BENTHIC FAUNAS OF FORESTED STREAMS AND SUGGESTIONS FOR THEIR MANAGEMENT

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SUMMARY: The influence of physical factors and forest type on the distribution of benthic invertebrates in 43 New Zealand streams was investigated using a systematic survey technique. A small nucleus of common taxa was numerically dominant at most sites regardless of forest type. The mayfly, *Deleatidium* was found at 42 of the sites and was the *most* abundant taxon at 27. Other widely distributed genera were *Nesameletus, Coloburiscus* (Ephemeroptera), *Stenoperla, Zelandoperla, Zelandobius* (Plecoptera), *Olinga* and *Hydrobiosis* (Trichoptera). Numbers of invertebrate taxa and relative abundance of shredders (large particle detritivores) were not correlated with stream gradient but were correlated significantly with stream stability. Implications of these findings for stream management are discussed, and it is suggested that combined physical-faunal surveys of the kind used in this study have the potential to identify streams which may require particular protection.

INTRODUCTION

All stream ecosystems are dependent on the surrounding terrestrial environment for a continuing supply of energy and nutrients in the form of dissolved and particulate organic matter. The surrounding catchment, therefore, can be expected to have a major influence on the nature and functioning of the stream ecosystem, or to quote Hynes (1975): ". . . in every respect the valley rules the stream. . . . We must, in fact, not divorce the stream from its valley in our thoughts at any time. If we do, we lose touch with reality." Given this situation, a potential conflict of interest between forestry and stream conservation is apparent.

In 1963, Ross hypothesised that certain North American Trichoptera (caddisflies) were "confined to distinctive terrestrial biomes" in response to the physical and biological influences of the local vegetation on the stream bed and, subsequently, much research has been conducted to clarify the links between forest and stream ecosystems (Fisher and Likens, 1973; Hynes, 1975; Meehan, Swanson and Sedell, 1977). In particular, continuing work in the Coast and Cascade Ranges of Oregon (Meehan *et al.,* 1977) and at Hubbard Brook, New Hampshire (see Likens *et al.,* 1977) has been invaluable in detailing terrestrial-stream ecosystem linkages and raising the general consciousness of parties involved in making forest management policy decisions.

Research being carried out by the New Zealand Forest Service at Maimai and Big Bush is providing information on the effects of logging practices on hydrology, sediment loads, and water chemistry of streams draining small podocarp-hardwood-beech forest catchments (e.g. Pearce, O'Loughlin and Rowe, 1976; Neary *et at.,* 1978; O'Loughlin, Rowe and Pearce, 1980). However, critical assessment of forestry practices on stream faunas is lacking in New Zealand. Only Graynoth (1979) has really addressed this question, and his study of Donald Creek is too limited, both taxonomically and in scope, to have general applicability for management.

Before impacts of forestry practices on stream faunas can be assessed adequately, it is important that the nature of faunas in undisturbed forest streams be known. No extensive comparative surveys of stream communities in relation to forest and other vegetational types have been made in New Zealand and the influence of physical factors (e.g., flow, substrate size, stability) on invertebrate distributions is poorly understood (Winterbourn, 1981). In order to partly rectify this situation we carried out surveys in 43 first to third order streams in a variety of indigenous forest types and exotic pine plantations in the three main islands of New Zealand.

At each site, the benthic invertebrate fauna was sampled and selected physical characteristics of the catchment, stream bed and adjacent banks recorded. So that objective comparisons of physical characteristics could be made, a survey procedure, developed by Pfankuch (1975) to measure stream stability in the U.S.A., was used.

METHODS

Forty-three streams in wholly or partially forested catchments were selected as study sites (Fig. 1, Appendix I). Sites were chosen either by perusing local topographical maps for potentially suitable streams, or by direct investigation of promising regions. Only streams bordered by riparian vegetation were selected and most sites were narrow (an active channel of < 6 m wide at sampling), well shaded reaches about 30 m long. Streams were sampled at various times of year with each stream being sampled once.

Streams were classified according to forest type as exotic *(Pinus* plantations), beech, podocarp-hardwood-beech, or podocarp-hardwood. This follows the scheme used by Wendelken (1976) except that his kauri *(Agathis australis)*-podocarp-hardwood category is included with other podocarp-hardwoods.

