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The long term effect of forest logging on the macroinvertebrates in a Fijian stream

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Abstract

The species richness and abundance of macroinvertebrates were assessed in two adjacent similar streams, the Nabukavesi and Wainikovu creeks (Viti Levu, Fiji) at intervals of 2 months for 3 years. Previous logging of rain forest in the Nabukavesi catchment had subjected it to suspended sediment loads and to sediment and grit deposition on its substrate, In contrast the forest in the Wainikovu catchment had not been logged. Species richness was significantly higher (11–18 species; total 38 spp.) in the unlogged Wainikovu Creek than in the Nabukavesi Creek (eight to 15 species; total 34 spp.) over the 3-year period. Diversity indices confirmed greater species diversity in the Wainikovu creek. The total abundance of invertebrates varied considerably within streams, but not significantly between them over 3 years. The most abundant species in both streams were the caddis fly, *Abacaria fijiana*, mayflies, *Cloeon* spp. and *Pseudocloeon* sp. and atyid shrimps, *Caridina* spp.

Introduction

Many stream ecosystems in tropical Asia have undergone modification, degradation and loss of species due to human activities (Dudgeon, 1994). Asian rivers have been modified by human activities such as deforestation and overgrazing, which cause increased suspended-sediment loads and extensive flooding. Dam building, irrigation schemes and pollution from industrial effluent, mining waste and sewage have also had devastating effects (Dudgeon, 1994; Trihadiningrum et al., 1996)

With increasing development and industrialisation in tropical islands their stream and river ecosystems are also threatened. Deforestation is occurring on the larger islands in Fiji and its long-term effects on the fauna of streams and rivers is important especially to inland Fijians who depend on freshwater fish, shrimps, crabs and snails for food. To study the long-term effects of logging operations two nearby streams were monitored for 3 years at 2-monthly intervals. Eighteen months previously, the Nabukavesi creek had been subjected to suspended-sediment loads and sediment deposit from the logging of rain forest in its catchment. The other stream, Wainikovu creek was of similar size but the forest in its catchment had not been logged (Figure 1).

Study area

The study area was on Viti Levu, the largest of the 300 islands in the Fiji group (Figure 1) in the South Pacific. The Fijian freshwater invertebrate fauna has taxa (crustaceans and most gastropods) whose ancestors originated in South East Asia and others (most insects) that are more closely related to Australasian forms.

Nabukavesi creek flows directly into the sea 13 km downstream from the site, while the Wainikovu creek flows into the Navua river before reaching the sea. However, the sites in the two streams were only 7 km apart and were at similar altitude of 90–120 m. The streams were approximately 10 m wide at normal water flow. Both were second order streams or, according to the classification in Resh & de Szalay (1995),

