The influence of riparian vegetation on the functional organization of four Hong Kong stream communities

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Abstract

Results of a comparison of the functional organization of macroinvertebrate communities in four Hong Kong streams with different riparian vegetation showed only weak agreement with the predictions of the River Continuum Concept (RCC). Shredders were relatively abundant at shaded sites with high detrital standing stocks, while scrapers and piercers (of plant cells) were more numerous in unshaded streams with an autochthonous food base. Abundance of predators and filter-feeders differed little between sites. Collectors were most numerous in the least shaded stream, but their representation was not clearly related to riparian conditions. Even at shaded sites, shredders were never very numerous, nor did scraper relative abundance (% of total population density) vary significantly among streams.

Multiple regression models indicated that the abundance of shredders and piercers could be explained by the standing stocks of detritus and chlorophylls, and predator abundance was related to the densities of potential prey. Notwithstanding, there was little evidence that interactions between functional groups determined community organization, and trophic structure did not seem to be closely related to the efficiency of energy utilization in the study streams.

A comparison of the results of discriminant function analysis, using morphospecies abundance or functional group representation as predictors of site identity, indicated that morphospecies could serve to assign correctly all samples to their stream of origin. However, functional group abundance gave an overall 80–90% correct classification indicating that simplified community structural data can give a good indication of habitat parameters.

Introduction

The River Continuum Concept (RCC) of Vannote *et al.* (1980) suggests that stream morphology, hydrology, and allochthonous and autochthonous inputs interact to influence the availability of food to invertebrate consumers. The original framework has been refined in recent years (Minshall *et al.*, 1985; Statzner & Higler, 1985), but still retains a basis in which the invertebrate communities are dynamically linked to energy sources, and predictably structured to utilize their energy income most efficiently (Vannote *et al.*, 1980).

A necessary corollary of the RCC is division of stream animals into functional feeding groups. This division can be a useful aid to understanding how food availability influences community organization. Comparisons of observed functional organization in Nearctic streams with predictions from the RCC have yielded good agreement with the generalized model (Minshall et al., 1985). Outside North America, departures from the model have been noted with regard to the importance of shredders (Winterbourn et al., 1981; Dudgeon, 1984a; Marchant et al., 1985; Bunn, 1986).

Knowledge of the feeding relationships of tropical stream invertebrates in scant, and it is unclear how they respond to changes in food base. Dudgeon (1988a) has described changes in community structure (species representation) between physically similar Hong Kong streams with differing riparian conditions. However, complete understanding of differences in community composition requires information on functional organization as replacement of species by ecological equivalents may not result in any change in trophic structure within the stream system.

In this study, differences in the functional organization of four Hong Kong streams with contrasting riparian vegetation are described, and related to the predictions of the RCC concerning community functioning in streams with autochthonous versus allochthonous energy bases. The data are also compared with intersite differences in community composition (Dudgeon, 1988a), to assess the relative usefulness of functional group representation and morphospecies abundance as indicators of stream habitat parameters.

Description of sites

The study areas consisted of four third-order streams in separate watersheds of the New Territories, Hong Kong. A full description of the sites is given elsewhere (Dudgeon, 1982a; 1984b; 1988a).

The streams were unpolluted and drained granite batholith valleys. Their waters were soft and slightly acidic, with low nutrient levels (except silicates). There was no evidence of intersite differences in nutrient status or water chemistry (Dudgeon, 1988a). The sites differed with respect to riparian vegetation: Tai Po Kau Forest Stream (TPKFS) was completely shaded by trees with canopies interlocking over the stream. Bride's Pool (BP) was fringed by trees but their canopies did not shade the entire stream bed. The semi-natural forest surrounding TPKFS and BP exhibited a floral composition close to the mixed broad-leaved evergreen forest thought to represent the local climax vegetation. Lauraceae were a major component, as well as Moraceae and Euphorbiaceae together with woody climbers and lianas. Litterfall in Hong Kong forests exceeds 1 kg m^{-2} yr^{-1} (Lam & Dudgeon, 1985), and shows less distinct seasonal periodicity than in temperate regions. Nevertheless, there is a peak in litterfall during spring and early summer (March–May) (Lam & Dudgeon, 1985), although typhoons can cause elevated litter production in summer while local concentrations of deciduous species (e.g. *Liquidambar formosana* [Hance]: Hamamelidaceae) may lead to pulsed inputs to streams from October to January (Dudgeon, 1982b).

Riparian vegetation in the upper Lam Tsuen River (LTR) comprised scrub and tall grasses with few trees, and the stream was largely exposed to sunlight. Pui O (POS) stream was unshaded and the riparian grassland vegetation was of low stature; dense growths of periphytic algae were present on the rocky substratum.

