



7 Impacts on the terrestrial fauna

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7.1 Introduction

Ideally the CELOS Management System (CMS) should offer the best of both worlds: the sustainable harvest of native timber tree species in a tropical rainforest environment, and the maintenance of the ecological integrity of this environment. Sustainable timber harvest remains the primary goal of the CMS, however. This is an economic goal with associated social goals, e.g. employment and other benefits for people living in remote areas. An important question that needs to be addressed is to what extent a CMS that achieves its economic goal, also achieves its ecological goal. Conservation organisations such as the WWF correctly point out that the fate of biodiversity in general, and threatened species in particular, will largely depend on what happens to them and their habitats outside of protected areas, e.g. in extensive forestry concessions. It is therefore relevant to assess whether or not the CMS results in a type of forest that satisfies the habitat requirements of the native fauna, and whether threatened animal species will find some form of refuge there. In this chapter information is provided on what is known of the impact of the CMS and similar types of disturbance due to logging on the terrestrial fauna.

7.2 Background

The socio-economic challenge to the foresters who developed the CMS from the 1960s to 1980s was to come up with a system that would allow regular timber harvests, but would only require a modest labor force and limited capital investment. As explained in earlier chapters, the silvicultural challenge to the foresters was to somehow enhance the natural regeneration of commercially interesting trees in the existing, 'natural' forests. The concept they came up with was to redirect the flow of energy and nutrients to a pre-selected subset of tree species with commercial value as timber, to the detriment of trees without such commercial value (non-timber trees). The basic concept of the CMS was and still is selective logging with low collateral damage, and the application of

silvicultural treatments. The most critical treatment is the 'refinement' of tree stands, i.e. the systematic killing of mature non-timber trees.

For the CMS to work, natural forest regeneration processes must be kept up and running, such as pollination, seed dispersal, seedling germination and growth, etc., at least as regards timber trees. In the initial version of the CMS, the mere maintenance of forest cover was considered adequate to maintain these processes at the required level. In later versions, additional provisions were made to maintain or enhance the regeneration of timber trees, such as leaving enough mature timber trees to function as parent trees (reproductive function). Another provision added was to restrict hunting, which was originally proposed as a general measure to maintain ecosystem integrity and conserve globally threatened animals (see below).



Photo 7.1. *Alouatta macconnelli* - Guianan Red Howler Monkey. (Photo P. Ouboter)

The importance of this provision has become increasingly clear in recent decades, as a result of research that demonstrated the effectiveness of rainforest animals, including game species, as dispersers of many timber tree species. A few cases in point, relevant to Suriname, are: i) in French Guiana, seeds of *Carapa* spp. (Jansen & Forget 2001) and *Voucapoua americana* (Forget 1994) are dispersed by agoutis, and are largely dependent on these to germinate successfully; ii) *Virola* spp. seeds are dispersed primarily by the Guianan Spider Monkey *Ateles paniscus* and toucan species in French Guiana (Ratiarison 2003, unpublished thesis: chapter II), with e.g. agoutis functioning as secondary dispersers (Forget et al. 2000), and iii) *Tetragastris altissima* is dispersed by a variety of birds and primates in French Guiana (Ratiarison & Forget 2005), and by the Yellow-footed Tortoise *Chelonoides* (= *Geochelone*) *denticulata* in the Brazilian Amazon (Jerozolinski et al. 2009).

In Suriname, fauna studies were implemented in two areas where the CMS had been experimentally applied between the early 1970s and 1980s (see Chapter 5, e.g. Table 5.1):

- at Akintosoela, an area with mixed high dryland forest on undulating land with loamy soil (see De Graaf 1986); fauna studies took place in the Akintosoela1 forest stand, which had been both logged (in 1966 and 1974) and refined (1975), and the Procter's Forest stand, which had been selectively logged only (1966 and 1974); and
- at Kabo, an area with mixed high dryland forest on a low sandy-loamy plateau (see Jonkers 1987); fauna studies took place in a forest stand called the MAIN Experiment, which includes plots that had been left undisturbed, had been selectively logged only (in 1978), and had been both logged (1978) and refined (in the course of 1982-83); the studies also took place in the dryland part of a nearby undisturbed forest stand called the Van Leeuwen Transect.

Below, the results of the CMS-related fauna studies will be reviewed, and discussed in the light of comparable studies that have taken place in Amazonia. Based on this discussion, an attempt will be made to assess the impact of the CMS on the fauna.