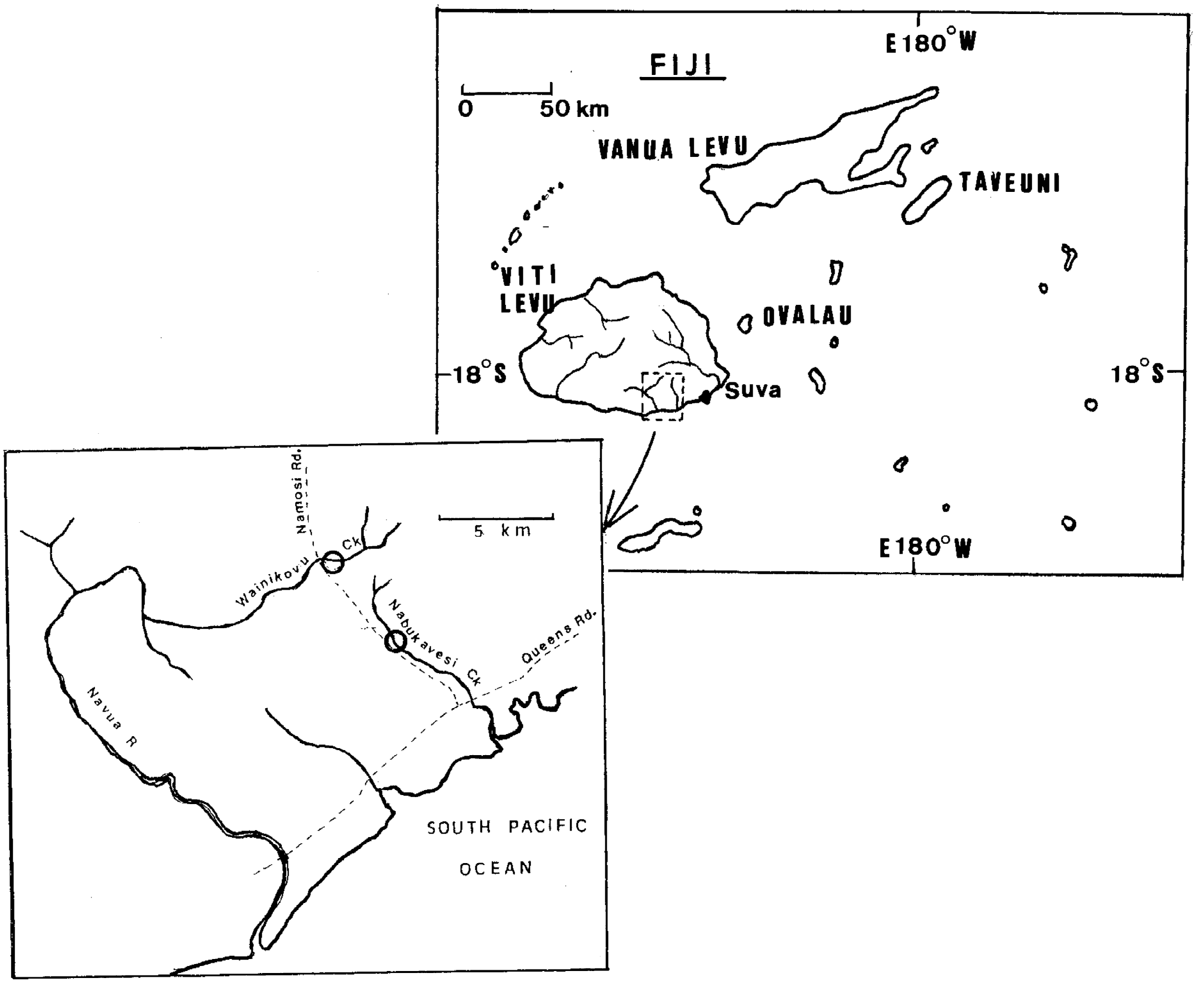

Figure 1. Map of the larger Fiji Islands and an enlargement of the sampling sites in the Nabukavesi and Wainikovu creeks in south eastern Viti Levu.

tropical island midwater reaches, although neither stream was shaded as were the midwater reaches of the streams in Moorea, French Polynesia and Hawaii (Resh & de Szalay, 1995). Grassy areas with low shrubs bordered the streams for 10 m on each side. These gave way to steep forested hillsides. Filamentous green algae grew on the cobbles but macrophytes were absent from both streams. Roots and leaves of grass, reeds and ferns hung down into the water and provided a habitat for invertebrates.

Previous to this study, the Nabukavesi creek had been sampled in April 1987 when 15 invertebrate taxa were found and again in April 1988 when 14 taxa were present. These were *Cloeon* sp. A, *Pseudocloen* sp., *Nesobasis* sp. A, sp. B, and sp. E, *Hydrobiosis* sp., *Anisocentropus* sp., *Nymphula* sp. A, *Abacaria fijiana*, *Tipula* sp., *Macrobrachium lar*, *Caridina longirostris*, *C. nilotica*, *Alyopsis spinipes*, *Varuna litterata*, *Fluviopupa pupoidea*, *Melanoides tuberculata*, *M. lutosa* and a species of planarian worm. Total abundance was 201 in 1987 and 176 in 1988.

During 1989–90 when 70% of the accessible forest was cut down 1.5 km upstream from the sampling site in the Nabukavesi valley, the stream was discoloured and the cobble and boulder bottom was covered with a 1–80 mm layer of mud and grit. Samples taken at that time from the same site revealed only five invertebrate taxa: net-building caddis fly larvae (*Abacaria fijiana*), mayfly nymphs (*Cloeon* sp. A and *Pseudocloeon* sp.), moth larvae (*Nymphula*) and the atyid shrimp *Caridina longirostris* (Haynes, 1994).

Table 1. The mean of the physical (15 samples) and chemical conditions (3 samples) of the water in the Nabukavesi and Wainikovu creeks March 1992–May 1995

	Nabukavesi creek			Wainikovu creek		
	Mean	S.D.	Range	Mean	S.D.	Range
Conductivity (μS/cm.)	47.4	3.14	45.1–51	44.7	2.27	43–47
Hardness (mg $CaCO_3$/l)	20.1	4.10	16.0–24.2	19.5	1.00	18–21
Phosphate (μg PO_4/l)	43.8	5.77	39.0–49.4	87.6	20.75	65–105.8
Current velocity (cm s^{-1})	52.3	9.45	38.0–66	51.1	10.53	38–76
Depth (cm)	20.6	3.78	16.0–29	21.6	5.0	17–27.5
Temperature (°C)	23.8	1.38	21.5–26.5	23.0	1.57	20–26
Discharge (m^3 s^{-1})	1.1	0.42	0.6–2.3	1.1	0.45	0.7–2.0
pH	7.4	0.56	6.9–8.3	7.2	0.64	6.1 - 8.0

The region of Viti Levu where the two streams are located is in the path of the south east tradewinds and are in the rain shadow of the hills (Figure 1). The cyclone season is from November–March when the air temperature is higher generally 28 –35 °C.

Materials and methods

Secondary growth covered the logged Nabukavesi hillsides when sampling began (a year and a half after logging stopped) on March 1992 and continued until May 1995. Each site in the Nabukavesi and Wainikovu creeks were sampled 15 times at approximately 2-monthly intervals.