Materials and methods

Streams were sampled in July 1983 during a period when there was no significant rainfall or fluctuations in stream discharge volume. Quantitative collections of the macrobenthos were made using a 'box' sampler (Coffman et al., 1971) which enclosed 0.1 m^2 of stream bed. In order to reduce intra-site sampling variation, only rubble substrata (particle diameter 30–200 mm were sampled). All substrata from within the box, as

well as the associated fauna and detritus, were removed using a trowel and a 200 μm mesh net. In addition, a stone from the sampled area was retained for estimation of periphytic algal standing stocks.

In the laboratory, fauna and organic debris were extracted by brine flotation and invertebrates were separated on a toluene-70% alcohol interface; detritus was oven-dried to constant weight (at 70 °C) after being checked for the presence of invertebrates. The periphyton associated with a stone of known surface area from each sample unit was estimated using a trichromatic chlorophyll technique (Vollenweider, 1974). Each habitat was visited once when 10 samples were taken (n = 40). Further details of sampling procedure and laboratory protocols are given elsewhere (Dudgeon, 1988a).

Macroinvertebrates were sorted to species wherever possible, otherwise to the lowest taxonomic level, and counted; this yielded 126 morphospecies from the four sites (Dudgeon, 1988a). Animals were assigned to functional groups with reference to published definitions (Merritt & Cummins, 1978). Observations of the morphology of the feeding apparatus and gut content analyses (Dudgeon, unpublished observations) were used to facilitate placement into functional groups. Because of the difficulty of assigning functional roles to most Chironomidae (Hawkins & Sedell, 1981), they were excluded from this analysis. Some taxa did not fit well into a single functional group and were treated as composites of other groups (see also Hawkins & Sedell, 1981). Collector/scrapers were treated as 0.3 scraper and 0.7 collector in all calculations, on the basis that gut contents of such taxa generally comprised approximately 70% by volume of fine detritus (Dudgeon, unpublished observations). Shredder/scrapers were treated in the same way, while shredder/collectors were viewed as one-half shredder and one-half collector in the light of relative proportions of fine and coarse detritus in their guts. A list of the functional designation of taxa is given in Appendix 1.

Assignment of taxa to functional feeding groups on the basis of gut contents is subject to the pitfall that material such as fine detritus could be obtained by collecting/gathering or generated by scraping. Moreover, gut content analyses upon which this study was based (where 10–20 individuals per species were examined) included only well-grown larvae. Changes in feeding behaviour which may occur during the life cycle can confound assignment of species to functional feeding groups. The extent to which such difficulties may have distorted the findings of the present study (as well as similar investigations) is not clear.

Analyses of functional group abundance were undertaken using multiple regression. Stepwise regressions of abundance on various combinations of detritus and chlorophylls (= independent variables) were undertaken to obtain a minmum of unexplained residual variance in terms of the smallest number of variables. Those independent variables which did not remove a significant proportion of the variation in abundance were dropped from the regression model (Walpole & Myers, 1978; Dudgeon, 1988b). While the variables which best explained the abundance of a given functional group may not have been the actual factors causing the observed pattern, they did give an indication of the parameters of the preferred habitat of that group and in this sense could be considered 'determinants' of abundance. Multivariate regressions using functional group abundance as independent variables were also undertaken where it was reasonable to assume that the density of one group (e.g. predators) might be influenced by the abundance of another (e.g. prey).

If riparian vegetation determines macroinvertebrate community structure by way of an effect on the energy base of streams, it may be possible to predict riparian conditions (i.e. site identity) from a knowledge of community composition. This suggestion was tested using discriminant function analysis, where samples were grouped on the basis of community composition and the resulting groups compared with respect to the origin of each sample (TPKFS, BP, LTR or POS) using a hit-and-miss table. A jackknifed classification was employed to reduce bias, which may have

resulted from the results of classification being based on the same cases used in developing that classification (Tabachnick & Fidell, 1983). Predictors of group membership used were: functional group abundance, functional group representation (%), morphospecies abundance (no. $0.1 \, \text{m}^{-2}$), and resource standing stocks (chlorophylls and detritus). Morphospecies data were derived from Dudgeon (1988a); only the 12 most abundant morphospecies at each site (comprising, on average, 76% of total population density) were used to predict group membership.

Statistical analyses (one-way analyses of variance [ANOVA], two-sample t tests, and least squares multiple regressions) were carried out on transformed data: $x' = \log(x + 1)$ for population densities, and $x' = \arcsin(\sqrt{x})$ for proportional data.