7.3 Studies in Suriname on the impact of the CMS on the fauna



Photo 7.2. *Pipra erythrocephala* caught with mist net.
(Photo B. O'Shea)

7.3.1 Impact on birds

In 1980-81, ornithological research was undertaken in the Akintosoela area. At two forest stands, Procter's Forest and Akintosoela1, birds were captured with mist nets, identified, tagged and subsequently released (De Jong 1982). Both stands had been logged (in 1966 and 1974), and the Akintosoela1 stand had in addition been refined in 1975 (see also Fig. 5.4). The aim of the research was to investigate the impact of refinement on the avifauna of logged forest. The total number of bird captures at both stands was virtually identical, as was the total number of bird species captured (Table 7.1). De Jong (1982) claims that there is a striking difference between the two forest stands when the data is analysed at the functional group level. He groups the bird species into four functional categories based on what he calls habitat preference, in fact preference for forest that has been subject to different levels of disturbance: i) bird species preferring primary forest (undisturbed), ii) secondary forest (disturbed), iii) bird species without such preference, and iv) with unknown preference. Compared to Procter's Forest, Akintosoela1 had about twice the number of captures and species

of birds that prefer secondary forest, but only about half the number of captures and species of birds that prefer primary forest. De Jong (1982) also analyzed his data by categorizing the bird species in groups based on food preference, but this did not reveal any striking differences between the two forest stands.

Table 7.1. Summary of the results of ornithological research by De Jong (1982) at Akintosoela, Suriname.

Forest stand	total	preferring primary forest	no preference	preferring secondary forest	preference unknown
<i>number of bird captures</i>					
Procter's Forest	185	28	108	26	1
Akintosoela1	180	9	95	54	1
<i>number of bird species captured</i>					
Procter's Forest	49	13	27	8	1
Akintosoela1	55	7	27	20	1

De Jong's (1982) results are in line with the expectation that increased forest disturbance due to refinement results in a bird fauna with fewer species that are typical of undisturbed forest and more species that are typical of disturbed forest. More importantly, the results suggest that this increased disturbance effect persists for at least five years. It should be noted that the refinement at Akintosoela¹ had been quite intense compared to some of the refinements that were applied later in the Kabo area.

7.3.2 Impact on invertebrates / arthropods

In 2000-2001 a series of parallel studies on the ecological impact of the CMS were undertaken in the Kabo area (NZCS and BBS 2001), including studies on arthropods (De Dijn 2001a). Sampling and data recording took place at 1 ha plots that were part of the MAIN Experiment forest stand, and at a 1 ha plot that was part of the Van Leeuwen Transect stand (De Dijn 2001c). The Van Leeuwen Transect stand and part of the MAIN Experiment stand had remained undisturbed till the research took place; other parts of the MAIN Experiment stand had been both logged (in 1978) and refined (in 1982-83), or had been logged only. The aim of the arthropod studies was to investigate the impact of forest disturbance by logging and refinement on the abundance and species richness of a variety of arthropod groups. Sampling took place in the following 1 ha plots¹:

- three plots in the MAIN Experiment stand that had been both logged (ca. 30 m³.ha⁻¹) and refined (non-timber trees with dbh > 30 cm poison-girdled), with the original treatment code E23-SR18 (Jonkers 1987; original plot numbers 15, 17 and 36);
- three plots in the MAIN Experiment stand that had been logged only (ca. 30 m³.ha⁻¹), with the original treatment code E23-S0 (plot numbers 14, 26 and 38); and
- two undisturbed control plots, one in the MAIN Experiment stand (original "virgin forest plot" number 41), and one in the Van Leeuwen Transect stand (plot established in 2000, and assigned number 51).

The main study targeted terrestrial arthropods that walk and fly near the soil surface, and can be captured in a standardized manner by means of pitfalls and yellow pots placed at ground level (De Dijn 2001a). Arthropods were sampled in August 2000 by means of these traps (nine traps of each type per plot). Trap contents were conserved, and in the lab the arthropods were sorted out and identified at group level (a total of 31 966 arthropod individuals were collected by means of pitfalls and 10371 by means of yellow pots). The main groups were: Scolytidae (bark beetles), other Coleoptera (beetles), Phoridae (phorid flies), other Diptera (flies, mosquitos, etc.), Formicidae (ants), other Hymenoptera (wasps, bees, etc.), Collembola (springtails), Orthoptera (grasshoppers, roaches, etc.), and Araneae (spiders). The bulk of the individuals collected belonged to these groups, and only these data were used for further analysis. Per individual trap and