At each sampling site the invertebrates clinging to 15 large stones and boulders (120–300 mm across) wore collected along a 10-m stretch of riffle and runs at each sampling. As only macroinvertebrates were being investigated, a square net of 1–mm mesh was held downstream while each boulder was sampled. The boulder was moved into the net and the contents of the net and the invertebrates and detritus adhering to the boulder were washed into a plastic bag and taken to the laboratory for identification and counting. Fifteen stones had previously been found to give a satisfactory index of precision (D) of 13% (Elliott, 1977).

Six net (1-mm mesh) sweeps of the side vegetation were taken along the 10-m stretch and the invertebrates were similarly identified and counted.

Identification of most taxa was possible to genus level because the invertebrate fauna of Fijian streams has received growing research attention. The atyid shrimps were investigated by Choy (1991), the gastropods by Haynes (1984, 1985, 1987), while Cowie (1981) made a survey of aquatic insect larvae. However, many aquatic young stages still cannot be matched with the adults. Adult Trichoptera were described by Mosely (1941), while Ross (1953) discussed the trichopteran genus *Apsilochorema*. Tillyard (1924) described an adult collection of dragonflies from Viti Levu.

Water temperature, depth, and pH were measured by a Hanna electronic water test meter and the velocity with a current stick on each sampling occasion. Discharge was calculated from these results. Water samples were collected from each stream on three occasions during 1993 and the samples were analysed for phosphates and hardness by the Institute of Applied Sciences, University of the South Pacific using standard methods (APHA, 1989).

Results

The water was normally clear and the chemistry was similar in both streams except for the higher amount of phosphate in the Wainikovu creek (Table 1).

Temperature, pH, depth, water velocity and discharge (Table 1) fluctuate according to the amount of rainfall during the 24 h prior to sampling. Mann–Whitney U-tests confirmed that there was no significant difference between the values in each stream.

The substrate of both streams was stable except during very heavy rainfall when some cobbles and boulders shifted. However, it is worth recording that cyclone Kina, which struck Viti Levu on 1 January 1994 and which caused extensive flooding of the Navua river over low-lying land, did not effect the invertebrate richness or abundance in either creek when

Table 2. Mean abundance and standard deviation of the taxa found when sampling the Nabukavesi and Wainikovu creeks 15 times between March 1992 and May 1995

	Nabukavesi creek				Wainikovu creek			
	Stones		Plants		Stones		Plants	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
TURBELLARIA								
Planarian sp.	0	0	0	0	0	0	0.13	0.35
GASTROPODA								
Clithon diadema	0.07	0.26	0	0	0	0	0	0
Physastra nasuta	0	0	0.2	0.77	0	0	0	0
Fluviopupa pupoidea	0.07	0.26	0	0	0.53	1.13	0.2	0.56
Melanoides lutosa	0.07	0.26	0.13	0.35	0.13	0.35	0	0
Melanoides tuberculata	0.27	0.59	3.6	0.37	0.6	0.74	1.13	2.2
CRUSTACEA								
Ostrocoda sp.	0.07	1.26	0	0	0.13	0.52	0	0
Varuna litterata	0.13	0.52	0	0	0	0	0	0
Caridina nilotica	0	0	0.53	1.36	0	0	5.2	14.39
Caridina longirostris	1.93	6.15	1.33	1.40	0.6	1.24	11.73	10.75
Alyopsis spinipes	0	0	0	0	0	0	0.27	0.59
Atyoida pilipes	0	0	0.40	0.91	0	0	1.13	2.03
Macrobrachium lar	0	0	0.20	0.41	0	0	0.27	0.59
ARACHNIDA								
Hydrachnellidae sp.	0.27	0.59	0	0	0.47	1.30	0.07	0.26
HEMIPTERA								
Limnogynous sp.	0	0	0	0	0	0	0.27	1.03
Anisops sp.	0.33	0.90	4.0	6.71	0	0	3.4	5.30
DIPTERA								
Tipula sp.	0	0	0.13	0.35	0.27	0.70	0	0
Chironomidae sp.	4.27	6.54	1.47	2.97	2.87	4.76	1.0	3.87
Simulium jollyi	0.4	0.83	0.13	0.35	3.53	6.74	0.87	2.59
LEPIDOPTERA								
Nymphula sp. A	3.27	4.23	0.17	0.26	3.33	4.39	0.27	0.59
Nymphula sp. B	0.67	1.40	0.13	0.35	0	0	0	0
COLEOPTERA								
Hydrophilus sp.	0.13	0.35	0.07	0.26	0.47	1.25	0.47	0.64
TRICHOPTERA								
Goera sp.	0.93	2.15	0	0	0.07	0.26	0	0
Odontoceridae sp.	1.27	2.05	0.20	0.56	1.87	4.55	0.40	0.83
Leptoceridae sp.	0.33	0.90	0	0	0.13	0.52	0	0
Anisocentropus sp.	1.87	4.49	0.07	0.26	0	0	1.33	4.64
Oxyethira sp. A	1.13	2.33	4.93	6.25	1.47	3.56	3.60	7.94
Oxyethira sp. B	0.13	0.52	0	0	1.53	3.80	0.13	0.52
Hydrobiosis sp.	0.07	0.26	0	0	1.13	4.12	0.27	1.03
Apsilochorema sp.	2.13	3.78	0.07	0.26	0.93	1.44	0	0
Philoptamidae sp.	0.07	0.26	0	0	0.2	0.56	0.13	0.35
Abacaria fijiana	40.33	30.42	0.67	1.23	36.13	23.89	0.07	0.26
ZYGOPTERA								
Nesobasis sp. A	0.13	0.35	0.27	0.80	0.67	1.18	0.40	1.30
Nesobasis Sp. B	0.40	1.06	1.47	4.22	0.53	0.99	1.33	3.15
Nesobasis sp. C	0.07	0.26	1.07	2.37	0.27	0.59	2.80	7.21
Nesobasis sp. D	0	0	0	0	0.13	0.35	0.40	1.12
Nesobasis sp. E	0	0	0	0	0.07	0.26	1.67	4.70
Nesobasis sp. F	0	0	0	0	0.13	0.52	0.93	2.46
EPHEMEROPTERA								
Pseudoclocon sp.	41.13	48.81	7.47	14.68	20.67	36.56	3.73	7.56
Cloeon sp. A	2.87	6.2	11.93	12.10	3.2	6.88	14.2	20.24
Cloeon sp. B	0	0	0	0	0	0	7.13	14.84

