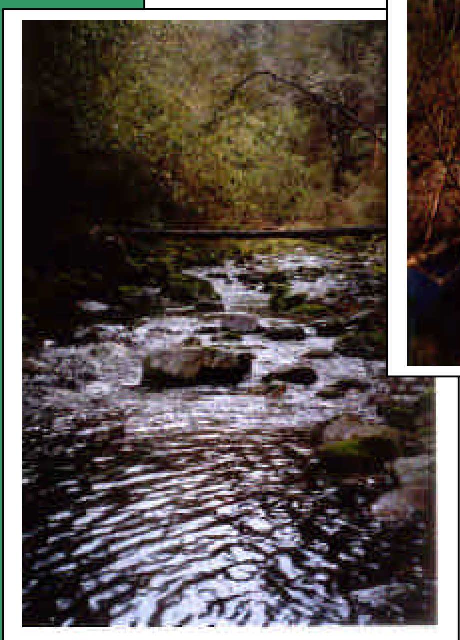
THE WEST COAST
REGIONAL COUNCIL

Final

The Effects of Stream Habitat Modification on the Life-Supporting Capacity in Farmland Streams on the West Coast



March 2002

THE WEST COAST
REGIONAL COUNCIL

State of the Environment
Technical Report # 02003

The Effects of Stream Habitat Modification on the Life-Supporting Capacity of Farmland Streams on the West Coast

A technical report presenting results of an investigation conducted from August – November 2001 into the effect of varying types and degrees of habitat modification on the ecological health of 1st – 4th order streams in the West Coast region. The report provides information on stream habitat, water quality, stream invertebrates and fish communities.

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Cover photos: Top left: Mosquito Creek, Rotomanu. Top right: Nicholas Creek, Taramakau Settlement. Bottom left: Souters Creek, Nelson Creek. Bottom right: Pidgeon and Puzzle Creek confluence.

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EXECUTIVE SUMMARY

West Coast Regional Council has basic functions under the Resource Management Act (1991) to protect and monitor the life-supporting capacity and natural character of wetlands, lakes and rivers and their margins as well as significant habitats for indigenous fauna and trout and salmon. The aim of this study was to compare the diversity and abundance of macro-invertebrates and fish in farmland streams of varying habitat condition caused by various activities. The study also aimed to estimate the regional extent of stream habitat modification in farmland.

Farmland streams were selected along with some reference forest streams chosen because:

1. There is relatively little existing information about fish biodiversity or the rate or extent of stream habitat modification in farmland streams on the West Coast.
2. Most of the activities that modify stream habitat are represented in farmland, particularly diary farmland.
3. Various activities associated with agricultural development in other regions have been found to cause very significant declines in native fish populations which suggests that there is a risk in this region also.
4. There is a large proportion of stream length potentially affected by agricultural land use.

Stream habitat was assessed using the following physical and chemical factors: channel and bank form, bank stability, bed substrate composition, water quality (conductivity, temperature and pH), and amount and type of riparian vegetation. On the basis of water quality measurements and knowledge of the location of point-source discharges, any polluted streams were excluded from sampling of macro-invertebrates and fish. Additional data from the National Fish Database and the West Coast Regional Council Macroinvertebrate Database were used in the analysis.

57.5 stream kilometres were assessed on 40 1st – 4th order, permanently flowing streams between August and October 2001. Periphyton percentage cover and the abundance and diversity of macro-invertebrate species were measured at all 40 streams. Fish abundance and diversity was measured at 28 sites.

For data analysis stream reaches assessed were divided into four disturbance classes (1 being the most highly modified), based on the following criteria: stream canalisation and straightening, amount of riparian vegetation that has been disturbed or removed and restriction of stock access.

Riparian vegetation associated with farmland streams approximately two thirds of the assessed streams was highly or moderately modified. Channelisation (evening of stream depth and width and battering of stream banks) was very common. Extensive straightening was only found in only two stream reaches. From observations the presence of significant trampling of the stream bed and banks appears to be highly correlated with farming type (eg. intensive dairy or extensive dry-stock farming). Rotational strip or mob-stocking seemed to give rise to the most extensive damage to the stream bed or banks. Fencing of cattle into narrow strips along the stream bank/beds was not common.

Macro-invertebrate diversity and abundance appears to be largely unaffected by stream habitat disturbance on the West Coast. This may because of recruitment by downstream drift from headwater tributaries and aerial colonisation from forested streams, which are never far from disturbed streams and/or bottom substrate is generally suitable.

Regardless of the degree of modification, most stream sites sampled sustained reasonable numbers and diversity of across all fish species. However, within a particular stream reach with disturbance class as 1, 2 or 3, there appeared to have poor communities of sensitive native fish such as Banded Kokopu, Shortjaw Kokopu, Giant Kokopu and Koaro. Trout communities appeared to be only affected by high to moderate levels of stream habitat modification. More information would be needed to determine the relationship between trout density and stream habitat modification and trout density and density of sensitive native fish.

The information produced in this study provides justification for consideration and implementation of measures that will better protect habitats of sensitive native fish from activities in the beds and riparian zones of small to medium-sized streams on the West Coast. Although farmland streams have been targeted in this study the same activities in other land use environments are likely to cause similar effects.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Objectives

The main objective of this study was to determine the extent to which different degrees of modification of the physical habitat of farmland streams, affect the life-supporting capacity (including biodiversity) of fauna such as macro-invertebrates and fish. The life-supporting capacity of waterways that are subject to stream habitat modification by activities such as land drainage by humping and hollowing, stream diversions and flood protection works, were compared with those that are little-modified or unmodified. This project did not attempt to determine the relative importance of the various functions of riparian vegetation such as stream light climate and temperature, in-stream carbon and food supply or filtration of contaminants such as nutrients and sediment in runoff on the streams assessed.

The project also aimed to assess the regional extent of stream habitat modification in order to determine the significance of the issue for resource management. Such information can be used to determine any changes to stream habitat over time. To determine these effects the following parameters were measured for each stream or reach of stream in an area:

- Broad scale catchment land use upstream
- Immediate land use beyond riparian zone at site
- Quality of riparian buffer
- Bank stability
- Channel alteration
- In-stream habitat/roughness/cover for Trout or native fish
- Substrate heterogeneity and quality
- Quality of periphyton (attached algae, fungi and bacteria)
- Macro-invertebrate diversity and abundance
- Fish diversity and abundance
- Water quality (chemical and physical parameters)

This study focused on farmland streams, as compared to reference native bush streams, for the following reasons:

1. The lack of existing information about fish biodiversity or the rate or extent of stream habitat modification in farmland streams on the West Coast.
2. Most of the activities that modify stream habitat are represented in farmland, particularly diary farmland.
3. Agricultural development have been found in other regions to cause very significant declines in native fish populations which suggests that there is a risk in this region also.
4. There is a large proportion of stream length potentially affected by agricultural land use.

Legislative Responsibility

The Resource Management Act 1991 gives regional councils clear responsibility to manage issues of resource use that potentially affect aquatic biodiversity. The underlying purpose of the Act (Section 5) requires that *the use, development and protection of natural and physical resources be used in a way or a rate which … safeguards the life-supporting capacity of water and ecosystems.*

Section 6 considers matters of national importance: *s6(a) "preservation of natural character of … lakes rivers and their margins and protection of them from inappropriate use and development", S6(e): Relationship of Maori and their culture and traditions with ancestral lands, water.* Matters in section 7 that are relevant are: *S7(c): Maintenance and enhancement of amenity values, S7(d): Intrinsic values of ecosystems S7(f): Maintenance and enhancement of the quality of the environment, S7(h): Protection of the habitat of trout and salmon.*

The Resource Management Act (1991) also charges individual resource users with using resources in a sustainable way (as described by the section 5 definition above).

The West Coast Regional Council Regional Policy Statement addresses the issue of changing ecosystems and decline of some indigenous species (Issue 9.2) with the following policy (Policy 9.2): *Recognise and provide for the protection of significant indigenous vegetation and significant habitats of indigenous fauna. Significance is defined by the following relevant matters: (l) the contribution of an area or habitat to the maintenance and enhancement of ecological and reproductive processes, (n) whether they occur near wetlands and (o) the importance of migratory species such as whitebait.*

Information about how stream habitat modification affects this life-supporting capacity is required to be taken into account in relevant plans such as the "Proposed Land and River Bed Management Plan". This feedback will ensure that regulation as part of the plan is effects-based and appropriate, that is, land use activities will not be unnecessarily restricted.

In addition to West Coast Regional Council's responsibility to maintain the life-supporting capacity of stream environments, the Department of Conservation has special legal responsibility under the Fisheries Act to manage native fish species (by controlling commercial or recreational whitebait fishing), and the NZ Fish and Game Council has statutory responsibility to maintaining the population of sport fish. Fish & Game West Coast believe that the quality and quantity of habitat for sport fish on the West Coast is integral in this process.

The West Coast Regional Council's Regional Monitoring Strategy ranked the issue of "Surface Water - Aquatic Ecology" as priority 11 out of 25 SOE monitoring issues. This is an equal priority to "groundwater quality" for which there has been a significant monitoring effort.

Background

Throughout the world, river and stream ecosystems have been modified by human activity, possibly more so than any other type of ecosystem (Allan and Flecker, 1993). Changes in the landscape due to deforestation, drainage of wetlands and farmland, grazing, water abstraction, impoundment and the introduction of exotic species have influenced watersheds directly and indirectly in many countries for several millennia (Allan, 1995) and in New Zealand for over 100 years. These changes, especially the loss of riparian vegetation and wetland drainage have had profound effects on rivers, streams and wetlands and their ecologies (McDowall, 1996). Some freshwater fish species seem ill-adapted to cope with these changes, and as a result, about 25% of the native fauna is now a conservation concern. Physical stream habitat disturbance can cause long-term and severe impacts on stream biodiversity (e.g. Gregory et al, 1991).

"Stream habitat" is defined as the whole stream environment including the streambed, banks and land use in the immediate vicinity of the stream (riparian zone). It includes physical and chemical factors such as channel and bank form, bed substrate composition, water quality and quality of riparian vegetation.

The forms of stream habitat modification on the West Coast that have the greatest potential to disrupt aquatic biodiversity are those associated with land drainage such as humping and hollowing, stream diversions and flood protection works. Activities like these can produce widening, deepening, channel re-alignment/straightening, clearing the riparian vegetation or stream channel of debris, and reshaping stream banks.