¹ these same plots were used for the parallel studies on forest habitat structure (De Dijn 2001b), tree diversity (Raghoenandan 2001), and amphibians and reptiles (see below).

group, the number of (adult) individuals and species trapped (in fact morphospecies²) was counted. These counts served as the basic abundance (A) and species richness (R) data for analysis by means of ANOVA³. Two types of ANOVAs were run to deal with an imbalance in the design of Jonkers' (1987) experiment⁴:

- "Full ANOVAs" using data on all treatments, with treatment as fixed factor (three levels: S = silviculturally treated (refined) and logged, L = logged only, and C = control (undisturbed)), and replicate block as random factor (2 blocks only: n°. 1 & 3); and
- "Partial ANOVAs" using only the data on S and L treatments, with treatment as fixed factor (2 levels: S and L), and replicate block as random factor (3 blocks: n°. 1, 2 & 3).

A meta-analysis of the significance of the many ANOVA results is done here: the actual number of significant results per series of ANOVAs is compared with the number of significant results expected based on chance⁵.

An overview of the results of these ANOVAs and of the meta-test results is provided in Table 7.2. The results regarding the fixed factor of the Full ANOVAs (see Table 7.2.a and c) show that there is no evidence of significant, consistent differences in the abundance and species richness of arthropod groups between forest that had been both silviculturally treated (refined) and logged, forest that had been logged only, and undisturbed forest. The results regarding the interaction between fixed and random factors do suggest that there was one significant, but inconsistent difference (as to Orthoptera abundance; cf. Table 7.2.c). However, the meta-test results suggest that this ANOVA test result is likely due to chance.

2 supposed species, differentiated on the basis of differences in shape, size, colour and texture of external body parts; morphospecies (a.k.a. operation taxonomic units; OTU) is a species concept typically used in ecological studies when species-rich groups are studied whose taxonomy is imperfectly known, or when limited expertise is available to identify the species.

3 in principle, the independent ANOVAs based on abundance (A) data in relation to the different groups was one series of tests, and the same based on species richness (R) data was another series; in practice, there were four series of ANOVAs because two types of traps were used, each resulting in A and R data for the different arthropod groups; an individual ANOVA was only performed if the dataset to be entered in the ANOVA passed a Kolmogorov-Smirnov (KS) test of normality.

4 Jonkers' MAIN Experiment incorporated a threefold replication (three replicate blocks), and included three (undisturbed) control plots (numbers 41, 42, 43); however, the location of all these control plots next to one of the blocks, and next to one another, made them pseudo-replicates; one additional control plot was added a posteriori in the form of plot 51, but a third one could not be established due to the widespread disturbance of the Kabo area.

5 based on binomial probabilities [$p = 0.05$; $q = 0.95$] for series of ANOVA test results obtained at significance level $p = 0.05$, and binomial probabilities [$p = 0.01$; $q = 0.99$] for results obtained at $p = 0.01$; cf. Sokal & Rohlf (1995: p. 686-7).

Table 7.2. Overview of the results of series of ANOVAs to determine if logging and refinement in the Kabo area (Suriname) had a significant impact on the abundance (A) and species richness (R) of a range of arthropod groups, based on samples taken by means of pitfall and yellow pot traps (De Dijn 2001a); including meta-test results (based on binomial probabilities) to assess if the number of significant test results per series of ANOVAs is significant.

A and R data was tested for normality using Kolmogorov-Smirnov tests. ANOVAs were only performed for those groups whose data passed this test (i.e. groups listed in the “arthropod groups” row). In case of significant differences in A or R (between treatment levels or replicate blocks), level of significance (p) is indicated with * (p = 0.05) or ** (p = 0.01); the nature of significant differences is indicated with < or > signs; the ~ sign is used to indicate differences that are not significant.

a. Full ANOVAs based on pitfall trap data, with treatment as fixed factor (S = silviculturally treated (refined) and logged, L = logged only, and C = control (undisturbed)), and replicate block as random factor (blocks no. 1 & 3).

