BEFORE THE INDEPENDENT COMMISSIONERS

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Canterbury Land and Water Regional Plan

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EVIDENCE IN CHIEF OF RUSSELL GEORGE DEATH ON BEHALF OF NELSON/MARLBOROUGH, NORTH CANTERBURY AND CENTRAL SOUTH ISLAND FISH AND GAME COUNCILS

4 FEBRUARY 2013

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QUALIFICATIONS AND EXPERIENCE

1. My full name is Russell George Death.

2. I am an Associate Professor in Freshwater Ecology in the Institute of Natural Resources – Ecology at Massey University where I have been employed since 1993. Prior to that I received a Doctor of Philosophy in Zoology from the University of Canterbury (1991) and was a Foundation for Research, Science and Technology postdoctoral fellow at Massey University (1991 1993).

3. I have been a Quinney Visiting Fellow at Utah State University. I am a member of the Ecological Society of America, British Ecological Society, New Zealand Ecological Society, the New Zealand Freshwater Sciences Society and the North American Benthological Society. I have refereed scientific manuscripts for seventeen scientific journals and several books. I am on the editorial board of the journal *Marine and Freshwater Research*. I have been commissioned by a number of governmental and commercial organisations to provide scientific advice on matters related to the management of freshwater resources.

4. I have had twenty two years' experience in professional ecology research, teaching and management. My area of expertise is the ecology of stream invertebrates and fish. I have 80 peer-reviewed publications in international scientific journals and books, including a number of invited reviews. I have written 40 plus consultancy reports and given over 60 conference presentations. I have been the principal supervisor for 38 post-graduate research students.

5. In preparing this evidence I have reviewed:

   a. Fish and Game's submission;

   b. Dr Roger Young's evidence on behalf of Fish and Game;

c. Proposed Canterbury Land and Water Regional Plan ("pCLWRP") Section 42A Report Volume 1 for Hearing Group 1; and

d. Provisions of the pCLWRP.

6. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

7. I have been asked by Fish and Game to prepare evidence in relation to freshwater ecology, waterbody ecological health and Salmonid fisheries in Canterbury rivers and streams.

8. This includes:

a. The state and trends in water quality particularly with respect to ecological health;

b. The most likely causes of the low water quality and ecological health of many of the regions waterbodies;

c. The appropriateness of the biological limits to maintain or enhance ecological health and Salmonid fisheries presented in table 1a and schedule 5 pCLWRP;

d. The effect of nutrients on waterbody ecological health and limits that would be appropriate to maintain ecological health;

e. The effect of deposited fine sediment from erosion and other land use activities on waterbody ecological health;

f. The efficacy of livestock exclusion and riparian buffers in preventing or lessening the detrimental effects of land use activities on waterbody ecological health; and

g. The importance of small and ephemeral streams for biodiversity, proper ecosystems function and the ecological health of the entire river network.

TERMS AND DEFINITIONS

9. Throughout my text I use the words 'life supporting capacity' and 'ecological health' interchangeably. Although there may be some distinction between these in a planning and/or legal arena they are the same in an ecological context. Furthermore, I also use the term 'adverse' and 'significant adverse' effect interchangeably. Again while there may be differences in these terms within the planning and/or legal arena they are identical in an ecological context.

EXECUTIVE SUMMARY

10. There is a considerable body of evidence that land use activities if not managed appropriately can and do have significant adverse effects on the ecological health and life supporting capacity of waterbodies in New Zealand. The principal driving factors for these adverse effects include increased nutrient levels, loss of riparian habitats, altered and reduced flows, and increased suspended and deposited sediment.

11. There is convincing evidence that the ecological health of many Canterbury rivers and streams, particularly lowland examples, is moderate to poor and would be unlikely to assimilate increased detrimental effects that may result from unmanaged increases in agricultural intensification if the environmental consequences of those increases are not also considered (Stevenson, Wilks & Hayward, 2010).

12. I have provided scientifically defensible water quality limits for each of the river types/management units listed in Table 1a (p 4-2) of the pCLWRP in Fish and Game's version of Table 1a from the pCLWRP (**Appendix 1**). These are derived from Environment Canterbury technical reports (e.g., Hayward, Meredith & Stevenson, 2009) and established national limits (e.g., Clapcott *et al.*, 2011). In my opinion

these represent the pragmatic bottom line (limit) for these parameters that balances consideration of current condition, resource use and protection of ecological health values in these waterbodies, not the optima that would be advocated if the focus were entirely ecological.

13. Healthy ecological systems require the appropriate chemical, physical and biological conditions. Both excess nutrients and sediment can detrimentally alter this environment. Improved ecological health will only result from managing both sediment and nutrients.

14. Land use, primarily agriculture, results in increased levels of deposited fine sediment in surface waterbodies (up to 2000% more) that smothers plants and animals, buries habitats and changes the composition of fish and invertebrate communities, in turn reducing ecological health. The pCLWRP identifies limits for deposited sediment (Table 1a p 4-2) derived from Hayward *et al.*, (2009). Amendments to these limits, as presented in **Appendix 1** are more consistent with national guidelines (Clapcott *et al.*, 2011) and will provide the most pragmatic protection of ecological health.

15. Some of the limits Fish and Game included in Table 1a in the original submission would be more appropriate in one of the tables in Schedule 5 or both. These have been corrected in the attached Table 1a and the table "Water Quality Standards for water not classified as Natural" from Schedule 5 (**Appendix 1**).