Table 3. Number of taxa, abundance, the most abundant taxon and its percentage of the total and the diversity indices for he Nubakavesi and Wainilovu creeks. Ab, *Abacaria*; Ca, *Caridina* spp., An, *Anisocentropus* sp.; Cl, *Cloeon* spp.; Ps, *Pseudocloeon* sp.

Date	3/92	5/92	10/92	12/92	2/93	5/93	9/93	11/93	1/94	6/94	8/94	10/94	12/94	2/95	5/95	Mean	S.D.
NABUKAVESI creek																	
Number of taxa	11	11	11	10	15	13	14	8	10	12	13	9	11	11	14	11.5	1.959
Abundance	108	207	43	91	162	333	139	19	162	278	66	78	114	188	194	145.47	86.186
Most abundant taxa	Ab	Ab	An	Ca	Ps	Ps	Ab	Ab	Ps	PS	Ab	Ab	Ps	Ps	Ps		
% of total	55.6	32.4	23.3	26.4	36.4	52.6	47.5	47.4	50.6	46.0	51.5	32.1	30.7	42.6	31.4		
Total number of taxa	:	34	Diversity indices														
Number of individuals	:	2182		Simpson's λ				:	0.2105		Evenness		:	0.5897			
				Shannon's H'				:	2.079								
				Hill's $N_1 = e^{H'}$				:	7.999								
						$N_2 = 1/\lambda$		:	4.751								
						$N_0 = S$		:	34								
WAINIKOVU creek																	
Number of taxa	12	15	17	11	12	15	17	11	17	16	13	17	15	15	18	14.73	2.374
Abundance	103	334	107	38	129	241	252	79	200	188	71	84	89	120	181	147.73	82.233
Most abundant taxa	Ab	Ps	Ca	Ca	Cl	Ps	Ab	Cl	Cl	Ab	Ps	Ab	Ab	Cl	Ab		
% of total	24.3	42.8	33.0	42.1	39.5	32.4	23.0	30.4	30.5	40.4	22.5	36.9	47.2	50.0	28.2		
Total number of taxa	:	38		Diversity indices													
Number of individuals	:	2216			Simpson's λ			:	0.1176	Evenness			:	0.7254			
					Shannon's H'			:	2.6385								
					Hill's $N_1 = e^{H'}$			:	13.992								
						$N_2 = 1/\lambda$		:	8.5034								
						$N_0 = S$		:	38								

they were sampled on 25 January 1994 (Tables 2 and 3).

The taxa, their mean abundance and standard deviation over 3 years for the two streams are shown in Table 2. Mean abundance and standard deviation from the boulder and the plant habitats are shown separately. The species found most often in the vegetation, although not exclusively so, were all species of shrimps, damselfly nymphs, caddis fly larvae *Oxyethira* sp. A, mayfly nymphs of *Cloeon* sp. A & sp. B, adult beetles, water skaters and the snail *Melanoides tuberculata*. However, the most abundant species, *A. fijiana* and *Pseudocloeon* sp., were found on stones and boulders.