	abundance (A)		species richness (R)	
arthropod groups	10: Scolytidae, other Coleoptera, Phoridae, other Diptera, Hemiptera, Formicidae, other Hymenoptera, Orthoptera, Collembola, Araneae		7: Scolytidae, other Coleoptera, Phoridae, other Diptera, Hemiptera, Formicidae, other Hymenoptera	
	groups for which differences in A or R were significant, based on ANOVA test results			
fixed factor	(none significant)		(none significant)	
random factor	(none significant)		(none significant)	
interaction	Orthoptera* C~S>L at 1; C~S<L at 3		(none significant)	
	probability that the observed number of significant ANOVA test results is due to chance			
	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)
fixed factor	0.60	0.90	0.60	0.90
random factor	0.60	0.90	0.60	0.90
interaction	0.40	0.90	0.40	0.90

b. Partial ANOVAs based on pitfall trap data, with treatment as fixed factor (S and L), and replicate block as random factor (blocks no. 1, 2 & 3).

	abundance (A)		species richness (R)	
arthropod groups	10: same as in a. (see above)		7: same as in a. (see above)	
	groups for which differences in A or R were significant, based on ANOVA test results			
fixed factor	(none significant)		(none significant)	
random factor	Scolytidae* 1>2~3		other Hymenoptera* 1~2>3	
interaction	Phoridae* L~S at 1 and 2; L>S at 3 Collembola* L~S at 2 and 3; L>S at 2		(none significant)	
	probability that the observed number of significant ANOVA test results is due to chance			
	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)
fixed factor	0.60	0.90	0.60	0.90
random factor	0.40	0.90	0.40	0.90
interaction	0.09	0.90	0.60	0.90

c. Full ANOVAs based on yellow pot trap data, with treatment as fixed factor (S, L and C), and replicate block as random factor (blocks no. 1 & 3).

	abundance (A)	species richness (R)		
arthropod groups	6: Scolytidae, other Coleoptera, Phoridae, other Diptera, other Hymenoptera, Collembola	5: Scolytidae, other Coleoptera, Phoridae, other Diptera, other Hymenoptera		
groups for which differences in A or R were significant, based on ANOVA test results				
fixed factor	(none significant)	(none significant)		
random factor	Scolytidae* 1>3 other Diptera** 1>3	Phoridae* 1>3 other Diptera* 1>3 other Hymenoptera* 1>3		
interaction	Orthoptera* C~S>L at 1; C~S<L at 3	(none significant)		
probability that the observed number of significant ANOVA test results is due to chance				
	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)
fixed factor	0.73	0.94	0.77	0.95
random factor	0.03	0.06	0.01	0.95
interaction	0.26	0.94	0.94	0.95

d. Partial ANOVAs based on yellow pot trap data, with treatment as fixed factor (S and L), and replicate block as random factor (blocks no. 1, 2 & 3).

	abundance (A)	species richness (R)		
arthropod groups	6: same as in c. (see above)	7: same as in c. (see above)		
groups for which differences in A or R were significant, based on ANOVA test results				
fixed factor	(none significant)	Phoridae** L<S		
random factor	other Diptera** 1~2>3	Phoridae** 1~2>3		
interaction	Scolytidae* L~S at 1; L<S at 2; and L>S at 3 Collembola* L~S at 1 and 2; L>S at 3	(none significant)		
probability that the observed number of significant ANOVA test results is due to chance				
	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)	ANOVA p = 0.05 (*)	ANOVA p = 0.01 (**)
fixed factor	0.73	0.94	0.77	0.05
random factor	0.26	0.06	0.77	0.05
interaction	0.03	0.94	0.94	0.95

The results of the Partial ANOVAs (Table 7.2.b and d) do point at a significant, consistent difference in Phoridae species richness (based on sampling by means of yellow pot traps) between forest that had been both refined and logged, and forest that had been logged only. This ANOVA result is not likely due to mere chance (see meta-test result in Table 7.2.d), and it would thus seem that there were indeed more Phoridae species in forest that was both refined and logged than in forest that was logged only. There was also evidence of significant, but inconsistent differences (e.g. not significant in all replicate blocks), such as in the abundance of Scolytidae and Collembola that were sampled with yellow pot traps.

The results regarding the random factor in the ANOVAs (especially those based on samples obtained with yellow pot traps; Table 7.2.c and d) are evidence that there were significant, consistent differences in the abundance and species richness of a number of arthropod groups between the replicate blocks.