Results

The study streams were chosen with respect to differences in the degree of shading by riparian vegetation which, it was assumed, would influence food availability to macroinvertebrates. There were marked intersite differences in detrital standing stocks (one-way ANOVA $F_{(3,36)} = 10.35, P < 0.0001$), which were higher in TPKFS and BP (the shaded sites) (Fig. 1); Chlorophyll a biomass also differed among sites ($F_{(3,38)} = 27.07, P < 0.0001$) and was greatest at the unshaded sites, attaining a maximum in POS. Similar trends were apparent for chlorophyll b ($F_{(3,36)} = 41.06, \quad P < 0.0001$); chlorophyll c standing stock was highest in POS ($F_{(3,36)} = 17.95, P < 0.0001$), with no significant differences between the other sites (Fig. 1). A clear overall distinction could be made between shaded streams, exhibiting an apparent allochthonous food base, and streams with an open canopy which had lower detrital standing stocks and greater autochthonous resources.

Population densities of all functional groups apart from predators differed significantly between sites (Table 1). Scrapers were most abundant at the unshaded sites (LTR, POS) while shredders were most numerous in TPKFS which had the highest standing stocks of detritus (Fig. 1). Filter-feeders were most abundant in LTR; piercers at POS. TPKFS had the lowest total population densities reflecting a scarcity of collectors, the commonest functional group elsewhere.

Intersite differences in proportional representation of functional groups, as revealed by one-way ANOVA, were insignificant for predators, scrapers and filter-feeders (Table 2). Greater numbers of scrapers at the unshaded sites (see Table 1) was a reflection of higher total population densities rather than a change in community composition. Shredders were relatively more abundant in TPKFS than elsewhere (Table 2), and piercers attained their greatest relative abun-

Table 1. Inter-site differences in functional group abundance (no. $0.1 \, \text{m}^{-2} \pm 1$ S.E.M.) revealed by one-way ANOVA and two-sample t tests. (T, Tai Po Kau Forest Stream; B, Bride's Pool; L, Lam Tsuen River; P, Pui O Stream).

	Tai Po Kau Forest Stream	Bride's Pool	Lam Tsuen River	Pui O Stream	$F_{(3,36)}$	P	Abundance rankings
Predators	26.4 ± 4.0	69.4 ± 36.3	48.3 ± 16.4	20.2 ± 3.7	0.8	0.617	–
Scrapers	38.8 ± 5.1	59.3 ± 8.1	113.0 ± 12.8	96.5 ± 14.8	10.64	<0.0001	P, L > B, T
Collectors	74.2 ± 10.4	312.7 ± 74.8	257.9 ± 28.7	202.8 ± 35.9	7.6	0.0005	B, L, P > T
Filter-feeders	83.3 ± 25.3	104.4 ± 31.1	215.4 ± 50.2	87.1 ± 14.1	3.35	0.029	L > B, P, T
Shredders	19.9 ± 3.4	4.9 ± 1.0	6.9 ± 1.6	0.5 ± 0.3	31.1	<0.0001	T > L, B > P
Piercers	0	0	0.1 ± 0.1	8.1 ± 2.4	23.77	<0.0001	P > L, B, T
Total population	240.8 ± 39.3	548.8 ± 128.9	665.8 ± 101.9	445.5 ± 63.8	4.97	0.005	P, B, L > T

Chlorophylls (a,b, c & total) (mg m−2)
Chl a, b & Total Chl: P>L>T,B (P<0.01); Chl c: P>L,T,B (P<0.01)