In the South Island, forests classified as beech occur predominantly east of the main alpine divide and even alongside streams few tree species other than *Nothofagus* occur (Burrows, 1977). On the other hand, in podocarp-hardwood-beech forests, deciduous fuchsia *(Fuchsia excorticata)* and wineberry *(Aristotelia serrata)* may occur along stream banks and contribute pulsed, allochthonous inputs (Cowie, 1980).

The podocarp-hardwood group encompasses a greater diversity of trees including species of Podocarpaceae (softwood timber trees such as matai *(Podocarpus spicatus)* and totara *(P. totara)),* many kinds of "broadleaf" hardwood trees (e.g., kamahi *(Weinmannia racemosa),* tawa *(Beilschmiedia tawa)* and mahoe *(Melicytus ramiflorus*[a], and an abundance of shrubs, ferns, tree-ferns, epiphytes and lianes.

Physical parameters were recorded first. Channel gradient was measured with an Abney level, stream width with a metric tape and pertinent observations on stream bed structure, catchment conditions and degree of shading noted. A survey designed by Pfankuch (1975) to evaluate channel stability was then carried out. The Pfankuch survey is a systematic procedure in which a series of physical factors are examined and given numerical scores. Upon summing the individual scores, an overall stream rating is obtained and this can be translated into one of four subjective categories: excellent, good, fair or poor. The stream rating represents a summary of the resistive capacity of stream channels to the detachment of bed and bank materials and provides information about the capacity of streams to adjust and recover from potential changes in flow and/or increases in sediment production (Pfankuch, 1975).

Use of this survey technique requires judgment which is obtained by practice and a thorough understanding of the criteria outlined in the survey guide {Pfankuch, 1975). In particular, it was important to consider the entire (approximately 30 m) reach in making judgments and to avoid keying in on one or a few indicators. As indicators are interrelated, over-

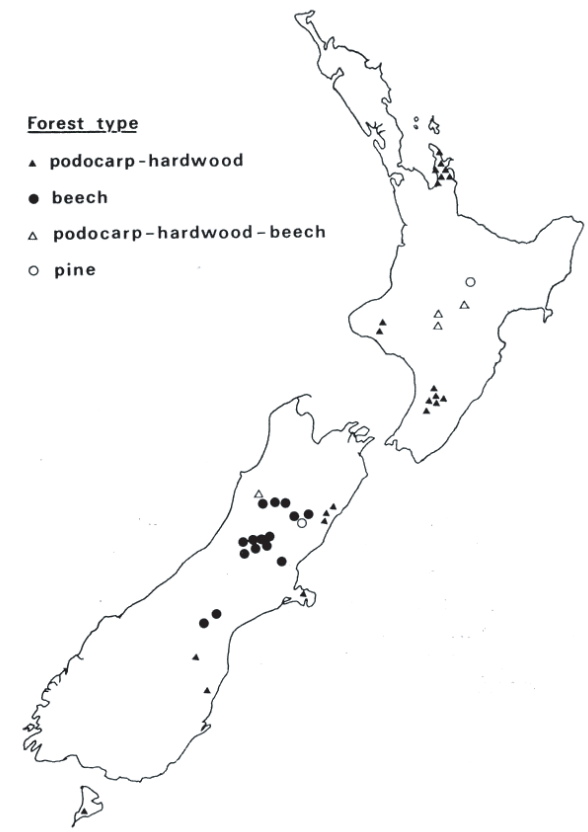

FIGURE 1. *Locations of the* 43 *streams surveyed in this study.*

and under-ratings tend to balance out, as pointed out by Pfankuch. In practice, the stream channel is divided into three components, upper banks, lower banks and channel bottom, so as to focus the surveyor's attention on the particular indicators to be evaluated(see Appendix II which is a sample survey form).

Survey repeatability was tested using several evaluators and found to be satisfactory. Thus, the total scores obtained by experienced evaluators usually were within 5 % of each other.