Table 3 shows the variation in species richness, abundance and and the means over 3 years. The most abundant species in both streams were either the caddis larvae, *A.fijiana* or *Anisocentropus* sp., or mayfly nymphs, *Cloeon* spp. or *Pseudocloeon* sp., or atyid shrimps, *Caridina* spp. The same species were the most abundant at the same time in both streams on only five occasions (Table 3). The most abundant species at each sampling comprised 23–56% of the total abundance. The total abundance of invertebrates fluctuated in both streams over the 3-year period but the difference in abundance in the two streams was found not to be significantly different by the Mann–Whitney U-test (calculated U =111.5, tabulated U =64) (Table 3). The number of invertebrate taxa varied from 8–15 with a mean of 11.5 in the Nabukavesi creek and from 11–18 with a mean of 14.7 in the Wainikovu creek (Table 3). The Mann–Whitney U-test (calculated U =34, tabulated U = 64) confirms that the mean number of invertebrate species in the Wainikovu creek was significantly higher over the period than the number in the Nabukavesi creek ($P < 0.05$).

Diversity indices also confirm greater species diversity in the Wainikovu creek between 1992–1995 (Table 3). The diversity numbers put forward by Hill (1973) (Table 3) incorporate Shannon's index H' and Simpson's index λ . Hill's numbers are in units of numbers of species, N_0 is the number of all species in the sample, $N_2 = 1/\lambda$ is the number of very abundant species and $N_1 = e^{H'}$ is the measure of abundant species (De Jong, 1975; Ludwig & Reynolds, 1988).

All diversity indices are less in the Nabukavesi creek than in the Wainikovu creek (except Simpson’s which increases with decreasing diversity). N_1 and N_2 indicate greater dominance of fewer species in Nabukavesi creek than in the Wainikovu. *Pseudocloeon* sp. and *Abacaria fijiana* accounted for 61% of the total invertebrates in the Nabukavesi creek while they only account for 42% in the Wainikovu.

Both streams had more grazers (68.2 and 65.5%) than any other type of consumer (Figure 2). Filter and gatherer collectors accounted for 48.5 and 54.7% of the consumers, and shredders only 7.5 and 7.7% in each stream (Figure 2).

Pseudocloeon sp. nymphs (and to a less extent *A. fijiana* larvae) abundance fluctuates in a similar way each year in both streams (Figure 3). The highest number occurred in May–June and the least in September–November, presumably because most had hatched into adults late In the year before the hot cyclone season began. They then spent this season, when the water temperature is higher and heavy rain is more likely, as adults or eggs.

Discussion

Over the 3-year period, 1992–1995, 34 invertebrate taxa were identified from the Nabukavesi creek and 38 taxa from the Wainikovu creek. Both streams are relatively species rich compared with many tropical Pacific Island streams. Haynes (1987b) found 19 benthic invertebrates over a 1-year period in the Wainivosule creek, a small lowland stream about 25 km inland in Viti Levu. A team surveying in the highland Monasavu area (600 m altitude) found 25 invertebrate species (INR, 1977). Resh et al. (1990) found that taxa richness in the Opunohu river, Moorea, French Polynesia ranged from 16–28 per site, while Maciolek & Ford (1987) found 29 invertebrate species along the length of the Nanpil-Kiepw river, Ponape, Caroline Islands. Continental tropical streams generally have more species. Stout & Vandermeer (1975) found as many as 62 species at a site in the Rio Java, Costa Rica.

Mayfly nymphs, caddis fly larvae and atyid shrimps were the most abundant taxa in both Nabukavesi and Wainikovu creeks. On the other hand, gastropods had the greatest biomass of all invertebrate taxa in the Wainivosule creek (Haynes, 1987b), and were more abundant than insect larvae from December–April. Caddis flies and mayflies were also scarce October–December in the Nabukavesi and Wainikovu creeks. The poverty of neritid gastropods in the Nabukavesi creek was unusual for a Fijian stream so near the sea (Haynes, 1985, 1987b) and can probably be attributed to sediment periodically covering the periphyton on which the gastropods grazed. Haynes (1985) found *Neritiina pulligera, N. pettiti, N. macgillvrayi* and *Septaria suffreni* in the Vago creek, a similar stream on Viti Levu.

Pacific islands such as Moorea (Marquet, 1991; Resh et al., 1990), Hawaii and Maui (Kinsie & Ford, 1977) and Ponape (Maciolek & Ford, 1987) also have more gastropods and decapod crustacean species richness in their lower reaches while insect species are more numerous upstream (Resh & de Szalay, 1995). Many island freshwater fish (e.g. gobies and eels) and invertebrates, e.g. crustaceans such as atyid shrimps, *Vanua litterata* and *Macrobrachium lar*, and neritid snails are diadromous and produce larvae that develop in the estuary or sea and the larvae or young adults then migrate upstream (Ryan & Choy, 1990; Maciolek & Ford, 1987).

The diversity of invertebrate taxa in the Wainikovu creek was significantly higher and it had more relatively abundant species than the Nabukavesi. However, although the density of invertebrates fluctuated in each stream, the means (145.5 and 147.7 per 15 stones and 6 sweeps) were not significantly different over 3 years.