Detritus (g m−2)
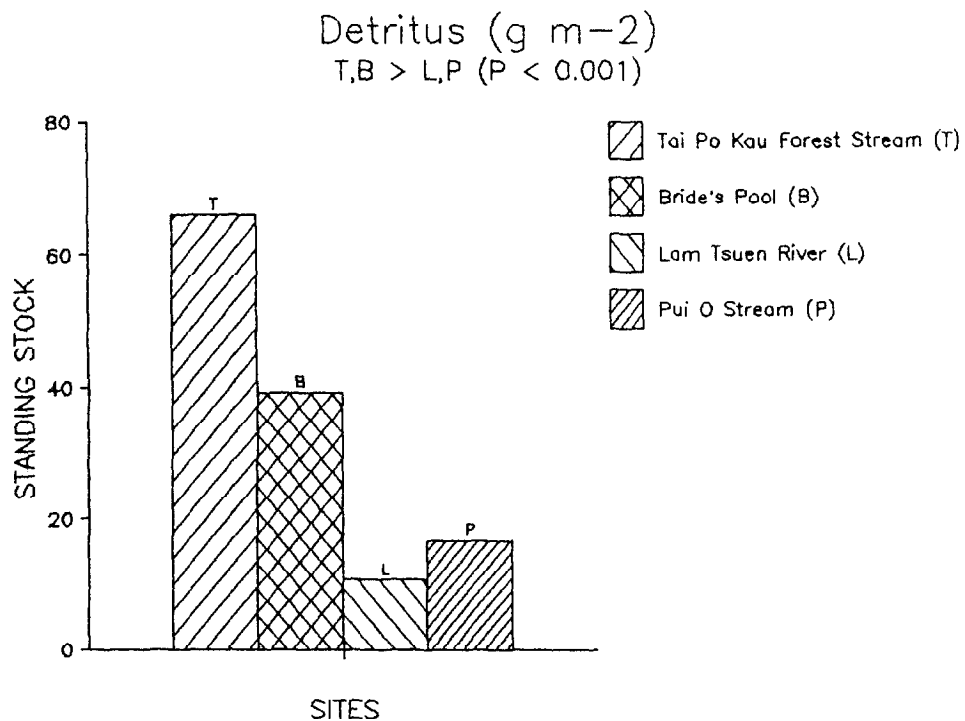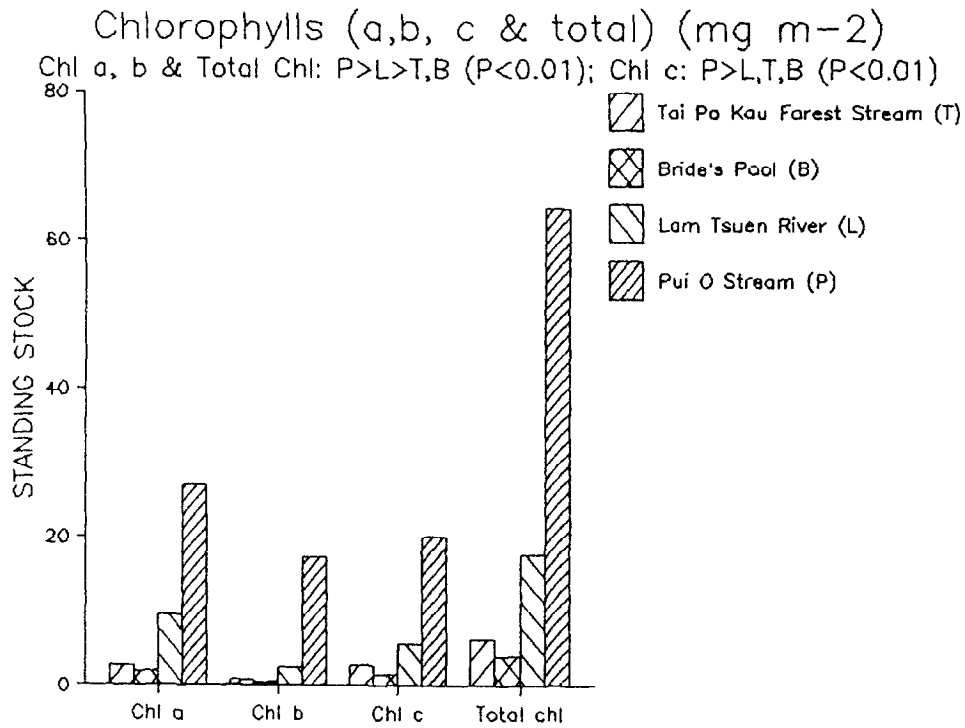### T,B > L,P (P < 0.001)

Fig. 1. Intersite differences in detrital and chlorophyll standing stocks; site rankings as indicated by two-sample *t* tests.

Table 2. Inter-site differences in proportional representation (%) of functional groups revealed by one-way ANOVA and two-sample *t* tests (Abbreviations as in Table 1).

	Tai Po Kau Forest Stream	Bride's Pool	Lam Tsuen River	Pui O Stream	$F_{(3,36)}$	P	Abundance rankings
Predators	10.3 ± 0.7	8.6 ± 2.3	7.2 ± 2.2	5.2 ± 1.4	2.01	0.1304	–
Scrapers	18.1 ± 3.1	14.1 ± 2.1	18.4 ± 1.2	21.1 ± 0.7	2.45	0.0789	–
Collectors	32.4 ± 3.3	55.1 ± 3.9	42.0 ± 2.3	52.6 ± 1.6	11.88	<0.0001	B, P > L > T
Filter-feeders	30.4 ± 5.4	21.1 ± 4.2	31.2 ± 3.8	19.4 ± 21	2.19	0.1061	–
Shredders	8.8 ± 1.2	0.9 ± 0.4	1.2 ± 0.4	0.1 ± 0.1	50.47	<0.0001	T > B, L > P
Piercers	0	0	0.01 ± 0.01	1.6 ± 0.5	26.25	<0.0001	P > L, B, T

dance at POS, where chlorophyll standing stocks were highest (Fig. 1).