Summarizing, the ANOVAs and meta-tests provided no evidence of consistent differences in arthropod abundance or species richness between the undisturbed control plots and the disturbed plots, and little evidence of such differences between forest disturbed due to both refining and logging, and forest disturbed due to logging only. The differences that were observed were mostly inconsistent, co-dependent on a 'random' factor. We assume that this random factor is linked to abiotic and biotic (e.g. vegetation) characteristics that vary independently of disturbance due to logging and refinement. A straightforward explanation for the limited detection of effects of logging and refinement on the arthropod fauna at Kabo may be the modest intensity of the experimental disturbance, and the 20 years of time between this disturbance and the fauna studies, time that in all likelihood has allowed the forest and its arthropod fauna to recover.

As part of the arthropod studies, butterflies were also studied at Kabo, using a sampling protocol that involved the sighting and capturing of butterflies that were active in the forest understorey. Butterflies were captured along trails in the plots with sweep nets; this took place around noon when butterfly activity peaked. A first round of observations and sampling took place in September 2000, and a second (replicate) round in October 2000. Butterflies were assigned to morphospecies, and to the extent possible were identified with their scientific species names. Virtually all belonged to the families Nymphalidae, Pieridae, Hesperidae, and Lycaenidae; only the data on species belonging to these families was used for further analysis (66 specimens belonging to 29 species collected in September, 120 specimens belonging to 57 species in October 2000).

Using the Jaccard and Sørensen similarity indices (see Krebs 1989), butterfly fauna comparisons were made between the differently treated plots (both refined and logged, logged only, and undisturbed) within each replicate block. The results of these comparisons (Table 7.3) do not provide overwhelming evidence of consistent differences in butterfly fauna between patches of forest that had been treated differently. Nevertheless, based on the more qualitative Jaccard index, one could cautiously conclude that the butterfly fauna of forest at Kabo that had been both logged and refined, differed more from that of undisturbed forest than it differed from that of forest that had been logged only. Caution with the interpretation of these results is warranted, since the size of the butterfly samples was modest.

Table 7.3. Comparison of butterfly fauna samples obtained in the Kabo area (Suriname) in forest plots that differed in terms of treatment (S = silviculturally treated (refined) and logged, L = logged only, and C = control (undisturbed)), using the Jaccard (S_j) and Sørensen (S_s) similarity indices (De Dijn 2001a).

	pairs of plots compared	September 2000 sampling		October 2000 sampling	
		S_j	S_s	S_j	S_s
replicate block 1	C and L	0.15	0.18	0.06	0.07
	C and S	0.11	0.13	0.08	0.08
	L and S	0.13	0.40	0.25	0.40
replicate block 3	C and L	0.00	0.00	0.15	0.23
	C and S	0.00	0.00	0.04	0.13
	L and S	0.38	0.50	0.06	0.06
replicate block 2	L and S	0.25	0.38	0.14	0.18

7.3.3 Impact on amphibians and reptiles

Parallel to the arthropod studies, a study of amphibians (Amphibia) and reptiles (Reptilia) was also undertaken at Kabo (Ouboter & Sahdew 2001). The amphibians and reptiles targeted were those that could be sighted and sampled in the understorey. Observations and the collecting of voucher specimens took place during both day and night, in both the wet season (August 2009) and the dry season (October 2009). Amphibians and reptiles encountered were identified in the field with their scientific names; identities were checked in the lab based on voucher specimens. A total of 63 Amphibia and Reptilia individuals, belonging to 26 species, were observed during the rainy season, and 75 individuals, belonging to 19 species, during more extensive sampling in the dry season (Table 7.4). Observations took place in most of the plots mentioned earlier (see 7.3.2), as well as outside these plots, along roads and trails leading to them. Both wet and dry season observations were realized only at plots 41 (control; undisturbed), 14 (logged only), and 15 (both logged and refined).

Table 7.4. Results of observations of amphibians (A) and reptiles (R) in the Kabo area (Suriname) in forest plots that differed in terms of treatment (S = silviculturally treated (refined) and logged, L = logged only, and C = control (undisturbed)), and outside these plots (O).

	wet season (August 2009)				dry season (October 2009)							
	O	C plot 41	L plot 14	S plot 15	O	C plot 41	L plot 14	S plot 15	C plot 51	L plot 38	S plot 36	
	number of individuals observed											
Amphibia (A)	18	5	2	1	10	2	8	3	4	1	7	
Reptilia (R)	18	8	5	6	10	9	3	7	6	3	3	
A & R combined	36	13	7	7	20	11	11	10	10	4	10	
	number of species observed											
Amphibia (A)	9	4	2	1	6	2	5	3	2	1	4	
Reptilia (R)	9	8	4	2	8	5	2	4	4	1	2	
A & R combined	18	12	6	3	14	7	7	7	6	2	6	