After the surveys had been completed, benthic fauna was sampled by taking and washing the surfaces of displaced stones into a 1 mm mesh stream net. An attempt was made to collect from a wide variety of microhabitats within the surveyed reach. However, sampling intensity inevitably varied between sites because of different stream bed characteristics, such as degree of substrate compaction, habitat

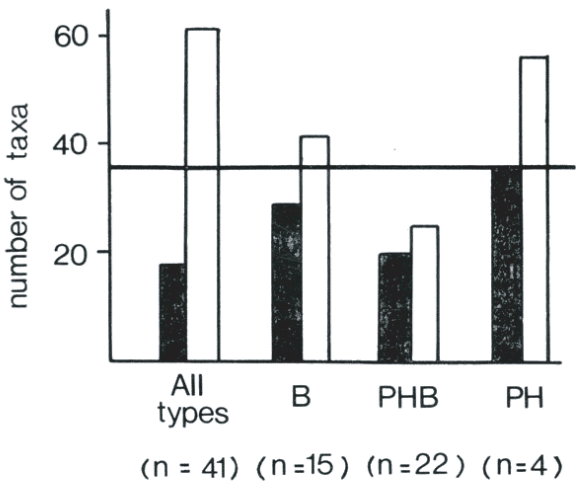

FIGURE 2. *Numbers of invertebrate taxa found in streams in three types of forest. Black histograms: taxa belonging to the top-5 abundance group* (35 *in all, horizontal line on graph). Open histograms: all taxa regardless of abundance. Forest types: B, beech; PHB, podocarp-hardwood-beech; PH, podocarp-hardwood.*

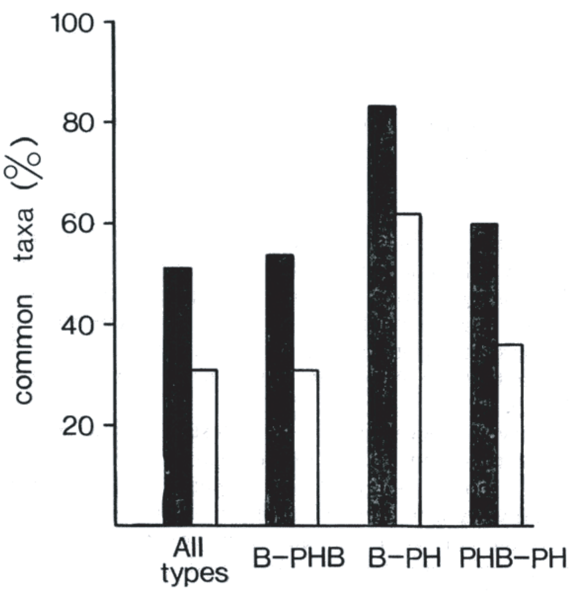

FIGURE 3. *The percentage of invertebrate taxa common to all forest types and to all possible forest pairs. Black histograms: taxa in the top-5 abundance group. Open histograms: all taxa. Forest types as in Figure* 2.

accessibility etc. Collected invertebrates were preserved in 70% ethanol prior to sorting, counting and identification. Wherever possible invertebrates were identified to the species level, but this is not possible for all New Zealand aquatic insects (Winterbourn and Gregson, 1981) and many could be identified only to genus or family. This was almost always the case with early instar larvae. However, information lost through inability to discriminate between congeneric species may not be crucial in many groups. As Wiggins and Mackay (1978) argued, the genus can be considered as an ecological type or theme and congeneric species are merely "subtle variations on this theme".

Because streams were sampled at various times of year, seasonal factors could be expected to account for some of the variation in invertebrate populations between sites. However many New Zealand stream insects have non-seasonal life history patterns (Winterbourn, 1978; Towns, 1981) and occur in streams as larvae throughout the year. Therefore, it is likely that collections made at any time are likely to include most, if not all, common species, although their relative abundances may be affected. For this reason, and because sampling intensity varied between sites, the animal data do not lend themselves to sophisticated community analysis and this has been resisted.

RESULTS AND DISCUSSION

Faunal-forest associations

Sixty-one taxa of benthic invertebrates (excluding Chironomidae, which were not considered in the surveys) were identified from the 43 streams. These were predominantly aquatic insects (87%) of which Trichoptera (36 % of total numbers), Plecoptera (13%) and Ephemeroptera (19%) were represented by most species.