The abundance of predators and filter-feeders was not significantly predicted by any regression model including chlorophylls and/or detritus, and the best model for collectors was only weakly significant (Table 3). By contrast, piercer abundance was determined by chlorophyll *b* standing stocks, while scraper densities were strongly (negatively) related to detritus, and shredder abundance could be predicted by a combination of detritus and chlorophyll *b*. Predator abundance

was strongly related to the densities of collectors plus filter-feeders, while filter-feeder densities were determined by the combined abundance of collectors, scrapers and shredders. In addition, a regression model for filter-feeders including scrapers as the sole independent variable had significant predictive power ($F_{(1,38)} = 11.79$, P = 0.0015, $100r^2\% = 23.7$, regression coefficient = 0.6979). The density of collectors was not significantly related to the abundance of other functional groups (Table 3).

Regression models predicting the relative abun-

Table 3. Results of multiple regression analysis of factors determining the abundance (no. 0.1 m⁻²) of macroinvertebrate functional groups in four Hong Kong streams.

	Variables of best-fit models	Coefficient of determination ($100r^2\%$)	F ratio	d.f.	P	Regression coefficient
Chlorophylls and detritus						
Predators	Chlorophyll *a*	3.5	1.37	1,38	0.2494	– 0.1532
Scrapers	Detritus	27.5	14.43	1,38	0.0005	– 0.3607
Collectors	Detritus	10.2	4.34	1,38	0.0144	– 0.2864
Filter-feeders	Total chlorophylls	0.7	0.28	1,38	0.597	0.0573
Shredders	Detritus &					0.3162 &
	Chlorophyll *b*	34	0.54	2,37	0.0005	– 0.4604
Piercers	Chlorophyll *b*	63.7	66.8	1,38	<0.0001	0.6758
Total population	Detritus	5.6	2.24	1,38	0.1428	– 0.1702
Other functional groups						
Predators	Collectors &					0.6305 &
	filter-feeders	50.5	18.85	2,37	<0.0001	0.4459
Filter-feeders	Collectors &					– 0.9777 &
	scrapers &					– 0.6911 &
	shredders	84.5	70.02	3,36	<0.0001	– 1.2135
Collectors	Shredders	5.4	2.17	1,38	0.1487	– 0.1649

dance of functional groups using chlorophylls and detritus as independent variables, were similar to those calculated for population densities with the exception that chlorophyll c replaced chlorophyll b as a determinant of piercer abundance (Table 4). Predator relative abundance was successfully predicted by the combination of scrapers, collectors and filter-feeders, and by scrapers alone ($F_{(1,38)}$ = 7.40, P = 0.0098, $100r^2\%$ = 16.3, regression coefficient = -0.4947) although the latter relationship was negative. Percentages of filter-feeders and collectors were related to those of collectors and shredders (respectively); both relationships were negative. The biological significance of these negative relationships between functional groups is obscure, but they may reflect differences in responses to chlorophyll and detritus rather than resulting from amensalism. For example, collector abundance and proportional representation was (weakly) negatively related to detrital standing stocks (Tables 3 & 4), while shredders apparently favoured detritus-rich sites. Different patterns of response to detritus could have given rise to a negative association between these functional groups.

The results of discriminant analysis indicated that morphospecies were the best predictors of group membership, and all samples were correctly assigned to their stream of origin on that basis (Table 5). Functional group abundance yielded 90% overall correct classifications, while functional group proportionate representation gave 80% correct overall. Classification of sites on the basis of resource standing stocks was correct in 73% of cases.

Discussion

Riparian vegetation had a significant influence on the energy base of the study streams. Two sites (TPKFS and BP) appeared to have a largely allochthonous food base (c.f. Dudgeon 1983), while autochthonous energy sources assumed greater importance in the streams with little or no riparian shading (LTR and POS). These differences had no significant influence on either absolute or relative abundance of predators. The greater abundance of shredders at shaded sites and the higher densities of scrapers and piercers (of plant cells) in unshaded streams with an autochthonous food base showed some agreement with predictions of the RCC (Vannote et al., 1980). Further agreement could be seen from the

Table 4. Results of multiple regression analysis of factors determining the proportional representation (%) of macroinvertebrate function groups from four Hong Kong streams.