Bisson et al. (1992) reported a decrease in invertebrate diversity in logged streams in northern California while invertebrate density increased. An increase of 17.2–27.6 times density and biomass of *Baetis* spp. occurred in an Appalachian stream, North Carolina, after its catchment had been logged (Wallace & Gurtz, 1986). In both streams logging involved the removal of overhanging vegetation that allowed more light to reach the stream and the water temperature to rise. This led to higher growth rates of periphyton, especially diatoms, and faster metabolism in invertebrates. Logging did not affect the amount of sunlight reaching the site in the Nabukavesi creek because the logging occurred 1–2 km upstream from the site, but the mayfly, *Pseudocloeon* sp. still reached higher densities in the Nabukavesi creek than in the unlogged Wainikovu creek. This suggests that the increase in abundance of some species in logged streams is not only caused by increased light reaching the stream but also to there being fewer species eating the available food.

Eight species – *Cloeon* sp. B, 3 species of damselflies *Nesobasis*, *Lymnogyrous* sp., *Alyopsis spinipes* and a small black planarian worm were present in Wainikovu creek but absent from the Nabukavesi

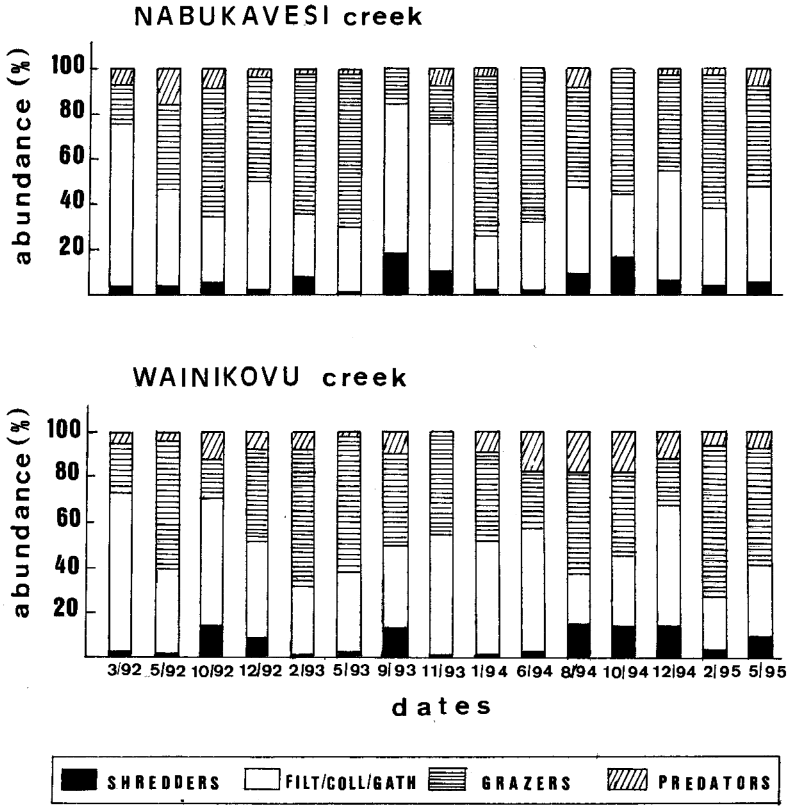

Figure 2. Percentage abundance of shredders, filtering and gathering collectors, grazers and predators in the Nabukavesi and Wainikovu creeks at each sampling date.

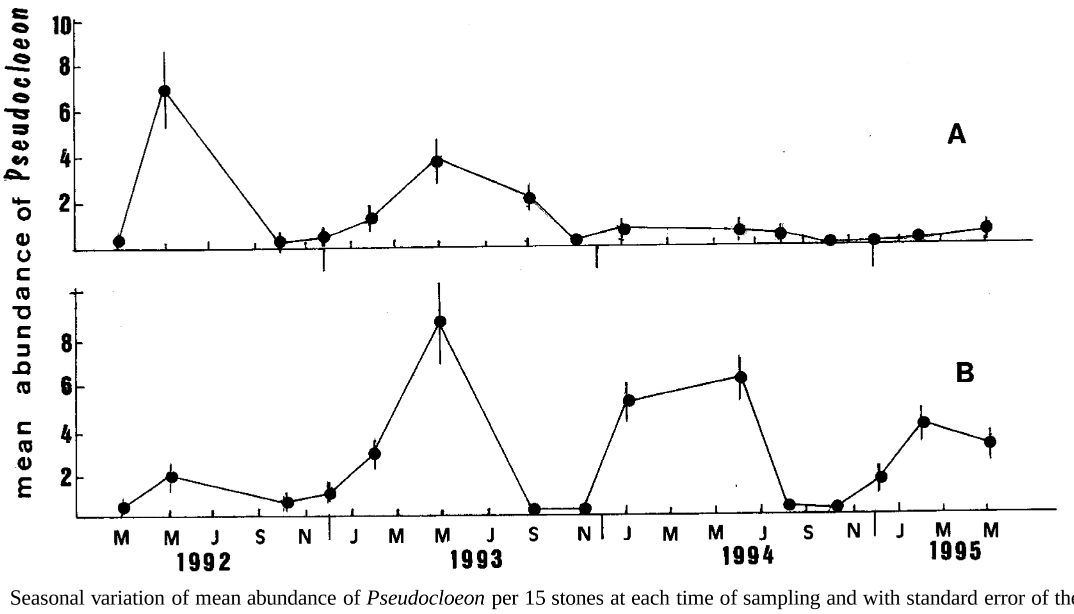

Figure 3. Seasonal variation of mean abundance of *Pseudocloeon* per 15 stones at each time of sampling and with standard error of the mean from March 1992–May 1995. (A) Wainikovu creek; (B) Nabukavesi creek.