Twenty-four to 56 taxa were taken from streams in the three forest types (beech-41 taxa; podocarp-hardwood-beechÖ24; podocarp-hardwoodÖ56) considered (Fig. 2) and a high percentage were held in common by all three types (Fig. 3). No obvious relationship between invertebrate fauna and forest type was apparent. The lower numbers of taxa found in podocarp-hardwood-beech forest are probably a result of the fewer sampling sites located in that forest type (podocarp-hardwood-beech, n = 4; beech, n = 15; podocarp-hardwood, n = 22). Since only two streams in exotic plantations were sampled, they were not included in this comparison.

At each site, five taxa (not necessarily the same ones at each site) accounted for a mean of 87.2% (range 66.7-100%) of the total fauna collected.

TABLE 1. *Number of occurrences and top-5 placings of taxa which occurred in the top-5 abundance group of at least one stream.*

	Total no. of occurrences	Times in Top-5	Top-5 Placing 1st	2nd	3rd	4th	5th
Ephemeroptera							
Deleatidium	42	42	27	9	2	3	1
Nesameletus	19	9	0	5	2	0	2
Coloburiscus humeralis	22	18	7	3	3	4	1
Arachnocolus phillipsi	2	1	0	1	0	0	0
Plecoptera							
Stenoperla prasina	27	12	0	1	3	4	4
Zelandoperla	16	9	1	2	2	1	3
Spaniocerca zelandica	8	6	1	2	1	0	2
Zelandobius	14	6	0	0	3	1	2
Austroperla cyrene	II	3	0	0	1	0	2
Megaleptoperla grandis	6	1	0	0	0	1	0
Trichoptera							
Olinga feredayi	20	14	0	4	4	5	1
Oeconesidae	10	9	3	0	1	3	2
Orthopsyche	10	8	0	1	4	1	2
Aoteapysche	13	7	0	4	1	1	1
Hydrobiosella	10	4	1	1	1	1	0
Hydrobiosis	18	4	0	1	0	3	0
Helicopsyche	7	2	1	0	1	0	0
Philorheithrus agilis	8	2	0	0	1	0	1
Costachorema	6	1	0	0	0	1	0
Polyplectro pus	3	1	0	0	0	0	1
Psilochorema	13	1	0	0	0	1	0
Pycnocentria	6	1	0	0	1	0	0
Pycnocentrodes	4	1	0	0	1	0	0
Triplectides obsoleta	6	1	1	0	0	0	0
Coleptera							
Elmidae	18	12	0	5	2	3	2
Helodidae	4	1	0	0	0	0	1
Ptilodactylidae	6	2	0	0	0	2	0
Diptera							
Austrosimulium	4	1	0	0	0	1	0
Aphrophila neozelandica	4	2	0	0	0	0	2
Other Tipulidae	16	4	0	0	3	0	1
Oligochaeta							
Eisenielia tetraedra	6	3	0	1	0	0	2
Decapoda							
Paranephrops	5	5	0	1	0	3	
Megaloptera							
Archichauliodes diversus	20	9	1	0	3	2	3
Gastropoda							
Potamopyrglls antipodarllm	8	1	0	0	1	0	0
Amphipoda	6	3	1	0	1	0	0

Ubiquitous was the leptophlebiid mayfly, *Deleatidium* which was found in 42 of the 43 surveyed sites (Table 1). *Deleatidium* was a member of the top-5 in all 42 streams and was the most abundant intertebrate at 27 of these 42 sites. Other invertebrates which were widespread and abundant were the ephemeropterans *Nesameletus* and *Coloburiscus,* the plecopterans *Stenoperla, Zelandoperla* and *Zelandobius* and the trichopterans *Olinga* and *Hydrobiosis.* These nine genera occupied 114 of the 207 possible top-5 positions and represent a core element in the New Zealand fauna. *Deleatidium, Olinga* and *Nesameletus* also were the most abundant species found in the two exotic plantation streams surveyed. When top-5 taxa are compared with respect to forest type, the lack of specialised, forest-associated faunas is clear (Fig. 3). Of the 35 taxa which occurred in the top-5, 18 were found in all forest types, 29 in beech, 20 in podocarp-hardwood-beech and 35 in podocarp-hardwood.