Riparian zones are the three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems. Intact riparian zones have been described as being the most diverse, dynamic and complex biophysical habitats on the terrestrial portion of the earth' (Naiman et al, 1993). Their location at the land-water interface and the biophysical processes they promote, enable the management of the relatively small amount of land in riparian areas to have a disproportionately large role in controlling the broader catchment activities on stream and downstream aquatic ecosystems (Collier et al 1995). Shading of streams is widely recommended for control of excessive growth of aquatic plant and maximum water temperatures. Trees, shrubs and tussock along waterways will increase supplies of terrestrial carbon to streams (including food supply for fish and macroinvertebrates) and increase the diversity of habitat of native plant and animal communities (Collier et al, 1995). Grazing animals, particularly cattle, can directly affect many of the erosion processes by trampling or browsing the bank tops base and sides. Very high stocking densities sometimes found in rotational strip and mob grazing practices are expected to damage stream beds and banks even if the soils are cohesive. National guidelines have been developed to address the above issues and have achieved widespread adoption throughout New Zealand (Collier et al, 1995). Many regional councils have published their own riparian management guidelines or strategies. Riparian restoration projects are now becoming common in many parts of the country. The costs of restoring stream habitat once it has be modified are much higher than consideration of such factors at the time of land development.

Native fish species, such as the Giant and Short-jawed Kokopu, that are common in many places on the West Coast, are rare on a national scale. Such species, with the inclusion of Banded Kokopu and Koaro, are considered to be "sensitive natives" and are members of the *galaxiid* family. Under the influence of habitat modification, introduction of exotic species and fisheries exploitation, the national conservation status of native fish species, such as many of the *galaxiid* family, has been affected, sometimes severely (McDowall, 2000).

Habitat degradation and introduced trout both have the potential to negatively impact galaxiids (McIntosh, 2000). It is unknown whether the same population decline in sensitive native fish is occurring in the West Coast region.

Table1.1 Threatened Fish Species Categories (Tisdall, 1994)

Threatened Species Category	Fish Species
A - highest priority species for conservation	Short-jawed Kokopu
B – second highest priority species for conservation	Giant Kokopu, Dwarf Inanga, Brown Mudfish, Canterbury Mudfish,
C - third highest priority species for conservation	Koaro, Banded Kokopu, Black Mudfish, Long-jawed Kokopu, Tarndale Bully.

Most of the sensitive natives found on the West Coast are migratory and the distribution is controlled by the natural factors of distance from the sea, elevation and natural barriers to fish passage as well as by human factors such as artificial barriers to fish passage, habitat modification, introductions of exotic species (eg trout), fisheries exploitation (McDowall,1996 and 2000). The habitat of sensitive native fish is well known to require instream and riparian vegetation cover to protect themselves from prey and to supply terrestrial invertebrates that make up a high percentage of the diet of these fish, particularly for Banded and Short-Jawed Kokopu (McDowall R.M., 2000). Such vegetation cover is found to a much greater extent in smaller streams (less than 2m wide). These kokopu are much less likely to be found in larger streams with low percentages of vegetation cover. In-stream cover, when present in natural streams or highly modified drains on the West Coast, is known to be preferred by Giant Kokopu (Bonnet, ML 2000). Wood that is retained within the stream and other debris has been well demonstrated to be very important for Giant Kokopu and other sensitive native fish (McDowall R.M. 2000; Bonnet, ML 2000). Table 1.1 below shows the categories for threatened native fish species.

Modification of stream habitat in the process of agricultural development has certainly led to substantial declines in native fish populations in New Zealand (eg Hanchet 1990, Rowe et al 1999, McIntosh and McDowall *pers comm*. 2002).

A study at Boatmans Creek, a tributary of Lake Haupiri, prior to a alluvial gold mining, showed very high numbers of Koaro (57 counted in a 100m reach) in part of the creek that flowed through a small, unfenced paddock used for extensive cattle grazing (van Dyk L and Hole N, 2001). The in-stream habitat may be enhanced by native forest being in close proximity (several hundred metres upstream of the sampled reach). Moderate to poor riparian condition exists at the sampled reach itself (some overhanging tussocks) but diverse substrate composition channel form are apparent.

The sensitive native fish, Koaro, appeared not to recover for at least one year after a diversion associated with alluvial gold mining activity was made operative in the, mountain-fed, Big Hohonu River, near Taramakau (Eldon G.A. et al, 1989). Recovery of macroinvertebrate density and diversity in streams appeared to occur within 91 days of the diversion channel being fully operative. Suspended sediment produced by mining and logging activities may have caused low fish diversity and changes in fish abundance one year after mining in Redjacks Creek, near Ngahere (Jowett, IG et al, 1996). Differences in fish abundance in the three land-use categories were often attributable to differences in physical habitat.

The introduction trout in the 1880's coincided with declines in native fish populations (McDowall, 2000). Trout consume sensitive natives when they reach a size of 130-160mm or more and favour more stable streams (McIntosh, 2000). Sensitive native fish are adapted to both stable and less stable stream environments.

Streams in farmland on the West Coast make up a reasonably large proportion (22% of lowland streams and 10% of spring-fed streams amounting to almost 3000km of stream) of all streams in the region (National Institute of Water and Atmosphere, 2001). The total riparian forest within farmland in the region is 1,195 ha or 0.8% of the total farmed floodplain area (Miller, 2001). The total floodplain area on the West Coast is 151,023 ha or 6% of the total regional land area. The percentage of wetlands in the region including riverine riparian wetlands have also declined in recent years. However this decline has been much less than in other regions (Gerbeaux, P 2002). From a register of Regional Council administered flood protection and drainage schemes it is known that there are approximately 220 km of stop-bank and approximately 2000 km of drains in the region (West Coast Regional Council, 2001).

Information about fish and stream habitat is often provided as part of resource consent applications for more significant stream diversions for alluvial gold mining operations. Information about streams of high conservation value are regularly gathered by Department of Conservation. Timberlands West Coast Ltd has embarked on a programme to collect such information before and after clear-felling in their forests. Information about extent of stream habitat modification and fish distributions in urban streams is very limited. Such streams make up a small proportion of all streams in the region.

To date the 'State of the Environment' monitoring of rivers and streams undertaken by West Coast Regional Council has focused on water quality and quantity. No regional baseline stream habitat monitoring has been ever been carried out on the valley-segment scale (i.e. 500m to several km of stream). Very limited information exists about fish distribution patterns in farmland on the West Coast. To accurately assess the effects of habitat disturbance, it is important to assess stream habitat at this scale.

Figure 1.1 Woody debris – a key habitat requirement for many sensitive native fish. Orangipuku Stream, near Inchbonnie.

2. METHODS

2.1 Site Selection

Only 2nd – 4th order, hill, lowland or spring-fed streams were chosen for sampling (with the exception of spring-fed streams, where 1st were also assessed). This was because these streams have been found to be the most sensitive to stream habitat modification. Sites were chosen largely on a stratified-random basis Streams were chosen to represent a range of different disturbance classes, source of flow types, and geological classes. Access difficulties restricted the use of some sites. Streams with the following conditions were excluded from the analysis: intermittently flowing streams (due to lower fish values), tidal streams (due to differences in ecological communities in saline or brackish waters) and streams with poor water quality (due to sensitivity of certain fish and invertebrates).

Most sites assessed were low-gradient streams in farmland. The only exceptions were reference sites in native bush catchments and two stream diversions associated with an alluvial gold mining operation, one of these having a steep cascade section.

Some of the sites had been sampled for fish and habitat in the past. Resampling at sites with high and low fish density or diversity were chosen. For example Molloy Creek tributary was classified in the top 20 electric fishing records (number of trout fry/m^2) from the West Coast Fish and Game Council.

The majority of sites selected were within 20 stream kilometres of the sea and all the sites were within 80 stream km of the sea which is well within the range of the majority of fish species. At a few sites Giant Kokopu may be near the inland part of their range (over one standard deviation from the mean distance inland; McDowall, 1996). All sites selected were of low elevation/gradient throughout the stream to the sea.

2.2 Sampling

Fieldwork was carried out between August and October 2001. There was relatively low rainfall in the period prior to and during most of the sampling. In the last 2 weeks of fieldwork (electrofishing) there were two rainfall events of approximately 30mm in 24 hours. Given that many of the streams sampled after these events were spring-fed, the effect of this rainfall is likely to be minor. Seventy-nine sites (Appendix 1.0) were assessed in 40 streams on the West Coast, from Birchfield in the north to Whataroa in the south, for a variety of stream habitat and biological parameters. See Appendix 1.0 for maps of all sampling sites. Sites comprised of a 500m to 1km reach with a total of approximately 57.5 km assessed. In deeper streams or streams with poor access or with thick riparian vegetation, a kayak was used for the assessment and sites were aggregated into 1km sections.

2.2.1 Stream Habitat Assessment

Stream habitat was assessed using a stream habitat assessment form modified from the one used by National Institute of Water and Atmosphere and Meredith et al (2001, unpublished) (Appendix 2.0). This system has been used extensively in Canterbury by Environment Canterbury and the National Institute of Water & Atmospheric Research (NIWA). The stream habitat at each site was assessed visually and included the assessment of macro- and microscale habitat parameters. Parameters assessed were: catchment land use, quality of riparian vegetation, bank cover. Riparian and bank features, reach scale parameters and in-stream habitat quality parameters were assigned a score 1-10 or 1-20 and were assessed as either being "poor", "marginal", "suboptimal" or "optimal". Photographs were also taken at each reach assessed and an extensive photographic record was produced and geographically referenced for all sampling sites. Water quality was measured at the downstream end of the sites using a WTW Multimeter. The quality parameters were conductivity, temperature and pH. Streams with poor water quality, high percentages of filamentous periphyton cover or presence of significant point-source discharges upstream of sampling, were excluded from the analysis.

To ensure quality results, habitat assessors were trained five days in groups or pairs to remove subjectivity and to "calibrate" the assessors. Subsequent to this stream habitat assessment were peer reviewed by West Coast Regional Council staff approximately every 10th assessment to ensure standardisation.

2.2.2 Biological Sampling

In conjunction with stream habitat, macro-invertebrates were collected at selected sites. Samples were collected in the runs of assessed reaches, using the semi-quantitative kick net method in a stream run developed by Stark (1993). Macro-invertebrate samples representing sites in unmodified streams and those in highly modified streams were selected and were sent to the Cawthron Institute for sorting and identification. Macro-invertebrates were identified to the genus or species level and counted. Each taxon was allocated a coded abundance or either rare (0-4), common (5-19), abundant (20-99), very abundant (100-499) or very very abundant (500+). The biotic indices of taxonomic richness, EPT (Ephemeroptera, Plecoptera, Trichoptera) richness, Macro-invertebrate Community Index (MCI) and semi-quantitative MCI (SQMCI) were also calculated for each site. The macro-invertebrate results used were from samples taken during this project as well as from the Regional Council database. It is assumed that data from previous years will be appropriate for current samples, as long as taken on the same site and same time of year.