	Variables of best-fit models	Coefficient of determination $(100r^2\%)$	F ratio	d.f.	P	Regression coefficient
Chlorophylls and detritus						
Predators	Detritus	10.5	4.46	1,38	0.0413	0.0362
Scrapers	Detritus	18.4	8.55	1,38	0.0058	-0.039
Collectors	Detritus	11.5	4.95	1,38	0.0322	-0.0484
Filter-feeders	Detritus	7.3	2.99	1,38	0.0916	-0.04533
Shredders	Detritus &					0.0303 &
	chlorophyll b	25.7	6.40	2,37	0.0041	-0.391
Piercers	Chlorophyll c	53.3	43.31	1,38	<0.0001	0.0401
Other functional groups						
Predators	Scrapers &					-1.0319 &
	collectors &					-0.9706 &
	filter-feeders	73.2	32.84	3,36	<0.0001	-0.9653
Filter-feeders	Collectors	64.1	67.88	1,38	<0.0001	-0.9417
Collectors	Shredders	27.2	22.51	1,38	<0.0001	-0.7135

Table 5. Statistics for discriminant analysis across habitats using functional group abundance (no. $0.1 \ m^{-2}$) or proportional representation (%), morphospecies or food resource standing stocks as predictors. Percentage correct discrimination into sites employs a jackknifed classification (Abbreviation as in Table 1).

Predictors	% correct					Wilk's lambda	d.f.	F ratio	P
	T	B	L	P	Overall				
Functional group abundance	100	100	90	70	90	0.0335	18,88	11.37	<0.0001
Functional group representation (%)	90	60	80	90	80	0.0362	18,88	10.94	<0.0001
Morphospecies	100	100	100	100	100	0.000028	78,33	13.95	<0.0001
Resource standing stocks	80	50	80	80	73	0.0572	15,88	10.76	<0.0001

strong relationship between the density and relative abundance of shredders and piercers with standing stocks of detritus and chlorophylls (respectively). However, the relative abundance of scrapers did not change across sites, in contrast to predictions arising from the RCC. Scraper abundance was negatively related to detrital standing stocks, which may have reflected an indirect effect of shading on periphyton rather than a deleterious influence of detritus *per se*.

The representation of collectors and filter-feeders (together comprising the most abundant functional group and the majority of the fauna at each site) was not clearly related to trophic conditions in the streams nor to predictions of the RCC. Relative and absolute abundance of collectors varied between sites, but showed no obvious correlation with riparian conditions. Collector abundance showed a weak negative relation to detritus, perhaps reflecting low collector representation at TPKFS where detrital standing stocks were highest. Filter-feeders were most numerous in LTR but did not vary in relative abundance between sites. This was in agreement with a lack of significant regression models predicting filter-feeder abundance using detritus and chlorophylls as independent variables.

Sources of confusion can arise in studies linking invertebrate community organization to food availability/riparian conditions. Firstly, standing stocks of detritus or algae may give a misleading impression of productivity or rate of food supply

and, moreover, give no indication of food (especially detrital) quality. Large differences in the quantity of detritus may represent small differences in food availability (Hawkins *et al.*, 1982). Thus inadequate characterization and/or quantification of potential food supply could lead to ambiguous relationships between consumer densities and standing stocks (Hawkins & Sedell, 1981). Furthermore, detritus may serve primarily as a substratum (Reice, 1980), or may be present in amounts exceeding the animals' requirements (Minshall & Minshall, 1977; Peckarsky, 1980; Dudgeon, 1988b) notwithstanding its importance as a food source (Cummins & Klug, 1979; Bird & Kaushik, 1981). In addition, confounding variables may influence patterns of macroinvertebrate distribution and abundance regardless of detrital or algal standing stocks; for example, avoidance of shade by certain taxa (Throup, 1966).

A major potential source of error in studies of invertebrate functional feeding groups is incorrect dietary categorization. There is evidence that benthic macroinvertebrates (especially insects) may be opportunistic detritivores feeding on a variety of food materials and particle sizes (Duncan & Brusven, 1985). Rounick *et al.*, (1982) showed that the same invertebrates differentially utilized allochthonous and autochthonous materials in New Zealand streams experiencing different degrees of shading, and thus drastic community shifts were not evident in a change from primarily allochthonous to autochthonous food

base. Indeed, such trophic flexibility may explain the lack of shredders in New Zealand streams (Winterbourn et al., 1981). A similar lack of shredders in Australian streams has been reported by Marchant et al., (1985) and Bunn (1986). In the Hong Kong study streams, a considerable change in species complement was observed between sites, with less than 10% of the 30 most numerous morphospecies occurring in all four streams (Dudgeon, 1988a). In these streams it seems likely that opportunistic dietary switches in different habitats would only have caused small errors in calculations of functional group densities, as few taxa were numerous at more than one site. However, even with supporting data on gut content composition, differences in the assimilation efficiencies and retention time of algae and detritus in the gut could lead to over- or underestimates of the importance of food categories to those taxa treated as composites of two functional groups (e.g. collector-scrapers). These difficulties are illustrated by a recent study which indicates that mayflies which ingest algae and detritus in nature will grow at different rates on pure diets of one or other food type (Webb & Merritt, 1987).