The presence of such "universal" core fauna in very different types of forest streams is in contrast with suggestions that close linkages exist between vegetation type and invertebrate community composition. This idea, often credited in the first place to Ross (1963), nevertheless has not been thoroughly tested, and a number of workers (e.g. Cummins, 1974; Boling *et al.,* 1975; Malmqvist, Nilsson and Svensson, 1978) appear to have overstated or misinterpreted Ross's initial claim.

Riparian vegetation can have an important role in fashioning stream habitat as a source of retentive structures, e.g. logs, and invertebrate food (leaves and other organic debris), and this may be reflected in benthic community structure (Meehan *et al.,* 1977; Hawkins and Sedell, 1981). However, in recent North American studies, Haefner and Wallace (1981) and Molles (1982) found that forest type had little effect on benthic species composition, and Webster and Pattern (1979) concluded that streams in old field and pine plantation watersheds were functionally little different from those in hardwood forest. Similarly, we found no evidence for an association between the distribution of stream invertebrates and forest type.

TABLE 2. *Spearman rank correlation coefficients (r_s) among physical and biological variables for the 43 surveyed streams. (*p<0.05, **p<0.01).*

	Stability rating	Number of taxa	Shredder abundance
Stream gradient	0.24	-0.16	-0.13
Stability rating		-0.34*	-0.47**
Number of taxa			0.38**

Influence of physical factors on benthic faunas

Sampling sites 10 the 43 surveyed streams had bed gradients between 0.5° and 23°, and Pfankuch stability ratings ranging from 41 to 147 ($\bar{x}$ 96, SD 26) (Appendix 1). The mean rating falls into the middle of the category described as "fair" by Pfankuch (1975). No New Zealand streams rated "excellent" and only 12 of the 43 sites were categorized as "good".

The degree of correlation among stream gradient, stability rating, number of benthic taxa collected and relative abundance of shredders (large particle detritivores) was examined by calculating Spearman's rank correlation coefficient (r_s). Results are shown in Table 2.

Neither bed stability nor numbers of taxa collected were correlated significantly with stream gradient. However, numbers of taxa were negatively correlated with Pfankuch rating (r_s = -0.34, $P < 0.05$) indicating that, in general, more taxa were present in the more stable streams. This is in agreement with Cowie's (1980) findings in a West Coast forest stream system and is probably a result of more stable streams offering a greater variety and constancy of habitats and food resources.

The distribution of shredders was examined because they can play an important role in organic matter processing in streams (Cummins, 1974), and because their apparent scarcity in New Zealand has puzzled stream ecologists. In New Zealand, shredders are represented by caddisfly larvae of the genus *Triplectides* (Leptoceridae) and the family Oeconesidae, and a stonefly, *Austroperla cyrene.* All can be identified with keys in Winterbourn and Gregson (1981). For the purposes of calculating correlation coefficients, streams were placed in three categories depending on whether shredders were (1) absent, (2) present and making up 0.1-3.0% of invertebrate numbers, or (3) abundant, i.e. constituting more than 3 % of the fauna. Shredder abundance was not correlated with stream gradient, but a significant correlation (r_s = Ö0.47, $p < 0.01$) was found with stability rating. As with total numbers of taxa, this indicates that shredders are best represented in the more stable streams. Most streams which scored over 100 lacked shredders, whereas streams which scored less than 100 had resident (if small) shredder populations. Comparative studies in two beech forest streams of contrasting stability in the Cass basin, South Island (Middle Bush Stream, stability rating 90; Craigieburn Cutting Stream, 110) indicated that organic matter retention was a major factor controlling shredder distribution (Rounick and Winterbourn, in press), and stability ratings are seen as providing a measure of this factor.

Suggestions For Management Of New Zealand Stream Ecosystems In Relation To Forestry Practices

The first step in deciding upon appropriate management practices is to determine what goals need to be met. With respect to forest-stream ecosystem management, a reasonable overall aim would seem to be to ensure that ecosystem functioning remains essentially unaltered as a result of forestry practices. Maintenance of unchanged benthic invertebrate communities (in the taxonomic sense) need not be of prime concern, since many species play equivalent roles in an ecosystem context, and losses or gains of particular species may be of little consequence in functional terms.