The abundance and diversity of fish at 28 sites on 28 streams was measured by electrofishing, carried out between 2-10-2001 and 17-10-2001. The work was carried out with the help of certified electric fishing personnel from the West Coast Fish and Game Council and University of Canterbury. Electrofishing is not possible in streams that are either too wide, too deep or too small. During electrofishing a current of 200-600 Volts is applied to the water, which stuns the fish nearby. A main set as well as a Kianga 300 backpack was used but electrofishing results from using backpack and generator will be processed together during the data analysis, as they were the same. For each assessed stream, a reach of 150 to 200 m^2 was fished, selected at each site including a range of stream habitat, which was judged to be representative of the whole stream. A stop-net (0.5 mm mesh size) was positioned at the bottom of the reach to prevent fish escape and each reach was electric fished twice. Fish captured were identified to species level, measured to the nearest 0.1 cm and returned live at the point of capture. Fish species and abundance was recorded for each site. It is assumed is that no fish escaped upstream during the sampling. Restrictions to fish passage were also recorded.

2.3 Data analysis

The data acquired were recorded in a database and possible relations between various stream habitat parameters scored and abundance or diversity of macroinvertebrates and fish was established by charting in MS Excel using confidence intervals of 95%.

Electrofishing-data

For the purpose of this study only the 28 sites of the 79 where both stream habitat assessment and electrofishing were done, were used in data analysis. Fish density (number/m^2) was calculated for each site as well as presence/absence data.
The different fish species were reduced to the categories brown trout, native fish, sensitive native fish and those categories were used for data processing (Table 2.1).
Fish distribution in the Lake Brunner area could be influenced by the presence of the Arnold River dam. This dam restrains fish from migrating towards see, which could affect the abundance of fish in the streams in this area. However, it is known that land-locked populations of sensitive native fish such as Koaro and Giant Kokopu do reside in the Lake Brunner catchment so these sites were included in the analysis.

Table 2.1 Composition of fish groups used to analyse electrofishing-data

Trout	Non-sensitive Native fish	Sensitive Native fish
Brown trout	Lamprey	Giant Kokopu
	Mudfish	Banded Kokopu
	Common Bully	Koaro
	Redfin Bully	Short-Jawed Kokopu
	Bluegill Bully	
	Inanga	
	Dwarf Galaxias	
	Torrentfish	

River Environment Classification

The River Environment Classification (NIWA 2001) was used to gain information about order of stream, geology and source of flow. After dividing all streams in groups with the same source of flow, geology and order however, no clear relations were found with certain habitat-parameters.

Disturbance classes

Channel and bank form and condition, amount of riparian vegetation and extent of restriction of stock access to streams were assessed at each stream site and were selected as those considered the most important variables with which to classify streams based on physical disturbance. Four stream disturbance classes were established using information on channel alteration, quality of riparian vegetative buffer and bank stability and extent of fencing. To separate stream sites into disturbance classes, the scores for riparian and bank assessments at each site were compared to the scores of reference sites provided by Department of Conservation. The criteria developed for the four stream disturbance classes are given in Table 2.2:

Table 2.2. Criteria for four disturbance classes

CLASSIFICATION CRITERION	CLASS 1: HIGHLY MODIFIED	CLASS 2: MODERATELY MODIFIED	CLASS 3: SLIGHTLY MODIFIED	CLASS 4: LITTLE OR NO MODIFICATION
Stream canalisation and straightening	> 70%	25-70%	10-25%	<10%
Amount of riparian vegetation that has been disturbed or removed	>70%	25-70%	10-25%	<10%
Restriction of stock access (pastoral areas)	<10%	10-70%	70-90%	>90%

In-stream habitat values and biological parameters were compared between the four stream disturbance classes to investigate the effects of different degrees of land development on West Coast streams. The presence of trampling by stock in waterways and riparian areas is shown in Appendix 5.0.

<u>Periphyton and substrate</u>
To score periphyton (percentage cover) and substrate of the streambed the program used was SHMAK (Biggs BJF et al 1998) which scores 1-50 with 50 for the 'best' stream condition and 1-20 with 20 for the 'best' streambed condition. (Appendix 3.0 and 4.0).

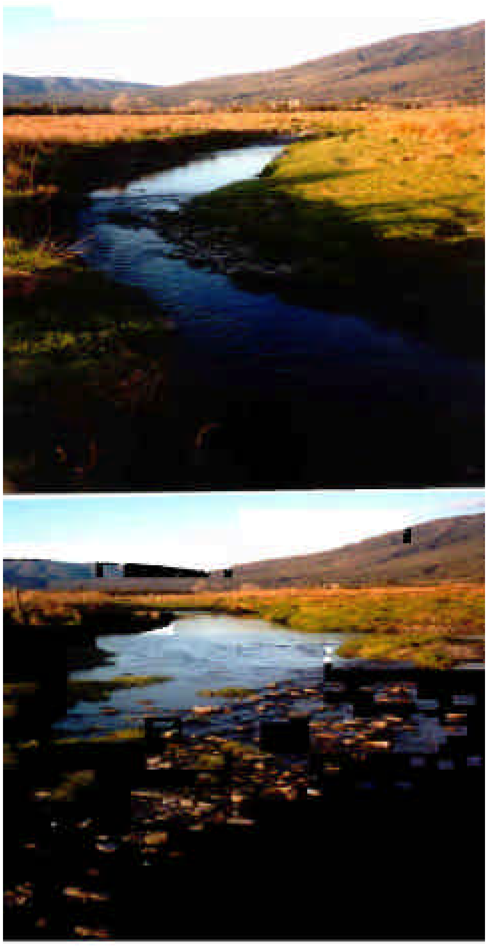

Figure 2.1 Puzzle Creek, disturbance class 1.

Figure 2.2 (above) Pidgeon Creek, Disturbance class 1.

Fig 2.3 Orangipuku River, disturbance class

3. RESULTS

3.1 Stream Habitat

Riparian vegetation associated with farmland streams approximately two thirds of the assessed streams was highly or moderately modified. Channelisation dredging of the stream to create an even depth and width and battering of stream banks was common but significant straightening of streams was only found in two cases (Mosquito and Arthur Creeks). Both these channel works were carried out more than 15 years ago. Other stream straightenings in small to medium-sized creeks that the Council is aware of but were not investigated were Muddy and Unnamed Creeks, Haupiri and Duffers Creek, Totara Flat and a tributary of Ellis Creek, Waitaha.

Very few creeks in the dairy farm environment were effectively fenced to exclude cattle. More than half the creeks surveyed had fencing on one side. The presence of significant trampling of the stream bed appears to be highly correlated with intensive dairy farming. Fencing of cattle into narrow strips along the stream bank was not common. The intensity of dairy farming appears to be correlated with significant trampling in the bed or banks of streams or slumping of banks produced by trampling (see Appendix 6.0). While the extent of trampling was recorded by general observation (no measurements of hoof-print density were taken), it was generally apparent that in creeks that are largely unfenced for most of their length extensive dry-stock farming caused much less trampling than rotational strip or mob stocking dairy cattle. Puzzle Creek is a good example of this, where, in the upper reaches there is intensive dairy farming use and in the lower reaches there is extensive dry-stock farming. Part of the lower reaches of Pidgeon Creek (a tributary of Puzzle Creek) were used as a cattle race that resulted in very significant trampling and damage to banks. Dry stock farming did result in significant trampling in the spring-fed tributary of Molloy Creek. This may be due to higher stocking densities than is general for dry-stock farming. Murray Creek had good fencing for much of its length and the amount of significant trampling was very low.

Of the 57.5 km of stream assessed, approximately 20.5 km (36%) of streams had less than 5% good quality riparian vegetation on both banks. A further 3km of stream had marginal (less than 20% good quality) riparian vegetation on both banks making a total of 41% of streams.

Modified spring-fed streams often had prolific growth of aquatic plants rooted in the bed. There was very little woody debris in many pasture streams. In hill-fed pasture streams channels were generally narrower and more deeply incised than stream-fed or forested streams.

3.2 Stream disturbance classes

The total habitat score contains the total average of all questions in the Stream Habitat Assessment sheets (Appendix 5.0) and the SHMAK scores of periphyton and substrate.
The total habitat score for all 28 sites ranged between 45.7 and 223 (the highest score being the least modified). The average score per group is shown in Figure 3.1.

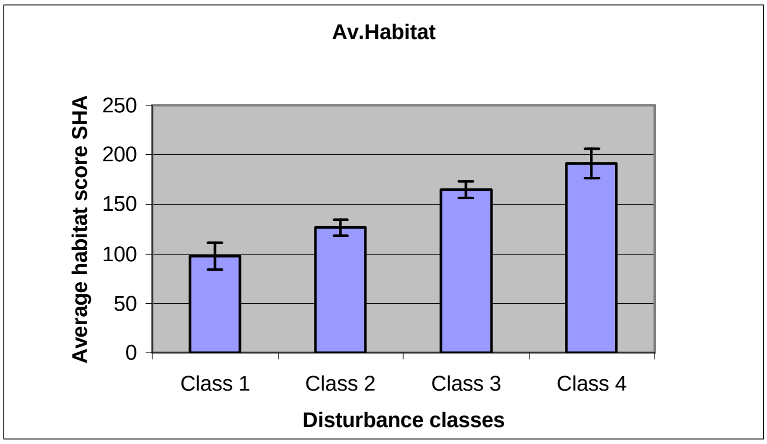

Figure 3.1. Differences in total habitat scores (mean ? Standard Error p=0.05) between four stream disturbance classes.

Distinct differences in total habitat scores were found between all four disturbance classes, with the two less modified classes of three and four scoring 164.9 and 191.4 respectively, and more disturbed classes of one and two scoring 97.7 and 126.8 respectively.

Similar patterns were found when stream habitat was examined in more detail. Reach scale and in-stream habitat features all scored higher in the less modified disturbance class four than disturbance class one streams (Figures 3.2-3.8). Reach scale features included channel alteration, frequency of riffles and channel sinuosity and were considerably worst in highly modified class one streams. Channel alteration did not appear to differ greatly between classes two, three and four, with mean scores ranging between 16-18 out of 20 for the three groups (Figure 3). The mean score for class one sites was considerably lower (score: 11) and suggests that a high percentage of streams in this class have had their channel and streambed altered.

The following results show the validity for analysing the results using the various disturbance classes outlined in the methods section.

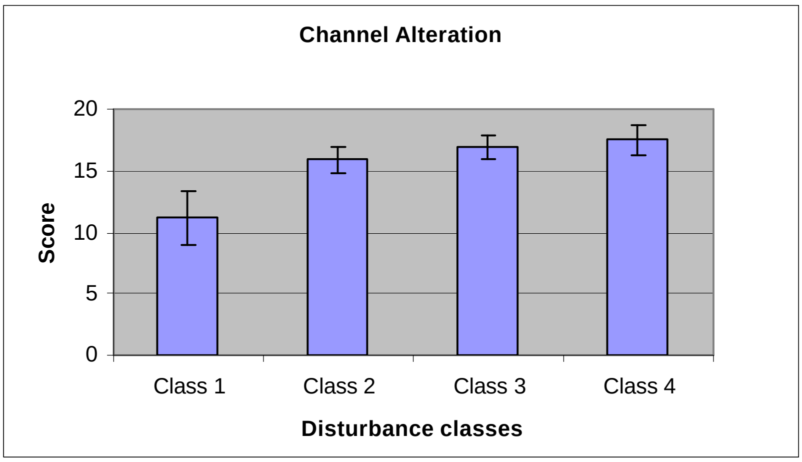

Figure 3.2 . Differences in channel alteration scores (mean ? SE, p=0.05) between four stream disturbance classes.