The main aim of the analysis of the Amphibia and Reptilia data was to assess if there were significant differences in species richness between differently treated patches of forest. The analysis was problematic, however, due to the low numbers of individuals observed in the field. Nevertheless, using a G test of independence (Sokal & Rohlf 1995), a significant difference ($p = 0.05$ level) in combined Amphibia + Reptilia species richness was observed, based on data obtained in the wet seasons at plots 41, 14 and 15: the undisturbed plot had more species than the plot that had been logged only, and this one had more species than the one that had been both logged and refined. A note of caution is again warranted because of the small sample size, and because data from the dry season and from other plots does not confirm this.

Based on their observations, Ouboter & Shadew (2001) also pointed out that:

- six of the species (1 amphibian, 6 reptiles) that were recorded in undisturbed plots (C), were not recorded in any of the disturbed plots (L and S); this includes the Collared Tree Lizard *Plica plica* and the Amazon Gecko *Coleodactylus amazonicus*, which they considered species that prefer undisturbed forest; and
- the plots that were both logged and refined were particularly poor in species, and not a single species was unique to these plots.

Ouboter & Sahdew (2001) concluded that there likely has been a local decrease in species richness of amphibians and reptiles at Kabo (particularly of species typical of undisturbed forest) as a result of logging and refining. They observe that in general the Amphibia and Reptilia fauna at Kabo is poor in species, and consists mostly of species that are adaptable opportunists. Given these characteristics of this fauna, they considered it likely that it can withstand the kind of disturbance caused by logging and refinement.

A very recent study by Landburg et al. (in prep.) investigated the possible recovery of the amphibian community in the Kabo area, 30 years after the CMS experiment had taken place there. Heavily logged plots ($46 \text{ m}^3 \cdot \text{ha}^{-1}$) and control plots (virgin forest) that were part of Jonkers' (1987) MAIN experiment were studied in 2010, both in terms of forest habitat and amphibian community. It is impossible to assess the actual recovery of the amphibian community of the logged plots due to a lack of data on that community from before the CMS experiment took place in the 1980s. Nevertheless, based on general habitat characteristics, and the data from the control plots, a baseline can be developed of the composition of the amphibian community that must have occurred there. The preliminary conclusions of this study are that 30 years after logging: i) the habitat structure between the two types of plots differed, but ii) amphibian diversity did not differ significantly.



Photo 7.3. *Ameerega trivittata* - Three-striped poison frog.
(Photo P. Ouboter)

7.4. Impact of the CMS on the fauna in the light of results of studies elsewhere in the region

7.4.1 Impact on birds

In a recent review on the impact of forestry on tropical birds De longh & Van Weerd (2006) concluded that overall bird abundance and species richness may decrease, increase or stay the same as a result of logging. Whether or not an overall effect is observed seems to depend very much on the context, such as 'time since logging' (the time between logging and the study of the fauna). Specific functional groups of bird, such as certain feeding guilds, seem to respond consistently to disturbance due to logging. One guild, the insectivores, always seems to be negatively affected by logging, at least in terms of abundance and species richness. The explanation thereof may lie



Photo 7.4. *Trogon viridis* - Amazonian White-tailed Trogon.
(Photo P. Ouboter)

in a logging-induced decrease in the habitat that is most preferred by many insectivorous birds for foraging, namely continuous forest with an open understory and closed canopy. Nectarivores and frugivores, on the other hand, were often found to increase in abundance after logging, presumably because forest disturbance favours lianas and herbs, many of which produce abundant food for birds, mainly nectar and berries. These conclusions by De longh & Van Weerd (2006) are in agreement with, and in part based on, results of studies in French Guiana⁶ (Thiollay 1992, 1999).

Near Manaus (Central Amazonia), Guilherme & Cintra (2001) found that edge and gap-specialist insectivores and nectarivores benefited from selective logging, but only at locations where logging had taken place recently (significant effects recorded in plots logged four years before the bird study, but not in plots logged ten years before). At these locations, the intensity of logging (13 to 25 m³ timber .ha⁻¹ felled) did not appear to modify the impact on birds, nor did silvicultural

treatments (frill-girdling). At the lower Rio Tapajos, in Eastern Amazonia, forest plots subject to Reduced Impact Logging (RIL; 18.7 m³ timber .ha⁻¹ felled) were studied about 1.5 years after logging (Wunderle et al. 2006). Here, in the logged forest plots, higher numbers of insectivorous, nectarivorous, and frugivorous birds were recorded than in the unlogged control plots. At three locations near Belém do Para (Eastern Amazonia), selective logging (RIL; 19 m³.ha⁻¹ felled) was observed to lead to a distinct increase in bird species richness some 0.5 years after the logging took place (Azevedo-Ramos et al. 2006).