Regressions of individual functional groups against other, potentially interacting, groups were generally insignificant or negative. For example, collectors were not positively related to the abundance of shredders (which comminute coarse detrital particles: Cummins & Klug, 1979) (see Table 3). Such data indicate that Hong Kong stream communities may not be highly structured entities with close interactions between functional groups. Notwithstanding a role of food in determining macroinvertebrate distribution and abundance, functional group interactions may be unimportant and subordinate to factors such as disturbance in determination of stream community structure (Reice, 1985; Statzner, 1987).

Differences between community organization in the study streams were high-lighted by discriminant function analysis. On the basis of chlorophylls and detritus, samples could generally be correctly classified as to site of origin. The classification was 100% correct when morphospecies were used as site predictors. However, enumeration of morphospecies is time consuming and difficult in tropical Asia where stream faunas are poorly known. By contrast, functional classification of invertebrates facilitates handling of poorly-known taxonomic groups, although great care must be taken in assigning taxa to feeding categories. Using these simplified community structural data as predictors in discriminant analysis, 90% of samples were correctly classified by functional group abundance, and 80% were correctly assigned according to functional group proportional representation.

In conclusion, riparian vegetation influenced in-stream food resources which, in turn, had an effect on macroinvertebrate functional organization in four Hong Kong streams. These results gave some agreement with the RCC, but there was little evidence that collectors and filter-feeders (the most abundant functional groups) responded predictably to changes in the relative contributions of allochthonous and autochthonous energy sources. Neither was scraper relative abundance affected by riparian conditions, although scraper population densities were highest at unshaded sites. Nevertheless, discriminant analysis indicated that stream samples could be classified correctly into sites on the basis of community composition, and that functional group abundance was almost as good a predictor as morphospecies abundance. Apparently, studies of functional group abundance could be a cost-effective way of investigating macroinvertebrate communities in regions where stream faunas are poorly known. The present study also indicates that knowledge of the relative abundance of functional groups had reasonable predictive power in discriminant analysis. Collection of such data may have ecological value in situations where quantitative samples on an areal basis are difficult to obtain.

Appendix 1 Morphospecies list and functional feeding group classification used in this study.

GASTROPODA	
Thiaridae	
Brotia hainanensis (Brot)	ShSo
EPHEMEROPTERA	
Oligoneuriidae	
Isonychia kiangsinensis Hsu	F
Baetidae	
Baetiella sp.	CoSc
Baetis T1	CoSc
Baetis T2	CoSc
Baetis T3	CoSc
Baetis T4	CoSc
Baetis T6	CoSc
Centroptilum Tx	CoSc
Pseudocloeon T2	CoSc
Pseudocloeon TD	CoSc
Heptageniidae	
Compsoneuriella T1	CoSc
Compsoneuriella T2	CoSc
Epeorus T2	CoSc
Iron T1	CoSc
Paegniodes cupulatus Eaton	CoSc
Leptophlebiidae	
Choroterpes (Choroterpes) sp.	CoSc
Habrophlebiodes gilliesi Peters	CoSc
Isca (Isca) purpurea Gillies	CoSc
Ephemerellidae	
cf. *Ephemerella* sp.	CoSc
Ephemerellina T1	CoSc
Serratella T2	CoSc
Serratella L2	CoSc
Teloganodes sp.	CoSc
Caenidae	
Caenodes T1	CoSc
Caenodes T2	CoSc
Caenis L2	CoSc
Ephemeridae	
Ephemera (Aethephemera)	
pictipennis Ulmer	CoSh
Ephemera (Ephemera) spp.	CoSh
(including *E. spilosa* Navas)	
Prosopistomatidae	
Prosopistoma sp.	CoSc
ODONATA	
Platystictidae	
Protosticta taipokauensis Asahina &	
Dudgeon	P
Euphaeidae	
Euphaea decorata Selys	P
Calopterygidae	
Mnias mneme Ris	P
Epallaginidae	
Rhinocypha perforata (Percheron)	P
Gomphidae	
Heliogomphus scorpio Ris	P
Onychogomphus sinicus Chao	P
Macromiidae	
Macromia sp.	P
Libellulidae	
Zygonyx iris insignis (Kirby)	P
PLECOPTERA	CoSh
Nemouridae	
Amphinemura cf. *chui* (Wu)	
Leuctridae	
cf. *Leuctra* sp.	Sh
Perlidae	
cf. *Neoperla* sp.	P
Perlidae #3	P
Perlidae #5	P
Perlidae #6	P
HEMIPTERA	
Naucoridae	
Aphelocheirus sp.	P
Heterotrephidae	
Heterotrephes sp.	P
MEGALOPTERA	
Corydalidae	
Neochauloides spp.	P
(including *N. boweringi* McLachlan)	
LEPIDOPTERA	
Pyralidae	
Cataclysta sp.	Sc
TRICHOPTERA	
Rhyacophilidae	
Rhyacophila T1	P
Rhyacophila T2	P
Glossosomatidae	
Agapetus sp.	Sc
Hydroptilidae	
Hydroptila sp.	Pr
Philopotamidae	
Chimarra T1	F
Chimarra L4	F
Stenopsychidae	
Stenopsyche angustata Martynov	F
Psychomyiidae	
Psychomyia sp.	Co
Xiphocentronidae	
Melanotrichia serica Barnard & Dudgeon	Co