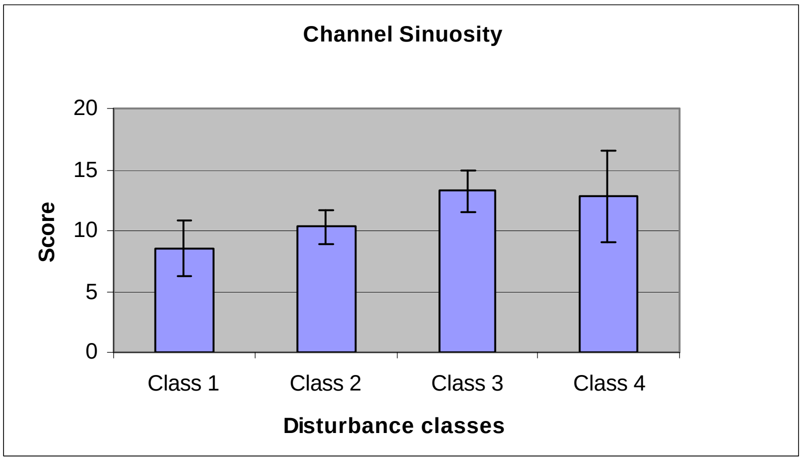

Figure 3.3. Differences in channel sinuosity scores (mean ? SE, p=0.05) between four stream disturbance classes.

The difference in channel sinuosity between groups was less clear but still showed a difference between the less disturbed class four (score: 13) and the highly modified class one streams (score: 9) (Figure 3.3). The small difference between classes was most likely due to the nature of channel straightening in disturbed streams. Streams are often only straightened for short distances and this can vary greatly between farms and different streams. Over a valley segment scale (the scale used in this assessment) few streams do not have a semi-natural to natural meandering pattern.

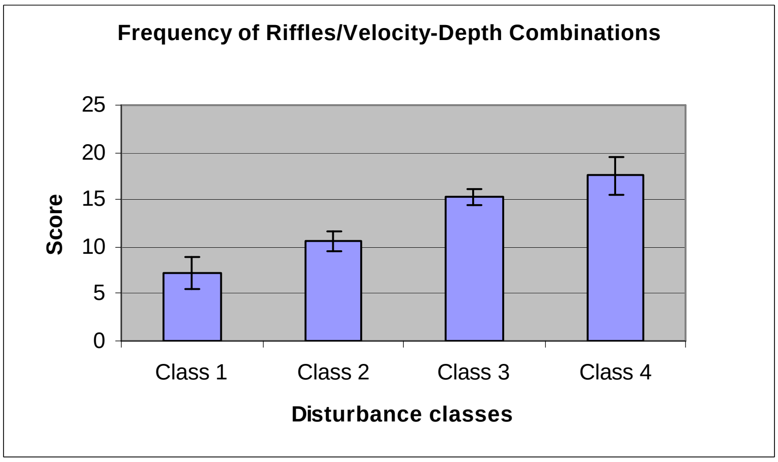

Figure 3.4. Differences in frequency of riffles/velocity depth combination scores (mean ? SE, p=0.05) between four stream disturbance classes

Frequency of riffles/velocity-depth combinations showed a more distinct difference between the four groups, with class one scores averaging 7 out of 20 and class four stream scores averaging 18 (Figure 3.4). This result supports the scores for channel alteration above. Streams that have been channellised have uniform width and depth, which reduces velocity-depth combinations.

In-stream habitat quality parameters were also assessed at each site and included the assessment of habitat cover for trout and native fish, siltation/ embeddedness and sediment deposition. All of these parameters showed the same pattern (Figures 3.5-3.8). The scores for less disturbed sites (class three and four) were consistently higher than those for classes one and two. Results from this study indicate that streams with a good vegetative buffer between surrounding land use and the streambed have scores between 11 and 20 (suboptimal-optimal) in-stream habitat/cover/roughness for trout. Streams in relatively undeveloped valley segments have bed substrate favourable for trout and native fish, hardly any siltation and stable streambeds.

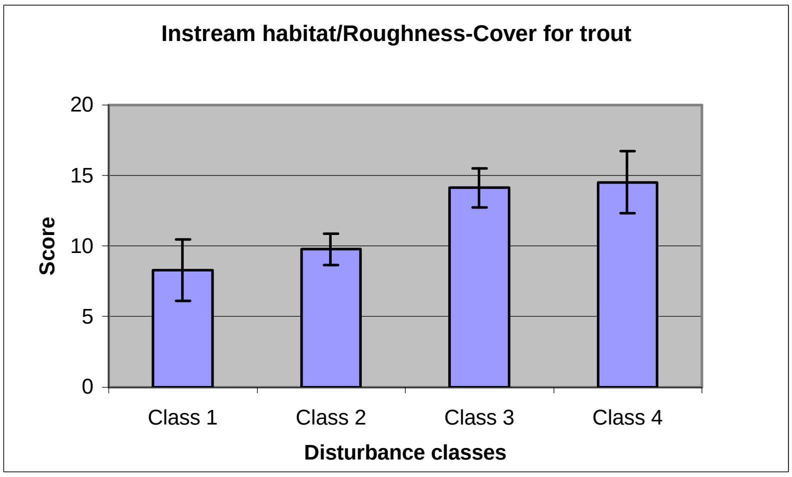

Figure 3.5. Differences in in-stream habitat for trout (mean ? SE, p=0.05) between four stream disturbance classes.

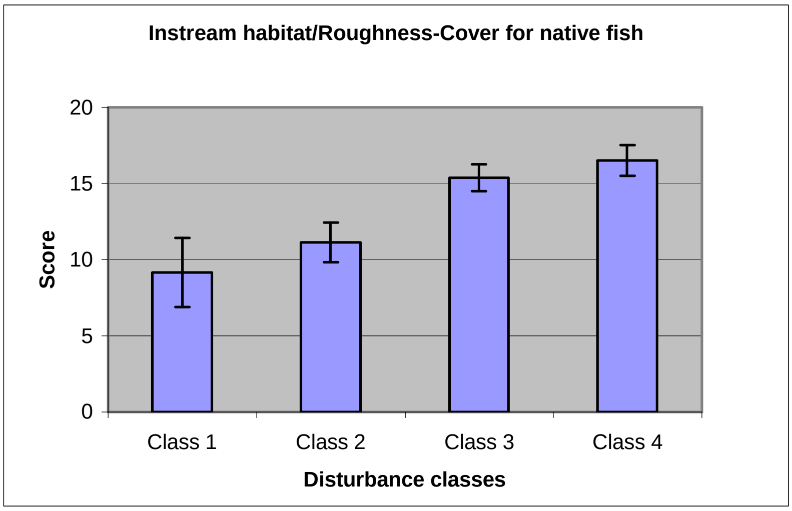

Figure 3.6. Differences in in-stream habitat for native fish (mean ? SE, p=0.05) between four stream disturbance classes.

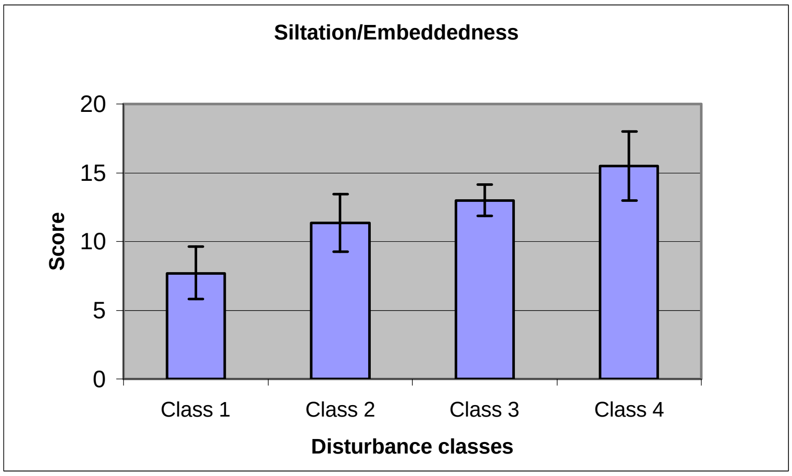

Figure 3.7. Differences in siltation/embeddedness scores (mean ? SE, p=0.05) between four stream disturbance classes.

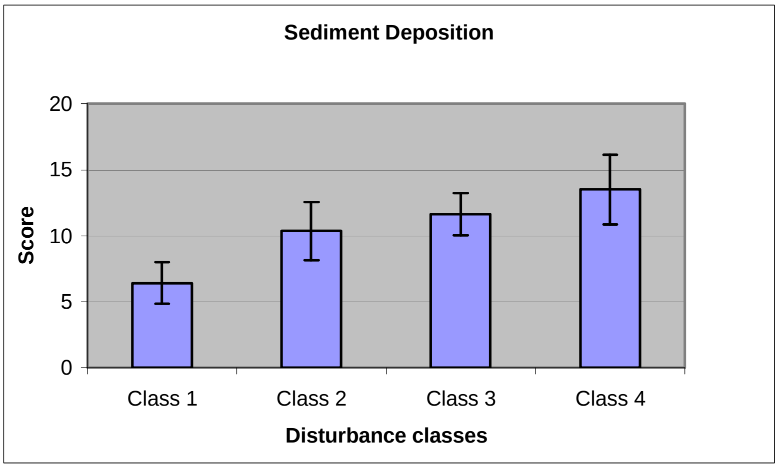

Figure 3.8. Differences in sediment deposition scores (mean ? SE, p=0.05) between four stream disturbance classes.

Periphyton-scores differed little between the four stream disturbance classes (Figure 3.9). All results suggest either: low nutrient concentrations, intensive grazing by in-stream insects, low temperature (sampling time was during seasonal low temperatures), low light conditions produced by riparian canopy cover or a combination of these factors. Canopy cover was strongly correlated with disturbance classes and this explains the similarity in the periphyton scores between classes (ranging between 1 and 10). Streams in all four classes had optimal periphyton cover consisting mainly of thin brown film on stones.