6 Observation took place in plots where ca. 10 m³ timber .ha⁻¹ was felled 1 or 10 years before the fauna study.

The following general conclusions may be drawn based on the results of these studies:

- there typically is a positive impact of selective logging and silvicultural treatments on certain bird guilds, especially nectarivores and frugivores, at least during the first years after logging; and
- there typically are longer-term negative impacts on the insectivorous bird guild.

The results of the CMS-related bird study in the Mapane area (see section 7.3.1) are in line with the Central Amazonian study of Guilherme & Cintra (2001), in the sense that the bird faunas of selectively logged plots and plots that had both been logged and silviculturally treated were quite similar. Since no undisturbed forest was studied in the Mapane area, it is not possible to say if the general conclusions formulated above are also valid in relation to the CMS.

7.4.2 *Impact on invertebrates / arthropods*

Azevedo-Ramos et al. (2004) present few general conclusions in relation to invertebrates (mostly arthropods), which is hardly surprising, given that the invertebrates are not a single, coherent group of animals, but a multitude of very different taxonomic groups (taxa) with equally different responses to disturbance, as e.g. demonstrated by Lawton et al. (1998). Even within a seemingly homogenous group such as ants, responses are not uniform (see review in Azevedo-Ramos et al. 2004). In the Kabo area (see section 7.3.2.), a heterogeneous set of invertebrate taxa was investigated, which should have increased the chances to detect changes. However, the low taxonomic resolution of the Kabo study (mostly Order level) may have obscured changes, assuming that many of those changes occurred at lower taxonomic levels, and are hard to detect at higher levels because they are likely to cancel one another out.

A number of studies from the Neotropics compared the butterfly fauna of disturbed and undisturbed forest areas. In Belize, Lewis (2001) hardly detected any differences between butterfly faunas of logged and undisturbed locations, while Lawton et al. (1998) found, in Trinidad, that disturbed forest had much more butterflies (both higher total abundance and more species). The result would, however, seem dependent on the methods applied, as evident from the latter study, where sampling based on passive trapping (using fruit baits) did not lead to the detection of differences, while sampling based on active spotting and sampling of butterflies did. In Lewis' study only a passive trapping method was used⁷. This is more than a methodological issue, though, as the fruit-trapping method targets the fruit-feeding butterfly guild only, while the active spotting methods detects a wider range of species belonging to a variety of functional groups or guilds (Wood & Gillman 1998). The impact of disturbance would thus seem to differ between guilds, and analyses would need to be done at the guild level, or better still at the species level.

Similar to the Trinidad butterfly study (Wood & Gillman 1998), recording of butterflies along trails at Kabo proved to be useful, and the results led to the same general conclusion: that the most disturbed plots (at Kabo: logged and refined) have the most divergent fauna.

⁷ Lewis (2001) argued that baseline levels of disturbance are high in Belize (where tropical hurricanes are common) and may explain the result of his study (no faunal differences between locations with different levels of anthropogenic forest disturbance).

7.4.3 Impact on amphibians and reptiles

Reviewing the literature on forest amphibians and reptiles, Azevedo-Ramos et al. (2004) concluded that on the one hand forest-interior species tend to be adversely impacted by logging disturbance, while on the other hand generalist frogs and lizards preferring sunny habitats benefit from such disturbance.

Recent detailed studies on the impact of selective logging on forest amphibians were undertaken in Guyana by Ernst, Rodel and collaborators (Ernst et al. 2006, 2007; Ernst & Rodel 2008). Their studies took place in undisturbed and heavily logged forest stands (57 m³ timber .ha⁻¹ felled) in the Mabura Hill area, an area that is comparable to the areas in Suriname where the CMS has been applied. Some key results of these studies are:

- selectively logged forest stands had an amphibian fauna similar to that of undisturbed forest stands, but with fewer species (impoverished);
- while the impact of logging on overall Amphibian species diversity was not clear, the negative impact of logging on functional diversity (number of functional groups or guilds) was very clear;
- the negative impact on Amphibian diversity was more obvious in more recently logged forest (10 vs. 15 years after logging); and
- within the same narrow guild of terrestrial *Leptodactylus* frogs that make foam nests, the impact of logging differed between species that differ in the selection of their breeding habitat.