Further, the presence, in New Zealand, of a common, widely-distributed core fauna, regardless of forest type, suggests that few, if any, species are dependent on particular types of terrestrial vegetation, and conversion from indigenous to exotic forest *per se* appears to have little impact on the nature of stream invertebrate communities.

The removal of stream-side vegetation has two obvious effects on streams:

(1) The stream bed is opened up, resulting in its exposure to higher light intensities.

(2) Rates of sediment and, frequently, nutrient input increase.

Opening up of the canopy can result in increasing aquatic production at all trophic levels (Murphy, Hawkins and Anderson, 1981) which also may be stimulated by increased nutrient level (Bormann *et aI.,* 1968). Murphy *et. al.* (1981) demonstrated a clear relationship between increased light levels and increases in primary production, microbial respiration, invertebrate and vertebrate production. How permanent such increased productivity will be is another matter, however, and will depend largely on patterns of regrowth (see Murphy and Hall, 1981).

The effects of canopy change (forested to open) on faunal composition has been investigated both overseas and in New Zealand. Overseas work (e.g., Erman, Newbold and Roby, 1977; Newbold, Erman and Roby, 1980) has demonstrated marked changes in stream faunal composition, particularly in catchments which have been logged without a riparian strip being left intact. This is in contrast to the local situation where observations on the nature of New Zealand stream faunas in general (Winterbourn, Rounick and Cowie, 1981) indicate that a nucleus of common' .genera and species prevail in many streams whether they be in native beech; podocarp-hardwood forest, exotic plantations or even grasslands. Many of these species clearly possess wide ecological flexibility with respect to habitat requirements, life history patterns and food requirements (Winterbourn *et al.,* 198l; Ronnick, Winterbourn and Lyon, in press).

Sedimentation, unlike canopy opening, results in reduced productivity and has long been recognised as a problem associated with logging practices. Forest vegetation plays a key role in stabilising slopes and reducing erosion and, when it is lost, increasing quantities of sediment and soil may wash into streams, often with disastrous effects for the fauna. Roads, tracks and landings have been identified as prime sources of sediments which enter streams as a result of either fluvial erosion or mass-wasting processes (Swanston and Swanson, 1976; O'Loughlin *et al.,* 1980) and for this reason, they should be carefully sited so as to minimise possible sedimentation problems.

Buffer strips, stands of vegetation left intact along stream banks, have been advocated as a means of protecting streams from logging impacts (Newbold *et al.,* 1980), and several studies have shown that they are effective for ensuring that no decline in fish populations occurs (e.g. Hall and Lantz, 1969), controlling stream temperature (Brazier and Brown. 1973), and sediment flows (Haupt and Kidd, 1965; Meehan *et al.,* 1977). In New Zealand, where direct forest vegetation-stream invertebrate linkages appear to be weak, it is probable that buffer strips are primarily of value as "policemen" (Newbold *et al.,* 1980) limiting direct sediment introduction and protecting stream banks from logging-induced erosion.

Physical and faunal surveys of the kind described here (carried out in conjunction) have the potential to identify streams which may require particular protection. That is, they can point out potential trouble spots. For example, the communities in relatively stable streams (those with low Pfankuch scores) are likely to be subject to relatively greater disturbance than those in unstable streams, since shredders' foods would be lost (riparian vegetation) and inputs of sediment would reduce habitat stability and heterogeneity.

On the other hand, in naturally unstable streams. shredders will already be absent and it is probable that only "common core" species occur. In such situations, forestry practices should have little effect on stream fauna, providing severe sedimentation is prevented.

New Zealand needs local management plans developed from local information. A survey technique such as this is the first step in assuring that both forestry and aquatic preservation goals become more compatible.

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Appendix I

Location, date sampled, forest type, physical and faunal characteristics of the 43 streams surveyed. Forest type: B = beech, PHB = podocarp-hardwood-beech, PH = podocarp-hardwood, P = pine plantation. Shredder abundance rating: 1 = absent, 2 = up to 3% of animal numbers, 3 = >3% of animal numbers.