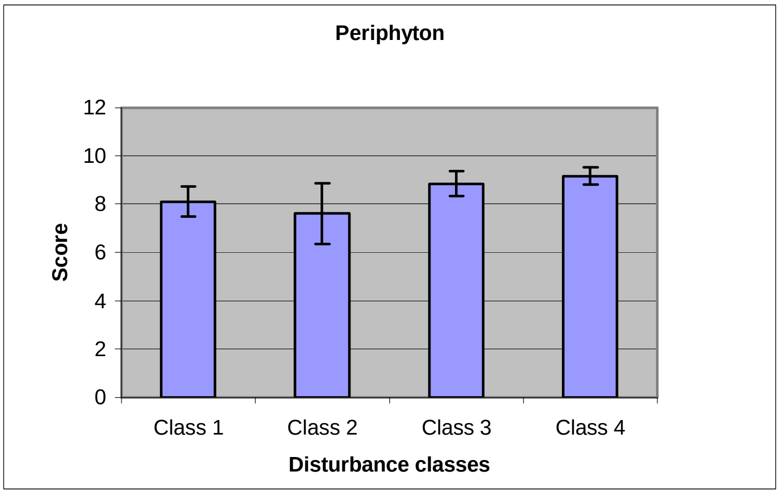

Figure 3.9. Differences in periphyton scores (mean ? SE, p=0.05) between four stream disturbance classes.

3.3 Fishdata

Fish densities were similar across the four stream disturbance classes, ranging from 0.228-0.316/m^2 (Figure 3.10). These results suggest that total fish densities vary little between streams with different degrees of disturbance.

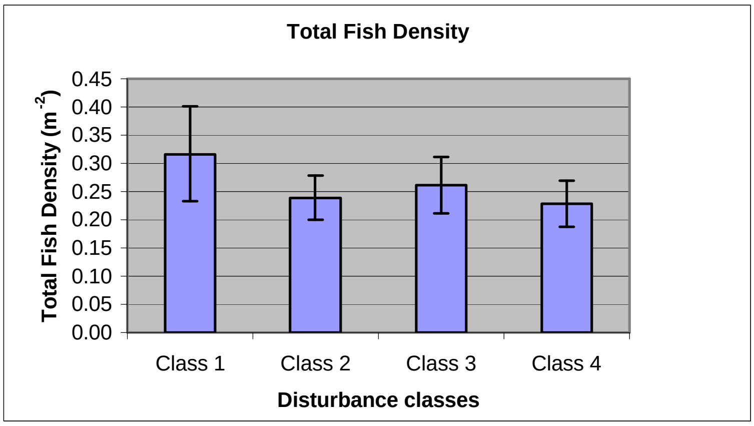

Figure 3.10. Differences in fish densities (mean ? SE, p=0.05) between four stream disturbance classes

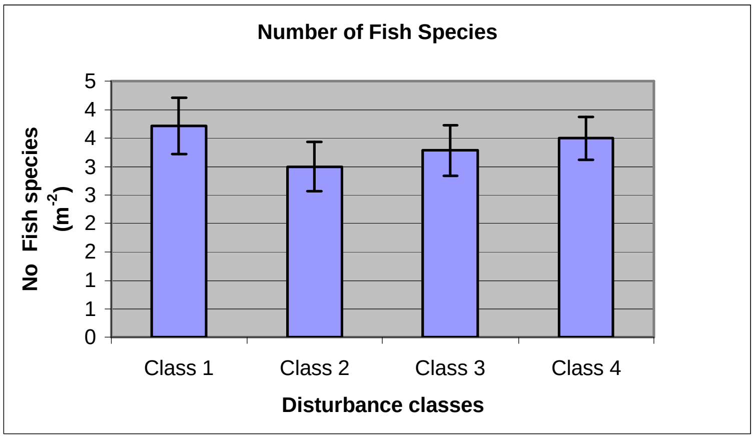

Figure 3.11. Differences in the number of fish species (mean ? SE, p=0.05) between four stream disturbance classes

The number of fish species showed a similar pattern to that of fish density. The number of fish species was similar across all four stream disturbance classes, ranging from 3.0-3.8/m^2 (Figure 3.11). The small differences in fish density and number of fish species across the disturbance classes suggests that, regardless of the degree of modification, most stream sites had stream habitat conditions sufficient to sustain reasonable numbers and diversity of total fish species. The fish population was dominated by bullies but more were found in Class 1 and 2 streams. Bullies occupy a large range of habitats (they are not particularly sensitive and can live in all 4 classes).

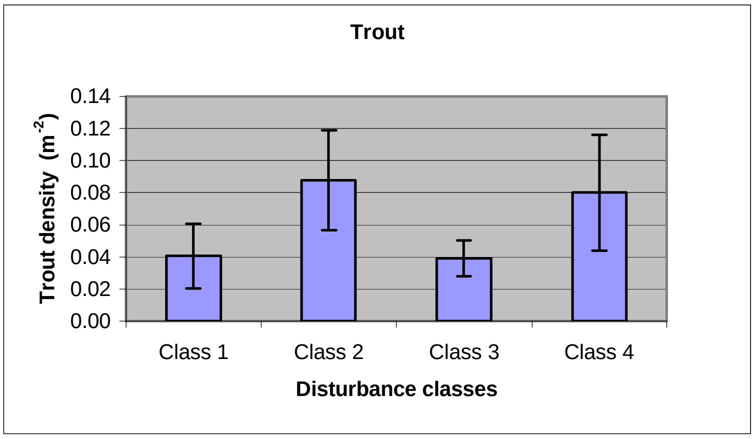

Figure 3.12. Differences in trout densities (mean ? SE, p=0.05) between four stream disturbance classes

Trout numbers in disturbance classes two (0.088/m2) and four (0.080/m2) were higher than those found for classes one (0.041/m2 and three (0.039/m2) (Figure 3.12). Although mean trout density was higher in class 4 and 2, there was no significant relationship with this factor and the various disturbance classes.

More information would be needed to determine the relationship between trout density and stream habitat modification. It could be that the high number of trout in Class 2 streams is due to trout migration from spawning areas rather than resident trout. Most of the fish caught were juvenile trout (40-50mm), which is the age/size that could be migrating down the catchment. However, this could also be due to the electric fishing methods that tend to catch more of the smaller trout than larger adults. It may also be that there are several streams in class 2 that have rip-rap flood protection works that are known in other regions to be useful habitat for adult trout. From analysis collected in this study, substrate and embeddedness did not appear to important factors in explaining trout density.

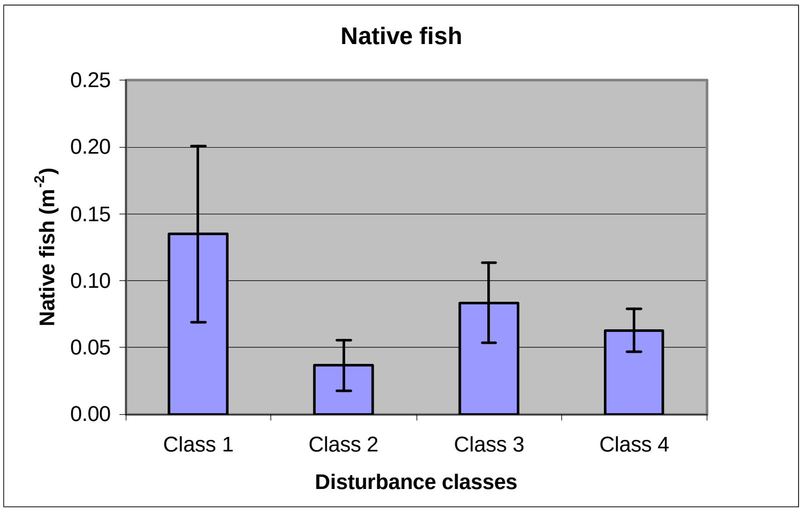

Figure 3.13. Differences in native fish densities (mean ? SE, p=0.05) between four stream disturbance classes

Differences in native fish communities appeared to be inverse to those found for trout. Native fish numbers in classes one (0.135/m2) and three (0.083/m2) were higher than those in classes two (0.037/m2) and four (0.063/m2) (Figure 3.13). The higher trout numbers in classes two and four may be displacing (through predation) some native bullies present in these streams. The bullies, that can tolerate a wide range of stream habitat conditions, may therefore be related more to trout density in streams than to certain levels of disturbance in habitat.

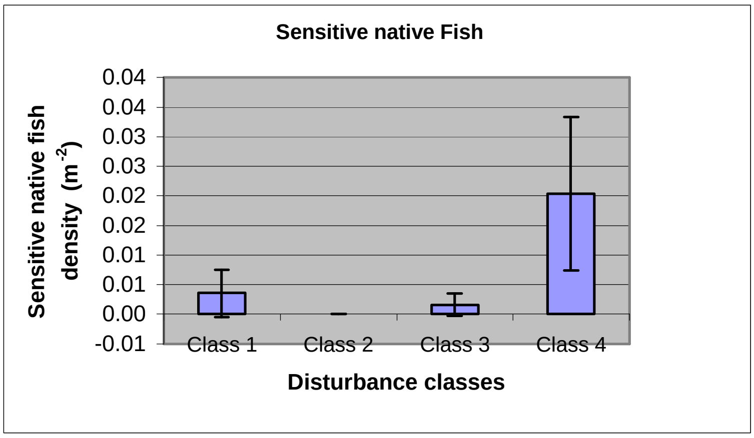

Figure 3.14. Differences in sensitive native fish densities (mean ? SE, p=0.05) between four stream disturbance classes

Sensitive native fish were found at a total of 9 sites. Koaro was the most common being found at 6 sites. Giant Kokopu were found at four sites including Fan Ck (near Birchfield), Lake Stream (near Fairdown), Molloy Ck (near Kotuku), and Three Mile Ck (Greenstone). Banded Kokopu were found in Lake Stream and Fan Ck. The only Short-jawed Kokopu recorded in the area under investigation was in Lake Stream.

Sensitive native fish density (Figure 3.14) showed a different pattern from the fish groups above. Sensitive fish density was highest in class four streams ($0.020/m^2$) and was absent in class two streams. The higher numbers of sensitive native fish in class four streams suggest that these fish species prefer streams with very little habitat modification and will live in this stream class regardless of trout numbers. The low numbers or absence of sensitive native in the other classes is most likely due to the poor stream habitat, particularly the quality of riparian vegetation and the amount of woody debris imbedded in the stream.

3.4 Macro-invertebrates

All classes had a large number of ecologically sensitive invertebrates (mayflies, caddisflies and stoneflies). As the class decreased and the stream became more disturbed, the numbers of pollution tolerant/habitat tolerant bugs increase (snails, midge larvae), but this pattern is not strong (see Appendix 6.0).

Macroinvertebrate abundance and diversity in well-designed permanent stream diversions, such as those at Three Mile Creek Greenstone, appear unaffected by the activity several months after construction unless the diversion channel does not maintain water flows. However, there was a dramatic loss in the total macroinvertebrate abundance in the area where the diversion channel crosses an area of alluvial gold mine tailings and the water flow is less consistent with greater periods of intermittent flow.