creek. However, the small planarian, *Nesobasis* sp. E, and *A. spinipes* were present in the Nabukavesi creek in 1987/88 before logging began (unpublished data). The freshwater crab, *V. litterata*, *Nymphula* sp. B and the snail *Clithon diadema* were present in the Nabukavesi creek but were absent from the Wainikovu Creek. The neritid snail *C. diadema*, which was present only once, is more often found nearer the sea.

There was a low percentage of shredders in both streams possibly because the forest leaves entering the stream are tough with thick cuticle and are broken down slowly. Similarly, shredders contribute a negligible amount to the biomass of other Pacific island streams (Bright, 1982; Haynes, 1987b; Resh et al., 1990). Filtering collectors, gathering collectors and grazers were the main consumers present. Gastropods graze on periphyton on the surface of the leaves and boulders. Mayflies, *Pseudocloeon* sp. browse on the boulders while the caddis fly, *A. fijiana* and atyid shrimps are filter feeders. The shredders, present only in small numbers, were Leptocerid caddis, *Hydrophilus* adult, *Nymphula* spp. *Tipula*, and possibly the palaemonid shrimp, *M. lar*, although *M. lar* behaves more often as a omnivore/predator, so that it and the damselfly nymphs, *Nesobasis* spp., are the main predators (Choy, 1991; Cowie, 1981; Haynes, 1985, 1987a; Resh et al., 1990).

Luedtke et al. (1976) studied the affects of sand sediment on the colonization of stream insects in Canada and suggested that complete stream rehabilitation depended on two factors, the elimination of the sediment source and the ability of the stream to flush out deposited material. Selective logging in Ulu Segama rain forest, Sabah, Malaysia over 27 months caused an increase of up to 18 times as much sediment in the water. A year after logging ceased sediment yields had fallen to 3.6 times those of the undisturbed catchment (Douglas et al., 1992).

By March 1992 most of the mud and grit had been flushed from the Nabukavesi creek and the logged hillsides further up the valley were covered in secondary growth and therefore previous deforestation was no longer affecting the amount of sediment being washed into the stream. The Nabukavesi, like the Wainikovu was discoloured only after heavy rain. Abundant species, such as *Pseudocloeon* sp. and *A. fijiana* persisted in the Nabukavesi creek during logging when sedimentation was high, nearly all species had returned 2 years after logging ceased but three species (planarian sp., *A. spinipes* and *Nesobasis* sp. E), originally present in the Nabukavesi creek had not returned after 5 years, although they were present in the unlogged Wainikovu creek.

After logging, species with patchy or sparse populations were slower to return to the Nubakavesi creek than more abundant ones. Many endemic species are found only in widely dispersed patches. Populations of the endemic Fijian shell-less opisthobranch gastropod, *Acochlidium fijiense* have been found only in the Nasekawa river, Vanua Levu (near Vunivesi village) and in the Lami river, Viti Levu (near Lami village) (Haynes, 1991) in spite of widespread gastropod surveys (Haynes, 1985, 1987a, b; Starmühlner, 1976). It seems probable, therefore, that one serious long term effect of sedimentation due to logging will be the extinction of some fresh water invertebrate species.

Acknowledgements

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References

APHA–AWWA–WPCF, 1989. Standard Methods for Examination of Water and Wastewater. American Public Health Association. 17th edn.: 1–1134.

Bisson, P.A., T.P. Quinn, G.H Reeves & S.V. Gregory, 1992. Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest river systems. In Naiman, R.J. (ed.), Watershed Management: Sustainability and Environmental Change. Springer-Verlag, New York: 189–233.

Bright, G.R., 1982. Secondary benthic production in a tropical island stream. Limnol. Oceanogr. 27: 472–480.

Choy, S.C., 1991. The atyid shrimps of Fiji with description of a new species. Zoologische Mededelingen 65: 43–362.

Cowie B., 1981. The Fiji Aquatic Insect Survey May–November 1980. Environmental Studies Report No. 9. Institute of Natural Resources, University of the South Pacific, Suva: 1–17.

De Jong, T.M., 1975. A comparison of three diversity indices based on their components of richness and evenness. Oikos 26: 222–227.