Study site	NZMS 1 Grid reference	Date sampled	Forest type	Width (m)	Gradient (°)	Pfankuch stability rating	No. of taxa	Shredder abundance rating
North Island								
Jerry Stream (Trib.)	N44 101450	1/2/80	PH	0.5	8	101	11	2
Kahutarawa (Trib. #1)	N149 115233	23/1/80	PH	1.5	10	98	6	2
Kahutarawa (Trib. #2)	N149 106210	23/1/80	PH	0.8	2	60	6	3
Kirikiri Stream (Trib.)	N49 086215	31/1/80	PH	0.5	12	139	1	1
Mahakirau River (Trib. #1)	N44 057608	1/2/80	PH	0.3	15	122	3	1
Mahakirau River (Trib. #2)	N44 055606	1/2/80	PH	0.6	9	114	6	2
Mangamate Stream	N112 250811	13/2/80	PHB	1.0	5	97	12	3
Mangawhero Stream (Trib.)	N121 996597	13/2/80	PHB	4.0	15	72	18	2
Ohau Stream (Trib.)	N152 890986	14/2/80	PH	2.3	9	88	6	1
Patea River	N119 803584	17/2/80	PH	5.0	0.7	79	20	1
Retaruke River (Trib.)	N121 852682	13/2/80	PHB	0.7	0.5	72	6	3
Sparrow Stream	N44 068603	1/2/80	PH	1.8	8	147	4	1
Taruru Creek	N49 035305	31/1/80	PH	0.8	10	100	8	1
Tiritea Stream	N149 163257	22/1/80	PH	5.0	3	99	10	3
Tiritea Stream (Trib. #1)	N149 166254	22/1/80	PH	1.0	8	70	16	3
Tiritea Stream (Trib. #2)	N149 163249	22/1/80	PH	1.0	6	87	10	2
Te Popo Stream	N119 715611	17/2/82	PH	3.5	4	77	30	3
The Wash	N76 762010	12/2/80	P	0.5	1	122	6	1
Whalebone Creek	N44 010426	31/1/80	PH	2.2	4	99	7	1
South Island								
Ackland Creek	S91 790138	22/11/81	B	1.3	4	92	12	2
Andrews Stream (Trib.)	S59 265221	16/3/80	B	2.5	6	68	6	1
Blue Duck Creek	S49 048069	15/5/81	PH	4.5	1.5	90	20	1
Boakes Creek	S46 813863	21/5/81	B	1.5	15	80	10	1
Craigieburn Cutting Stream	S66 216030	15/3/80	B	2.0	11	128	16	1
Dog Stream	S54 207795	19/12/79	P	3.0	2	97	8	1
Forest Park Stream	S66 200034	10/4/80	B	1.3	15	93	11	3
Glentui River	S67 180954	17/12/81	B	5.0	1.5	69	14	2
Kaituna River	S84 095334	1/5/76	PH	4.5	5.5	84	32	3
Manson Creek	S66 225065	15/3/80	B	3.5	11	70	19	3
Manson Creek (Trib.)	S66 225056	15/3/80	B	1.5	15	134	5	1
Middle Bush Stream	S66 236173	15/3/80	B	1.0	23	90	14	3

Mikonui Stream	S59 798760	16/5/81	PH	1.5	3.5	76	19	3
Nature Walk Creek	S54 213798	19/12/79	B	4.0	8	75	7	3
Otira Creek	S59 056436	23/5/81	B	2.5	15	110	15	1
Palmer Creek	S49 922008	15/5/81	PH	3.5	23	60	16	2
Paterson Creek	S46 814894	21/5/81	B	3.0	10	107	10	1
Powerline Gully Stream	S38 256336	20/5/81	PHB	3.5	2	98	7	3
Rata Stream	S91 765133	23/11/81	B	8.0	12	127	5	1
Rough Creek	S46 700962	21/5/81	B	3.0	6	78	8	2
Tasman Smith Reserve Stream	S110 412591	15/1/82	PH	2.0	4	83	10	2
Trotters Creek	S146 295381	19/4/81	PH	5.5	0.4	99	20	2
Waterfall Creek	S54 212798	18/12/79	B	4.5	4	66	10	3
STEWART ISLAND								
Belltopper Falls Stream	Not available	11/11/81	PH	3	0.5	41	9	3