3.5 Water quality

Conductivity of most stream waters tested was indicative of good water quality. Five streams had moderate levels of conductivity (Whale Ck 141 ?S/cm, Thorpe Ck 121 ?S/cm, Vickers Ck 117 ?S/cm, Molloy Ck 112 ?S/cm, and Ash Ck 102 ?S/cm) with the remaining streams having conductivity close to background (less than 80 ?S/cm).

Temperature results were all moderate to low and typical for lowland streams in the spring season. Results for pH were generally circum neutral.

Table 3.5.1. Averages of conductivity, temperature and pH for four disturbance classes

	Av. Conductivity (?S/cm)	Av. Temperature (^{o}C)	Av. pH
Class 1	74.00	12.82	6.98
Class 2	92.63	11.94	6.81
Class 3	89.29	13.60	6.80
Class 4	39.25	11.33	7.16

4. DISCUSSION

Stream habitat modification in West Coast streams in developed land areas is common especially in the dairy farm environment. Removal or disturbance of riparian vegetation and stream channelisation was common in streams running through farmland. The effects of this modification were common to that of pasture streams in other regions ie increased growth of aquatic plants, very little woody debris in the bed, channels were generally narrower and more deeply incised. It appears that the practice of straightening streams for significant distances is rarely practiced in recent years, if not at all.

The occurrence of significant trampling in the bed or banks of streams or slumping of banks produced by trampling was more apparent in intensive dairy farming areas compared to extensive dry stock farming (see Appendix 5.0). Trampling in turn has negative effects on the abundance and diversity of fish. From the observations made during this study, there are a large percentage of streams that are already fenced on one bank and temporary fencing appears as effective as permanent. In some streams, cattle were fenced in to an area of stream bounded on both sides by fences. This practice caused very extensive damage to the stream banks and bed. The practice of rotational strip or mob-stocking at cow densities of several hundred per hectare over periods of hours to days seems to give rise to the most extensive damage to the stream bed.

Dividing the streams into the four disturbance classes using the three course parameters of stream channellisation and straightening, amount of riparian vegetation that has been disturbed or removed, and ristriction of stock access appeared to be effective at explaining the variation in many other stream habitat parameters investigated. Streams from highly disturbed classes had poor scores for reach scale parameters, velocity-depth combinations and in-stream habitat like fish cover, siltation/embeddedness and sediment deposition. Only channel sinuousity and alteration and periphyton growth on substrate showed no evident relation with disturbance classes, which could be caused by the limited scale of assessing streams.

Stream habitat disturbance appears to have limited effect on the abundance and species richness of macro-invertebrate communities, except at sites where there was evidence of stock being herded along streams where macroinvertebrate abundance and diversity was greatly compromised. This result contrasts to studies in other parts of the country (Rutherford et al 1999) and could be due to the fact that on the West Coast any parcel of developed land is generally less than 10km distant from significant blocks of native forest. The high level of macro-invertebrate species richness (particularly of the sensitive species) in the more disturbed classes could be due to recruitment by downstream drift from headwater tributaries and aerial colonisation from forested streams. This result and the periphyton percentage cover results concurs with the water quality results suggesting that the streams water quality was moderate or good. Macro-invertebrate indices may not be a suitable indicator of stream habitat disturbance on the West Coast apart except where there is low water flow in creeks caused by the disturbance. Maintenance of water flows in creeks appears to be critical to the macro-invertebrate community.

Total fish abundance or diversity does not appear to be related to stream habitat disturbance. The density of fish was higher for the most disturbed stream class because of the preference of some fish such as bullies to proliferate in these habitats. This result was also found in studies in the Card Creek Catchment after the deposition of large amounts of fine sediment to the bed of the creek (Cottam D.P. et al, 2002). The similar diversity in streams of different disturbance classes could be due in part to the displacement of sensitive natives with more hardy species such as trout and bullies in streams that have been slightly to highly disturbed. This displacement could be due habitat as trout are not so sensitive to loss of riparian cover in streams. Numbers of native fish could be influenced by predation by trout as they occurred in higher numbers in streams where trout were lower in numbers. However, measuring the extent of predation is very difficult to quantify (McIntosh, 2000). Sensitive native fish appear to be considerably affected by stream habitat disturbance with significantly higher population densities in streams with very little habitat disturbance. The quality of riparian vegetation, amount of in-stream woody debris and stock access to streams are the most significant factors affecting sensitive native fish. This pattern is consistant with that found in other parts of New Zealand. It appears that in stream reaches that have 80% or more of intact riparian vegetation are more likely to support greater numbers of sensitive native fish. Aquatic plants in streams appear to provide poor habitat for sensitive native fish when compared to other substrate such as imbedded woody debris. High quality riparian vegetation throughout the valley segment of a stream is considered unnecessary in this regard as is complete stock exclusion. An effective width for a riparian buffer could be in the order of 2 to 5 metres depending on the size and type of stream.

Although mean trout density was higher in class 4 and 2, there was no significant relationship with this factor and the various disturbance classes. This is could be due, in part, by the preference of trout for streams with little forest canopy cover (more light enables trout to locate their prey more easily).

It is likely that the reason that spring-fed streams often had prolific growth of aquatic plants rooted in the bed with reduced shade. Examples of such streams include: Titwatch Stream Tributary, Murray Creek and Harris Creek. Although this factor is likely in reducing habitat for spawning or adult fish more work would be needed to confirm this relationship.

Water quality parameters such as conductivity, water clarity observations and periphyton cover results indicate that concentration of contaminants such as dairy farm effluent at the time of sampling was generally low and low to moderate for five streams in the dairy farm environment. This suggests that the variation in fish or macro-invertebrate abundance or diversity is unlikely to be controlled by water quality. Due to considerable seasonal variation in temperature, with highest temperatures occurring in January to March, more sampling would be required throughout the year to assess whether temperature had a controlling effect on macro-invertebrate or fish numbers or diversity. Lowland-fed creeks such as Paddy's Creek could be prone to high summer temperatures.

6. CONCLUSION

This study showed that habitat modification in farmland streams on the West Coast is relatively widespread. The most common forms of habitat modification are: riparian vegetation disturbance or removal, bank reshaping and accelerated erosion, reduction in channel and bed substrate diversity, and trampling of stream banks and bed by stock. These activities, rather than the land use per se, were found to:

1. Cause no affect on the abundance or diversity of macro-invertebrates except where water flows in a creek are not maintained.
2. Cause no effect on total fish numbers and diversity appeared unrelated to stream habitat disturbance.
3. Produce no clear pattern in trout density and habitat disturbance. However, more information would be needed to determine the relationship between trout density and stream habitat modification.
4. Significantly adversely affect sensitive native fish. Like other studies in New Zealand, this group of fish appears ill-adapted to cope with much habitat disturbance. Predation may also be a factor in limiting the distribution of sensitive native fish.

Similar effects on aquatic ecology in response to the same activities that modify stream habitat are expected on streams which has a catchment land use is dominated by exotic forestry, mining or other resource use.

7. RECOMMENDATIONS

The results of this investigation should be considered in decision-making associated with resource management plans, processing of resource consent conditions and compliance and enforcement priorities. The information should be used for educational activities of the Council.

Further monitoring and analysis that is identified as a result of this study includes:

- Repeat the stream habitat assessment and fish monitoring using similar methods to those used in this study on a 3-4 year rotation using the same sites to gain long-term information about the modification of stream habitat and distribution of fish species and to assess trends in quality and quantity over time. More frequent monitoring of fish distribution may be required but the full stream habitat assessment is not considered necessary because the rate of habitat disturbance is considered low.
- Compare results of stream habitat monitoring and fish distribution in farmland streams (this study) with that of other land uses such as exotic forestry(before and after logging), mining and urban. Integrate the analysis and interpretation of this data with historical fish records and those of two other very similar projects (currently in progress): 1. University of Canterbury, Hans Eikaas (PhD student) and 2. Department of Conservation (Philippe Gerbeaux).
- Carry out annual or biennial aerial surveillance where there are no recent aerial photos available. This activity would be best linked with compliance monitoring programmes. Aerial surveillance is important because it is cost effective, very efficient and is very likely to locate non-compliances in regard to stream habitat and wetland modification which can not be located from viewing from roads.
- Deploy logging temperature probes in up to 3 streams in lowland-fed creeks where more than 70% of riparian vegetation has been removed.
- Carry out further fish surveys using spotlighting and trapping techniques on streams that were too large to electrofish or streams with large boulders or considerable woody debris.
- Use multi-variate analysis to gain information about relations between different parameters. Compare the distribution of sensitive native fish in the catchment upstream of the Arnold River hydroelectric dam with those with unrestricted access to the sea.

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GLOSSARY

EPT Richness	Sum of the total number of Ephemeroptera (mayflies) Plecoptera (stoneflies) and Trichoptera (caddisflies) species collected.
GIS 3.2	Geographical Information System 3.2
Humping & Hollowing	Form of land drainage
Macro-invertebrates	Small animals (0.5-60 mm in length) such as insects, flies, shellfish and worms that spend most of their lives in streams, rivers, lakes and wetlands.
MCI	Macro-invertebrate Community Index is an index based on adding the "pollution tolerance" scores of all species found at a site.
NIWA	National Institute of Water & Atmospheric Research Ltd
Periphyton	Mixture of algae, bacteria and fungi that lives on the surface of stones and other substrates on river beds.
Pool	deeper parts of the waterway that do not flow freely downstream
REC	River Environment Classification – a computer-modelled tool to allow easy identification of the dominant important influences on a stream for any particular reach. Source of flow, geology and land cover are the most important factors in the classification.
Riffle	part of the waterway where the surface of the water is punctuated by the bed.
Riparian	relating to the margins of waterways and wetlands
Run	Part of the waterway that is flowing freely downstream but where the surface of the water is punctuated by the bed.
S.E.	Standard Error
SHMAK	Stream Health Monitoring and Assessment Kit. This Kit has been designed to monitor the "health" of the stream by farmers and lay people. Developed by NIWA
SQMCI	Semi-Quantitative Macro-invertebrate Community Index is a variation of the MCI that accounts for the abundance of pollution sensitive and tolerant species.
Taxonomic Richness	Total number of species macro-invertebrates collected at a site.