These results of these studies fit into what may be a general (pantropical) pattern, namely that forest disturbance leads to a change in the composition of the soil surface and litter inhabiting amphibian communities, in the sense that these communities impoverish (lose species) and lose functional diversity (guilds).

The relatively low amphibian and reptile species richness that was observed some 20 years after logging and refinement in the Kabo area (Ouboter & Shadew 2001) is in agreement with this. Preliminary results of a more recent study at Kabo suggest that the amphibian fauna has largely recovered 30 years after logging (Landburg et al. in prep.).

7.5 Final remarks and conclusions

An issue with the above mentioned CMS-related studies in Suriname is the absence of baseline data, i.e. data on the fauna that was present before treatments were implemented. This would not have been a major issue if enough zero-treatment control plots were available for study, but this was not the case either. Lessons should be learnt from this when follow-up research is planned, and when monitoring protocols are developed for 'green' certification.

It also should be noted that even the best data collected so far on the CMS and its impact, is based on the application of one or two timber harvests, followed by a single experimental refinement. The results of the CMS-related fauna studies in Suriname suggest that the impact of the CMS is mild. However, what will happen to the fauna after more than one round of logging and refinement? This question is relevant since

each round of logging and refinement adds changes to the structure and composition of the forest (cf. de Graaf 1986).

An important lesson learnt from logging impact studies in the region is that the impact on the fauna has to be studied at the 'correct' taxonomic and functional or guild level. As regards birds and butterflies, based on the results of several studies mentioned earlier, it is appropriate to study effects at the level of feeding guilds. The studies on amphibians in Guyana (Ernst et al. 2006, 2007; Ernst & Rodel 2008) confirmed the importance of guilds for logging impact studies, although in the case of amphibians, they may need to be defined as breeding guilds.

Although a final conclusion on the impact of the CMS on the fauna cannot be drawn yet, the studies on the impact of the CMS in Suriname and of similar forestry activities in the region do suggest the following:

- negative impact on insectivorous birds, and positive on nectarivores and frugivores;
- reduction of the number of species and guilds of soil surface and litter dwelling amphibians, likely also of amphibians and reptiles in general;
- significant changes in the butterfly fauna, but methodological issues obscure the results of studies implemented to date; this is also true for other arthropod studies, which are faced with the magnitude, heterogeneity and limited knowledge of the ecology of the taxa;
- the difference in impact on the fauna between logging only (traditional forestry; RIL), and logging and refinement (which is what defines the CMS) is not very obvious, although there are indications that the refinements do have a greater impact;
- the impact on the fauna persists up to 10-20 years after the initial disturbance (logging, refinement), but impact is often greatest in the first years after disturbance; and
- the impact is not necessarily consistent, but may depend strongly on the context, i.e. the local conditions at particular forest stands which do not fundamentally change as a result of logging or refinement, such as topography, soil, hydrology, etc.



Photo 7.5. Heliconius butterfly. (Photo B. De Dijn)

A final remark on hunting and the collecting of animals is also appropriate here, although not directly related to CMS-related studies that have been implemented to date. In areas where the CMS is carried out, the forest will likely become more accessible for hunters and animal collectors. Birds and mammals with a body weight of more than one kilogram typically suffer most from any type of forest disturbance that is associated with open access for hunters and collectors (see Thiollay 1999; Meijaard et al. 2005). As these animals are important as seed dispersers, hunting and animal collecting is a potential threat to sustainable forestry.

Furthermore, a number of threatened and rare animal species are being used as bushmeat, also in Suriname⁸; other species are collected, kept alive and traded as pets⁹ (Van Andel et al. 2003). To avoid the extinction of threatened species, and to sustain the fauna that disperses timber tree seeds, it would make sense to enforce an animal hunting and collecting prohibition in forestry concessions, or at least to tightly regulate and supervise such activities in the concessions.

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8 these include the Lowland Tapir, *Tapirus terrestris*, the Guiana Spider Monkey, *Ateles paniscus*, and the Giant Armadillo, *Priodontes maximus*, which are listed on CITES Appendix 1, and are listed as vulnerable (VU) by IUCN.

9 such as all species of Macaw (genus *Ara*), and several species of monkey, such as the Brown Capuchin, *Cebus apella*; these are all listed on CITES Appendix 2.

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