Appendix II. *Stream channel stability evaluation form.*

Item Rated	Stability Indicators by Classes							
UPPER BANKS	EXCELLENT		GOOD		FAIR		POOR	
Landform slope	Bank slope gradient <30%	(20)	Bank slope gradient 30-40%	(4)	Bank slope gradient 40-60%	(6)	Bank slope gradient 60%+	(S)
Mass-wasting (existing or potential)	No evidence of past or any potential for future mass-wasting into channel.	(3)	Infrequent and/or very small. Mostly healed over. Low future potential.	(6)	Moderate frequency and size, with some raw spots eroded by water during high flows.	(9)	Frequent or large, causing sediment nearly year-long OR imminent danger of same.	(12)
Debris jam potential (floatable objects)	Essentially absent from immediate channel area.	(2)	Present but mostly small twigs and limbs.	(4)	Present, volume and size are both increasing.	(6)	Moderate to heavy amounts, predominantly larger sizes.	(8)
Vegetative bank protection	90%+ plant density. Vigor and variety suggests a deep, dense, soil binding root mass.	(3)	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	(6)	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	(9)	<50% density plus fewer species and less vigor indicate poor, discontinuous and shallow root mass.	(12)
Channel capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	(1)	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8 to 15.	(2)	Barely contains present peaks. Occasional over-bank floods. W/D ratio 15 to 25.	(3)	Inadequate. Overbank flows common. W/D ratio >25.	(4)
LOWER BANKS								
Bank rock content	65%+ with large, angular boulders 12"+ numerous.	(2)	40 to 65%, mostly small boulders to cobbles 6-12".	(4)	20 to 40%, with most in the 3-6" diameter class.	(6)	<20% rock fragments of gravel sizes, 1-3" or less.	(8)
Obstructions Flow deflectors Sediment traps	Rocks and old logs firmly embedded. Flow pattern without cutting or deposition. Pools and riffles stable.	(2)	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	(4)	Moderately frequent, moderately unstable obstructions and deflectors move with high water causing bank cutting and filling of pools.	(6)	Frequent obstructions and deflectors cause bank erosion year-long. Sediment traps full, channel migration occurring.	(8)
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	(4)	Some, intermittently at outcurves and constrict-ions. Raw banks may be up to 12".	(6)	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	(16)
Deposition	Little or no enlargement of channel or point bars.	(4)	Some new increase in bar formation, mostly from coarse gravels.	(8)	Moderate deposition of new gravel and coarse sand on old and some new bars.	(12)	Extensive deposits of predominantly fine particles. Accelerated bar development.	(16)
BOTTOM								
Rock angularity	Sharp edges and corners, plane surfaces roughened.	(1)	Rounded corners and edges, surfaces smooth and flat.	(2)	Corners and edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	(4)
Brightness	Surfaces dull, darkened or stained. Gen. not "bright".	(1)	Mostly dull, but may have up to 35% bright surfaces.	(2)	Mixture, 50-50% dull and bright, ±15%, i.e. 35-65%.	(3)	Predominantly bright, 65%+, exposed or scoured surfaces.	(4)
Consolidation or particle packing	Assorted sizes tightly packed and/or overlapping.	(2)	Moderately packed with some overlapping.	(4)	Mostly a loose assortment with no apparent overlap.	(6)	No packing evident. Loose assortment, easily moved.	(8)
Bottom size distribution and percent stable materials	No change in sizes evident. Stable materials 80-100%.	(4)	Distribution shift slight. Stable materials 50-80%.	(8)	Moderate change in sizes. Stable materials 20-50%.	(12)	Marked distribution change. Stable materials 0-20%.	(16)
Scouring and deposition	Less than 5% of the bottom affected by scouring and deposition.	(6)	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)	30-50% affected. Deposits and scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly year-long.	(24)
Clinging aquatic vegetation (moss and algae)	Abundant. Growth largely moss-like, dark green, perennial. In swift water too.	(1)	Common. Algal forms in low velocity and pool areas. Moss here too and swifter waters.	(2)	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	(3)	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
COLUMN TOTALS								

Add the values in each column for a total reach score here (E___ + G___ + F___ + P___ = ___).

Reach score of: <38 = Excellent, 39-76 = Good, 77-114 = Fair, 115+ = Poor.