is more dependent on disturbance than is colony growth. There was no evidence suggesting a density-dependent relationship for colony establishment.

Herbivory by other sap-suckers

Other sap-sucker species were recorded infrequently on *S. mombin* during this study, in both the logged and the unlogged plots (table 2). Aleyrodid whitefly other than *Aleurothrixus* were recorded more frequently in disturbed quadrats than undisturbed quadrats in both the logged and unlogged plots. This was also the case for diaspid scales (Homoptera: Diaspididae), while Pseudococcid scales (Homoptera: Pseudococcidae) were recorded only in the logged plots. Leaf-hopper nymphs (Homoptera: Cicadellidae) were recorded on *S. mombin* in both logged and unlogged plots, but only from quadrats in disturbed areas.

Herbivory by defoliators

Small lepidopteran larvae that folded and skeletonised pieces of the edges of leaves were recorded from several *S. mombin* seedlings at two sites, San Pastor and New Maria, between December 1995 and February 1996, with one or two seedlings being attacked through to the final enumeration in May 1996. In the logged plots at the two sites, defoliation by this larva was recorded from 63% of quadrats (with *S. mombin* seedlings) in disturbed areas (gap types 1, 2 and 3), and from only 20% of quadrats in undisturbed areas. In the unlogged plots, the larva was recorded in 67% of quadrats in disturbed areas (gap type 5), but not in any quadrats in undisturbed areas. Leaf damage was minimal, rarely causing more than about 3% defoliation of a plant.

Defoliation by other insect herbivores occurred at a low level, usually 20% or less of leaf area, to seedlings in disturbed and undisturbed areas of both logged and unlogged plots. Defoliation by leaf-cutting ants *Atta* spp. (Hymenoptera: Formicidae) was not recorded from any *S. mombin* seedlings during this study.

Conclusions

This analysis shows that *Spondias mombin* seedlings germinated in both the logged and the unlogged plots during this study. Growth of the newly germinated seedlings occurred during the wetter months and was higher in areas disturbed during the logging operation, presumably due to the increased light levels in these areas, but even in these disturbed areas growth was not rapid. The seedlings tended to drop significant numbers of their leaves during the drier months. There was no evidence to suggest that leaf-drop was related to herbivory. Herbivory by insects was generally higher in disturbed areas of both the logged and the unlogged plots than in undisturbed areas. The major insect herbivore of *S. mombin* seedlings encountered during this study was the whitefly *Aleurothrixus*. The establishment of colonies of *Aleurothrixus* was much more frequent in disturbed areas than undisturbed areas, but once established there was little difference in intensity of attack in different areas. The only other commonly recorded insect herbivore was a small lepidopteran defoliator. These larvae also tended to occur in disturbed areas rather than undisturbed areas, but leaf damage was minimal.

The selective logging operation undertaken during this study did have an impact on the seedling dynamics of *Spondias mombin*, but it appears that the ecological significance of this impact is not great. Local disturbances in the logged plots were more significant than the disturbance to the logged plots as a whole, perhaps due to the success of the measures taken during the logging operation to minimise damage to the remaining stand. It should be recognised that the Chiquibul forest where this study was carried out has a long history of disturbance, from large-scale clearance for agriculture by the ancient Maya through hurricanes, fires and logging. This logging operation, therefore, can not be regarded as a major disturbance event in the life of the forest, and so the ecological significance of the operation may be restricted to species that are specifically selected against, such as highly desirable timber trees and their associated fauna and flora. *Spondias mombin* is used for timber in Belize, but it is not currently considered highly desirable and consequently is likely to be resilient to logging disturbances.

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