APPENDICES

APPENDIX 1.0 - Maps of assessed stream reaches

APPENDIX 2.0 - Stream habitat assessment field sheet Sept. 2001

Stream Habitat Assessment Sept 2001

Stream Name: ______________________________ **Sampler**: ________ **Date:** _____________

Weather: Fine / overcast / drizzle / rain Weather in past week: ____________________
Photo No.s ____________________

Colour: blue / green / tannin brown / ________________ **Clarity:** Clear / slightly turbid/ moderately turbid / highly turbid

Conductivity: _____________µS/cm Temp: _______ pH _______ Dissolved Oxygen: ___________%

Average width: __________________ m Average depth:

Grid reference: Start E _____________ N _____________ Finish: E _____________ N _____________

Stream Type: ____________________________ Disturbance Class: ______________________________

Catchment Scale Features

Habitat Parameter	**Category**			
1. Broad scale catchment landuse upstream – affecting stream inputs (From LCDB)	Undisturbed native vegetation – forest, scrub or tussock	Disturbed native vegetation and/or exotic forest and/or low intensity grazing	moderate intensity pastoral landuse or low impact horticulture	Intensive pastoral landuse (dairy/deer) to intensive horticulture, urban/industrial
SCORE				

Habitat Parameter	**Category**			
2. Immediate landuse beyond the riparian zone at site	Undisturbed native vegetation – forest, scrub or tussock	Disturbed native vegetation and/or exotic forest and/or low intensity grazing	moderate intensity pastoral landuse or low impact horticulture	Intensive pastoral landuse (dairy/deer) to intensive horticulture, urban/industrial
(TLB)				
(TRB)				

Dominant land use in catchment**:** **Farming**: dairy / dry stock / sheep **Forestry**:
Mining:

Riparian and Bank Features

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
3. Quality of Riparian Vegetative Buffer to nearest human influenced landuse (score each bank riparian zone)	Human activities (i.e. grazing, parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone. Complete effective fencing.	Human activities have impacted zone only minimally.	Human activities have impacted zone a great deal.	Little or no riparian vegetation due to human activities. Little or no fencing.
SCORE ___ (TLB)	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
SCORE ___ (TRB)	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Average width of riparian buffer: TLB ____________________m TRB ____________________ m

Fencing: TLB Permanent __________% Temporary ____________% None ____________%
TRB Permanent ____________% Temporary ________________ %
None ________________ %

Humping and hollowing TLB _______________ % TRL _____________________%

Flood protection works TLB _______________% TRL _____________________ %

Type of flood protection: Groynes / deflector banks / stopbanks / rip-rap / other

Vegetation types:
Native Forest TLB ____________ % TRB _________________%
Exotic Forest TLB ____________ % TRB _________________%
Scrub TLB ____________ % TRB _________________%
Willow TLB ____________ % TRB _________________%
Flax/raupo TLB ____________ % TRB _________________%
Tall grass/tussock TLB ____________ % TRB _________________%
Short grass TLB ____________ % TRB _________________%
Other TLB ____________ % TRB __________________%

Average canopy cover: ____________________________% of bed covered

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
4. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (TLB)	10 9	8 7 6	5 4 3	2 1
SCORE ___ (TRB)	10 9	8 7 6	5 4 3	2 1

Type of erosion: slip / slump / scour / trampling

Reach Scale Parameters

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
5. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Frequency of Riffles (or bends) / Velocity-Depth Combinations	Great diversity of channel widths and depths forming a series of riffles, runs and pools; large variation in velocity throughout the stream (all 4 velocity/depth patterns present)	Little diversity in channel width, good diversity in stream depth, velocity still variable throughout stream. (3 velocity/depth patters present).	Little diversity in channel width and depth, velocity within channel only slightly variable. (2 velocity/depth patterns present)	No change in both channel width and depth, constant velocity throughout channel (or no velocity).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas).	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

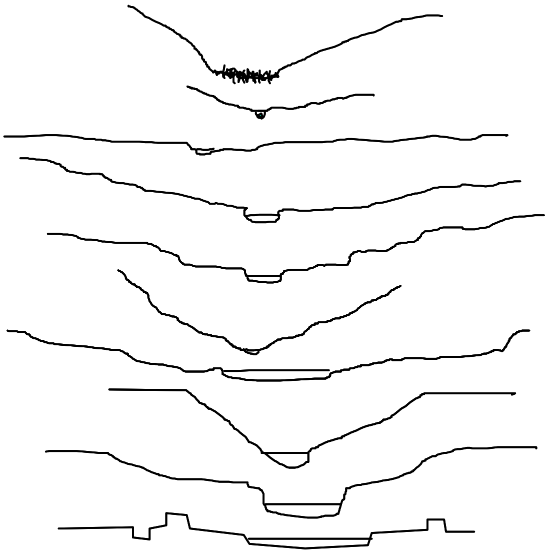
Ratio of wetted area to dry bed: ________________________%

Average Stream profile - runs

Average Stream profile - riffles

Average Stream profile - pools

Representative cross-sections **Riparian classes**



Headwater wetland HW
Vegetated drain VD
Upper floodplain low relief UFL
Shallow V-shaped rolling SVR
U-shaped hill valley UHV
V-shaped hill valley VHV
Upper floodplain high relief UFH
V-shaped entrenched VE
Entrenched floodplain EF
Lower floodplain LF

In-stream habitat quality parameters - to be assessed in runs only.

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
8. Instream habitat / Roughness - Cover for trout.	Greater than 70% of substrate favourable for faunal cover/ utilisation and fish cover – mixture of cobble,boulder, snags, undercut banks etc.	40-70% cover of suitable habitat including cobbles, boulders logs and snags	Only 20-40% cover is suitable habitat – habitat dominated by fine or unstable sediments, lack of in-stream cover features	Little stable cover or habitat, substrate open, fine, unstable.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Trout favour clear, medium to large, faster-flowing water with good mix of pools, riffles and runs. Requires cool, well-oxygenated water and clean sand and gravel for redds.

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
9. Instream habitat / Roughness - Cover for native fish.	Greater than 70% of substrate favourable for faunal cover/ utilisation and fish cover – mixture of cobble,boulder, snags, undercut banks etc.	40-70% cover of suitable habitat including cobbles, boulders logs and snags	Only 20-40% cover is suitable habitat – habitat dominated by fine or unstable sediments, lack of in-stream cover features	Little stable cover or habitat, substrate open, fine, unstable.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Native fish generally favour small to medium sized slower-flowing streams overgrown with vegetation and with under-cut banks, and hides behind cobbles/boulders and woody debris.

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
10 Siltation / Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Habitat Parameter	**Category**			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
11. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Substrate:	QUADRAT					
	1	**2**	**3**	**4**	**5**	**Average**
Quadrat Location (eg edge-riffle, midstream-run)						
As a percentage of quadrat bed area -						
Boulders (>250mm)						
Large Cobbles (120-250mm)						
Small Cobbles (60-120mm)						
Large Gravels (30-60mm)						
Small Gravels (10-30mm)						
Sand (0.5-10mm)						
Silt/Mud (< 0.5 mm)						
Woody Debris						
Water plants (rooted in bed)						
Bedrock						

Periphyton (on exposed surfaces)	Run 1					Run 2					Run 3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Thin mat/film: Green															
Light brown															
Black/dark brown															
Medium mat: Green															
Light brown															
Black/dark brown															
Thick mat: Green															
Light brown															
Black/dark brown															
Filaments, short: Green															
Brown/reddish															
Filaments, long: Green															
Brown/reddish															
Bare rock															
Mosses/ liverworts (not included in total)															

APPENDIX 3.0 - SHMAK scores for Periphyton and substrate per assessed stream divided into four disturbance classes

Stream name	Periphyton	Substrate
Class 1		
J33-KANI-ARTHUR 1	7,37	20,4
K32-LABR-MOSQUITO 1	9,97	19,7
K32-LABR-PUZZLE 2	7,83	20,6
K32-LABR-HOMESTEAD 1	9,64	25,1
K32-LABR-PIDGEON 1	8,9	22,3
J32-HOKI-PADDY N 1	6,4	10
J33-KANI-LAWYER 2	6,61	21
Class 2		
J33-KANI-WALL 1	9,2	15,7
J33-KANI-HARRIS 1	8,52	23,4
K31-AHAU-CLEAR 1	7,86	19,8
I34-HARI-BERRY 2	9,55	16,5
J33-KANI-WHITES 1	0	6,5
I34-HARI-THORP 1	8,29	19,4
I34-HARI-VICKERS TRIB 1	7,91	14,2
I34-HARI-VICKERS 1	9,52	24,9
Class 3		
K31-AHAU-BRANDY-JACKS 2	9,67	21,6
K31-AHAU-HATTERS 2	10	12,6
J33-KANI-DUCK 1	6,86	20,8
K32-LABR-BROWN 1	7,06	23,7
I34-HARI-ASH 1	9,73	17,5
I34-HARI-WHALE 1	9,83	21,8
K29-WEST-FAN 1	9,62	25,1
K32-LABR-MOLLOY TRIB 2	8,02	24,6
Class 4		
J33-KANI-RAFT 1	9,92	19,1
K32-LABR-ORANGIPUKU 3	9,64	21
rJ32-HOKI-3MILE 4	8,5	25,7
K32-LABR-SOUTERS 1	8,6	28,1

Note: Periphyton scores from 8-10 indicate low concentrations of nutrients or intensive grazing by insects. Scores from 6-7.9 indicate moderate to low nutrient concentrations.

Substrate scores of 0-10 indicate moderately high proportions of cobbles providing good invertebrate and periphyton habitat. Scores of 10-20 indicate large proportions of cobbles providing good invertebrate and periphyton habitat.

APPENDIX 4.0 - Results for certain parameters of streem habitat assessment

(all scores out of 20)

	Riparian Vegetation Quality	Bank Stability	Channel Alteration	Frequency of Riffles	Channel Sinuosity	Instream Cover -trout	Instream Cover Natives	Siltation / Embeddednes	Sediment Depostion
I34-HARI-ASH 1	11	6	20	17	19	16	16	14	12
I34-HARI-BERRY 2	6	7	16	11	9	15	16	14	8
I34-HARI-THORP 1	3	5	15	10	8	11	10	13	14
I34-HARI-tVICKERS 1	5	9	18	7	10	7	6	16	17
I34-HARI-VICKERS 1	4	8	18	9	9	10	11	16	17
I34-HARI-WHALE 1	11	6	16	15	13	14	16	12	13
J32-HOKI-3MILE 4	18	9	16	13	7	12	15	11	10
J32-HOKI-PADDY N 1	2	4	13	6	8	7	16	1	1
J33-KANI-ARTHUR 1	1	8	5	6	4	5	5	11	8
J33-KANI-DUCK 1	12	9	14	17	9	9	15	15	9
J33-KANI-HARRIS 1	5	3	13	15	11	12	9	16	13
J33-KANI-LAWYER 2	2	2	13	8	14	12	14	11	8
J33-KANI-RAFT 1	16	8	15	19	10	17	15	14	9
J33-KANI-WALL 1	8	4	16	12	9	8	11	6	5
J33-KANI-WHITES 1	6	7	19	8	18	7	15	1	1
K29-WEST-FAN 1	16	8	18	17	10	16	16	18	18
K31-AHAU-BRANDY-JACKS 2	7	5	16	13	12	14	16	6	6
K31-AHAU-CLEAR 1	6	4	12	13	8	8	11	9	8
K31-AHAU-HATTERS 2	8	8	17	11	9	9	12	13	9
K32-LABR-BROWN 1	11	6	14	15	14	18	13	9	8
K32-LABR-HOMESTEAD 1	2	7	17	12	8	16	13	13	7
K32-LABR-MOSQUITO 1	1	1	2	1	1	1	1	3	3
K32-LABR-ORANGIPUKU 3	14	7	19	18	14	18	18	18	16
K32-LABR-PIDGEON 1	3	2	13	6	8	6	8	6	6
K32-LABR-PUZZLE 2	2	2	15	12	17	11	7	9	12
K32-LABR-SOUTERS 1	20	10	20	20	20	11	18	19	19
K32-LABR-tMOLOY 2	9	8	20	17	20	17	19	17	18