Appendix 1 (Continued)

Polycentropodidae	
Pseudoneureclipsis TA1	Co
Pseudoneureclipsis TA2	Co
Pseudoneureclipsis TA3	Co
Ecnomidae	
Ecnomus sp.	P
Hydropsychidae	
Hydropsyche Lz	F
Hydropsyche Ly	F
Hydropsyche Lw	F
Hydropsyche Tv	F
Hydropsyche Ts	F
Cheumatopsyche T1	F
Cheumatopsyche TdB	F
Cheumatopsyche Tz	F
cf. *Hydropsychodes* sp.	F
Macrostemum brisi (Navas)	F
Macrostemum fastosum (McLachlan)	F
Macrostemum floridum (Navas)	F
Diplectrona sp.	F
Calamoceratidae	
Anisocentropus maculatus Ulmer	Sh
Leptoceridae	
Leptoceridae genus indct #1	Co
Leptoceridae genus indet #2	Co
Ondontoceridae	
Psilotreta kwantungensis Ulmer	Sc
Lepidostomatidae	
Goerodes sp.	Co
COLEOPTERA	
Dytiscidae	
Hydrovatus sp.	P
cf. *Rhantus* sp. (larvae)	P
cf. *Rhantus* sp. (adults)	P
Gyrinidae	
Orechtochilus sp.	P
Hydrophilidae	
Berosus sp.	Co
Enochrus sp. (larvae)	Co
Enochrus sp. (adults)	Co
Helodidae	
Helodes #1	Co
Helodes #2	Co
Ptilodactylidae	
Eulichas sp.	CoSh
Psephenidae	
Ectopria sp.	Sc
Eubrianax sp.	Sc
Mataeopsephus #1	Sc
Mataeopsephus #2	Sc
Psephenoides sp.	Sc
Elmidae	
Elmidae larva #1	CoSc
Elmidae larva #2	CoSc
Elmidae larva #3	CoSc
Elmidae larva #4	CoSc
Elmidae larva #5	CoSc
Elmidae larva #6	CoSc
Elmidae larva #7	CoSc
Elmidae larva #8	CoSc
Elmidae larva #9	CoSc
Elmidae adult #1	CoSc
Elmidae adult #2	CoSc
Elmidae adult #3	CoSc
Elmidae adult #4	CoSc
Elmidae adult #5	CoSc
Elmidae adult #6	CoSc
Elmidae adult #7	CoSc
Elmidae adult #8	CoSc
Elmidae adult #9	CoSc
Elmidae adult #10	CoSc
DIPTERA	
Nymphomyiidae	
Palaeodipteron sp.	CoSc
Tipulidae	
Antocha cf. *bifida* Alexander	Co
cf. *Limnophila* sp.	P
Prionocera sp.	P
Psychodidae	
cf. *Pericoma* sp.	Co
Simuliidae	
Simulium T1	F
Simulium T2	F
Empididae	
Empididae genus indet. #1	P
Empididae genus indet. #2	P
Ceratopogonidae	
cf. *Atrichopogon* sp.	CoSc
cf. *Bezzia* sp.	P
Dasyheleinae genus indet. #1	CoSc

Key to functional groups:

Co	Collectors
Sc	Scrapers
Sh	Shredders
F	Filter-feeders
P	Predators
Pr	Piercers-suckers of plant cells
ShSc	Shredder/Scrapers
CoSh	Collector/Shredders
CoSc	Collector/Scrapers

Total morphospieces (all streams) = 126

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