Douglas, D., T. Spencer, T. Greer, K. Bidin, W. Sinun & W.M. Wong, 1992. The impact of selective commercial logging on stream hydrology, chemistry and sediment loads in the Ulu Segama Rainforest, Sabah, Malaysia. Phil. Trans. r. Soc. Lond. B335: 397–406.

Dudgeon, D., 1994. Research strategies for conservation and management of tropical Asian stream and rivers. International Journal of Ecology & Environmental Sciences 20: 255–285.

Elliott, J.M., 1977. Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates. Freshwater Biological Association Publication No. 25: 1–156.

Haynes, A., 1984. Guide to the Brackish and Fresh water Gastropods of Fiji. Institute of Natural Resources. University of the South Pacific, Fiji: 1–37.

Haynes, A., 1985. The ecology and local distribution of non marine aquatic gastropods in Viti Levu, Fiji. Veliger 28: 204–210.

Haynes, A., 1987a. The gastropods in the streams and rivers of five Fiji islands: Vanua Levu, Ovalau, Gau, Kadavu and Taveuni. Veliger 30: 377–383.

Haynes, A., 1987b. Species richness, abundance and biomass of benthic invertebrates in a lowland tropical stream on the island of Viti Levu, Fiji. Arch fur Hydrobiol. 110: 451–459.

Haynes, A., 1994. The effects of development on Fijian island freshwater invertebrates. Mem. Qld. Mus. 36: 87–91.

Haynes, A. & W. Kenchington, 1991. *Aochlidium fijiensis* sp. nov. (Gastropoda: Opisthobranchia: Acochlidiacea) from Fiji. Veliger 34: 166–171.

Hill, M.O., 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 61: 237–249.

Institute of Natural Resources, 1977. Report on Biological studies conducted in the area around the proposed Monasavu hydroelectric dam. Environmental Studies Report No. 1, University of the South Pacific, Suva: 1–34.

Kinzie, R.A. & J.I. Ford, 1977. A limnological survey of lower Palikea and Pipiwal streams, Kilahulu, Maui. Technical Report 17. Cooperative National Park Resources Study Unit. Dept. of Botany, University of Hawaii at Manoa: 1–44.

Ludwig, J.A. & J.F. Reynolds, 1988. Statistical Ecology. A Primer on Methods and Computing. John Wiley & Sons, New York: 1–337.

Luedtke, R.J. & M.A. Brusven, 1976. Effects of sand sedimentation on colonization of stream insects. J. Fish. Res. Bd Can. 33: 1881–1886.

Maciolek, J.A. & J.I. Ford, 1987. Macrofauna and environment of the Nanpil-Kiepw river, Ponape, Eastern Caroline Islands Bull. mar. Sci. 41: 623–632.

Marquet, G., 1991. Freshwater crustaceans of French Polynesia: taxonomy, distribution and biomass (Decapoda) Crustaceana 61: 125–140.

Mosely, M.E., 1941. Fijian Trichoptera in the British Museum. Ann. Mag. Nat. Hist. (Ser) 11(7): 361–374.

Resh, V. H., J.R. Barnes & D.A. Craig, 1990. Distribution and ecology of benthic macroinvertebrates in the Opunohu river catchment, Moorea, French Polynesia. Annls Limnol. 26: 195–214.

Resh, V.H. & F.A. de Szalay, 1995. Streams and Rivers of Oceana. In K.W. Cummins & G.W. Minshall (eds), Ecosystems of the World Series, Vol. 22. Elsevier, Amsterdam: 717–739.

Ross, H.H., 1953. Relationship of the Fijian species of *Apsilochorema* (Trichoptera, Rhyacophilidae). Occasional Papers of Bernice P. Bishop Museum 20: 175–182.

Ryan, P.A. & S.C. Choy, 1990. Observations on the mass upstream migration of *Varuna litterata* (Fabricius) megalopae (Decapoda, Brachyura, Grapsidae) in Fiji. Crustaceana 58: 237–249.

Starmühlner, F., 1976. Beitrage zur Kenntnis der Susswasser-Gastropoden pazifischer Inseln. Ann. Naturhist. Mus. Wien 80: 473–656.

Stout, J. & J. Vandermeer, 1975. Comparison of species richness for stream-inhabiting insects in tropical and mid-latitude streams. Am. Nat. 10: 263–280.

Tillyard, R.J., 1924. The dragonflies (Order Odonata) of Fiji with special reference to a collection made by Mr H.W. Simmonds, F.E.S. on the island of Viti Levu. Trans. r. ent. Soc. Lond. 1923: 305–346.

Trihadiningrum, Y., N. De Pauw, I. Tjondronegoro, R.F. Verheyen, 1996. Use of benthic macroinvertebrates for water quality assessment of the Blawi river (East Java, Indonesia). In Schiemer, F.A. & K.T. Boland (eds), Perspectives in Tropical Limnology. SPB Academic Publishing, Amsterdam: 199–221.

Wallace, J.B. & M.E. Gurtz, 1986. Response of *Baetis* mayflies (Ephomeroptera) to catchment logging. Am. Midl. Nat. 11: 25–41.