Appendix 5.0 - Type of Significant Erosion Associated with Differing Fencing and Farming Practice

Stream name	Fencing TLB	Fencing TRB	Type of Farming	Erosion
WHITES CK 1	0	0	Deer farm	Sl/Sc
MOSQUITO Ck1	0	0	Dairy	Sl/Sc
ARTHUR CK 1	0	100	Dairy/Dry	Tr
HOMESTEAD 1	15	5	Dairy	Sl/Tr
PUZZLE Upper	0	0	Dairy	Sl/Sc/Tr*
PUZZLE Ck Lower	10	10	Dry stock	
PADDY'S N BRCH 1	0	0	Dairy/Dry/Sh	Sl/Tr
LAWYER CK 2	100	0	Dairy	Sl/Tr
BERRY 2	0	0	Dairy/Dry/Sh	Tr
PIDGEON 1	0	0	Dairy/Dry	Sl/Tr
THORP 1	0	0	Dairy/Dry	Sl/Tr
CLEAR (Totara Flat) 1	100	10	Dairy/Dry/Sh	Sl/Tr
VICKERS 1	20	10	Dairy/Dry	Tr/Sl
HARRIS 1	55	45	Dairy/Dry	Sl/Tr
VICKERS Trib 1	0	100	Dairy	Tr
WALL CK 1	50	100	Dairy/Dry	Sl/Tr
ASH CK1	0	10	Dairy/Dry	Sl/Tr
HATTERS 2	0	50	Dairy	Sl/Tr
BRANDY JACK 2	80	20	Dairy	Sl/Tr
MOLLOY Ck Trib 2	0	20	Dry/Sh/F	Tr
WHALE 1	100	20	Dairy/Dry	Sc/Tr
BROWN 1	10	10	Dry	Sc/Tr
ORANGIPUKU 3	100	0	Dairy/Dry	Sl/Sc/Tr
DUCK 1	0	30	Sheep	Tr
FAN 1	0	0	Dairy/Dry	Sl/Sc
3MILE 4	0	0	None	Sc
RAFT 1	0	0	Dry/Deer	Sl/Tr
BRUCE CK	0	0	Dairy	
MURRAY CK 1	90	30	Dairy	
MURRAY CK 2	5	10	Dairy	
MURRAY CK 3	100	0	Dairy	
CLEAR CK / NICHOLAS CK	0	0	Dairy	Sl/Tr
SOUTERS 1	0	0	Dry stock (about to change to dairy	Sc

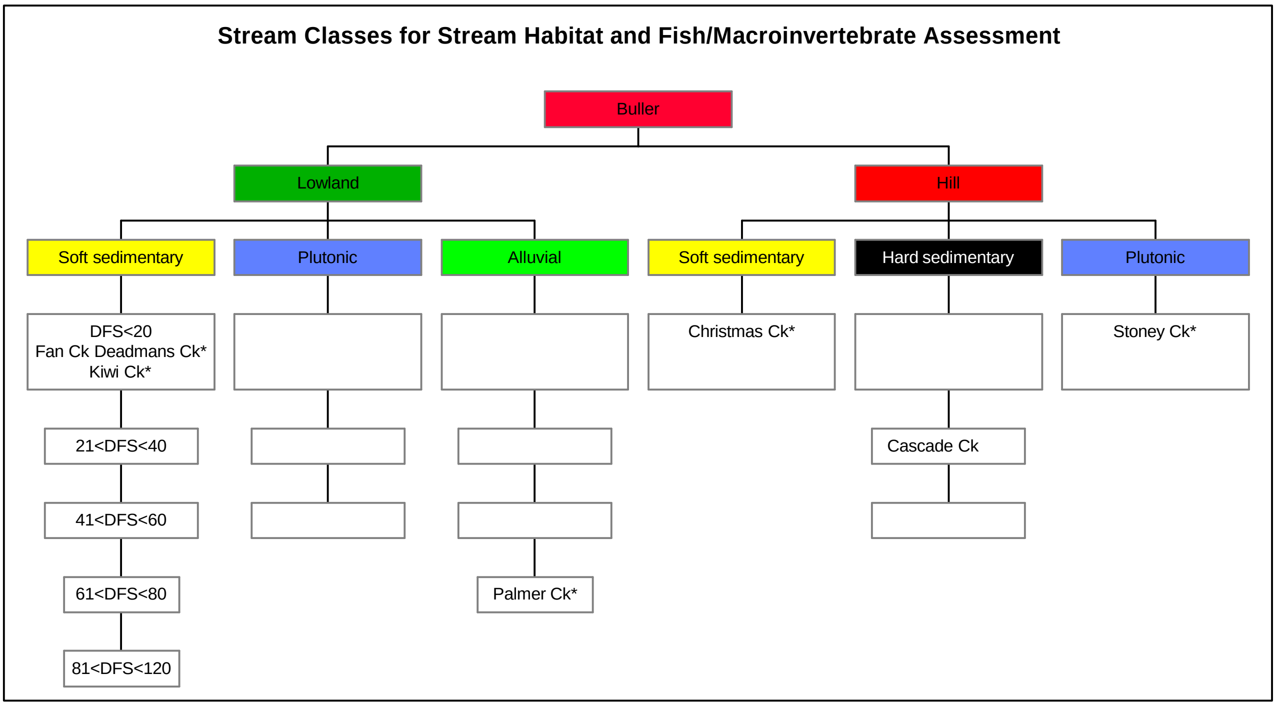
Tr = Significant trampling
Sl = Significant slumpling
* = Very extensive

APPENDIX 6.0 Results of macro-invertebrate samples

Stream name	Disturbance class	Tax Richness	% EPT taxa	EPT taxa	MCI	SQMCI
J32-HOKI-3MILE 4	4	24	41,67	10	117	7,58
K32-LABR-PUZ 2	1	18	50	9	120	5,32
K32-LABR-MOS 1	1	17	64,71	11	116	6,64
J33-KANI-ART 1	1	8	62,5	5	129	7,77
K32-LABR-PIDG 1	1	25	52	13	121	5,52
K31-AHAU-CLE 1	2	28	46,43	13	113	5,14
K32-LABR-HOME 1	1	17	64,71	11	126	5,04
J33-KANI-HAR 1	2	26	61,54	16	121	6
J33-KANI-DUCK 1	3	27	62,96	17	123	6,89
I34-HARI-BER 2	2	28	53,57	15	118	7,26
J33-KANI-LAW 2	1	10	60	6	108	3,63

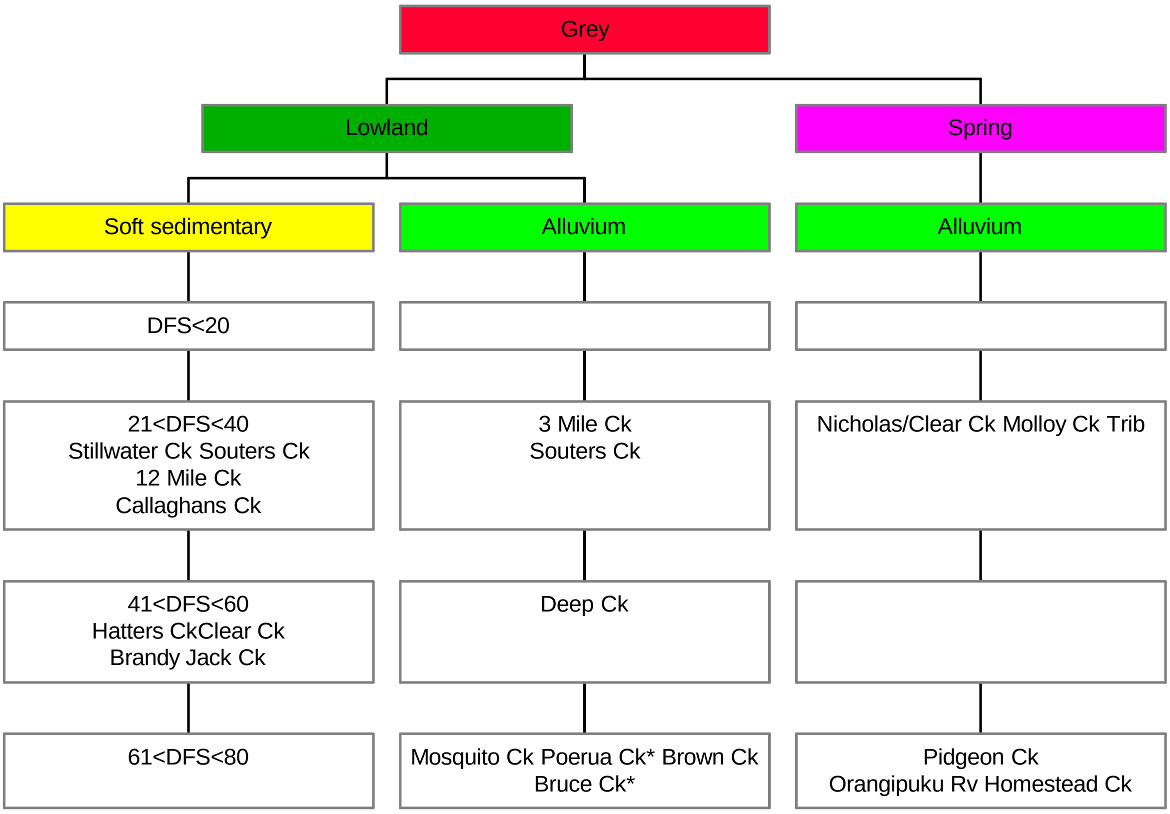
Note:
Taxonomic richness: <10 Moderate-poor, 10-15 Moderate-good, 15-20 Good, >20 Excellent
EPT taxa: >5 good
MCI: >100 moderate-good >120 Excellent
SqMCI: 5-6 Moderate, 6-7 Good, >7 Excellent

APPENDIX 7.0 - Classification of Sampling Sites on the Basis of Source of Flow , Geology and Distance from the Sea (DFS).



Stream Classes for Stream Habitat and Fish/Macroinvertebrate Assessment

Stream Classes for Stream Habitat and Fish/Macroinvertebrate Assessment



Stream Classes for Stream Habitat and Fish/Macroinvertebrate Assessment