16. Management of both nitrogen and phosphorus in all waterways is important to avoid the adverse effects of nutrient enrichment on aquatic biota. If nutrients are not managed below certain thresholds this results in cascading effects through riverine food webs that result in degraded water quality and ecological health. The pCLWRP has water quality standards for waters not classified as Natural for DIN (dissolved inorganic nitrogen) and DRP (dissolved reactive phosphorus) in Schedule 5 (p 16-9) derived from (Hayward *et al.*, 2009). These nutrient quantities should also be better added to Table 1a (**Appendix 1**). The concentrations of nutrients presented in Table

1a (**Appendix 1**) are levels that should provide protection for waterbody ecological health.

17. To achieve protection of the Salmonid fishery in each of the river management units the QMCI limits of Table 1a in the pCLWRP would need to be modified to those in accordance with **Appendix 1**. A Quantitative Macroinvertebrate Community Index (QMCI) of 6 should protect a sustainable and healthy trout fishery, a QMCI of 5 a moderate, but not sustainable trout fishery and a QMCI of 4 is not suitable for any trout fishery value.

18. Chlorophyll *a* values in Table 1a of 200 mg/m^2 should be reduced to 120 mg/m^2 to be consistent with the percent filamentous algae cover column and to provide for the critical values of the relevant management units.

19. Stock access to waterways will increase stream bank erosion, sediment deposition, nutrient enrichment, pathogenic organism abundance in waterways, instream habitat destruction and, if riparian buffer zones are also open to stock access, the buffering ability of streamside vegetation will be undermined, greatly exacerbating the detrimental effects of land use activities.

20. As water runs downhill, management of small and ephemeral streams is critical to the management of larger downstream waterways and biodiversity. For that reason, protection and management also needs to be given to all ephemeral streams greater than 1 m, and all permanently flowing streams.

21. As aquatic ecological communities are complex ecosystems that are affected by multiple interacting stressors, the effects for ecological communities of specific management practices that focus on controlling only one of these stressors (e.g., reductions in nitrogen loadings) is difficult to predict. Improvement in the ecological health of these waterbodies will require the management of all the interacting stressors, however, any reductions in nutrients, deposited sediment,

faecal contamination, and restriction on stock access to waterbodies will result in an improvement from the current degraded state.

22. Given the large body of evidence demonstrating the detrimental effects of agriculture on waterbodies worldwide, data and models from Canterbury streams and rivers, it is, I believe, undeniable that agriculture is having a significant adverse effect on many of the Region's waterbodies. If the decline in water quality and ecological health is to be halted, an effective management regime needs to be put in place that ensures the instream effects from intensification of agriculture do not result in physicochemical conditions outside the limits I have identified in Table 1a.

Stream biological communities

23. Periphyton is the algae (often only visible microscopically or as a coating of slime) that forms the basis of most stream and river food webs. Some periphyton is required as food for many aquatic invertebrates; however, too much algal growth can dramatically change the ecology and habitat conditions of a river.

24. Aquatic invertebrates consume this periphyton either directly (along with other organic sources) or by predating the smaller grazing invertebrates. The types of invertebrate present in a river will indicate the nature of the river habitat and to what extent it is affected by human activities, and how well it might support healthy, sustainable Salmonid populations. This is utilised by scientists to create indices (e.g., QMCI) that measure the ecological health and/or water quality of a stream or river. The higher the QMCI on a scale of 0 – 10 the healthier the ecological condition of a stream and the more likely it is to support a healthy robust Salmonid fishery.

25. Native and sport fish eat these invertebrates. All of the biological components of a river food web require the correct habitat and water

quality conditions in order to maintain healthy populations and functioning ecosystems.

26. The river ecosystem does not end at the water margin. Both as larvae within the river and as flying adults these invertebrates form an important dietary component for both aquatic (e.g., fish (McDowall, 1990) and terrestrial e.g., birds, spiders, bats (O`Donnell, 2004; Polis, Power & Huxel, 2004; Burdon & Harding, 2008)) food webs. Changes to the invertebrate and fish communities can potentially have significant widespread effects on ecosystem functioning both in the waterbody and within the wider catchment.

27. Apart from the effects of land use management practices on ecological health and water quality discussed below, the aquatic habitat is also intimately linked with the terrestrial riparian zone. The riparian zone provides suitable habitat for the adult stages of many aquatic invertebrates (the in water life stage of many aquatic animals is the juvenile form with winged adults emerging from the water to mate and reproduce) (Collier & Scarsbrook, 2000; Collier & Winterbourn, 2000; Smith, Collier & Halliday, 2002; Smith & Collier, 2005). The riparian zone also provides instream habitat for fish (from overhanging vegetation), maintains and increases instream habitat diversity (natural character), and improves bank stability. Many fish species in New Zealand also use the riparian zone for egg laying (Charteris, Allibone & Death, 2003; McDowall & Charteris, 2006). Terrestrial insects and mammals from riparian zones often form a major component of the diet for many native and sport fish at certain times of the year (Main, 1988; McDowall, 1990). Thus riparian buffer zones also serve to maintain the proper ecological functioning of instream ecosystems.

State, trends and drivers of freshwater ecosystem health

28. Canterbury Regional Council Scientists present in (Stevenson *et al.*, 2010) the state of ecological health at their State of the Environment

river and stream monitoring sites. (Clapcott & Goodwin, 2010) have used this and other data to map the MCI (a measure of ecosystem health similar to the QMCI) for all the rivers and streams in the Canterbury region. This is presented in Fig. 1

29. The higher altitude mountain areas have rivers and streams with the cleanest water, with a steady degradation as these waterways enter the hills and eventually flat areas of the Canterbury Plains. Urban areas around Christchurch and Timaru have some of the most degraded waterbodies.

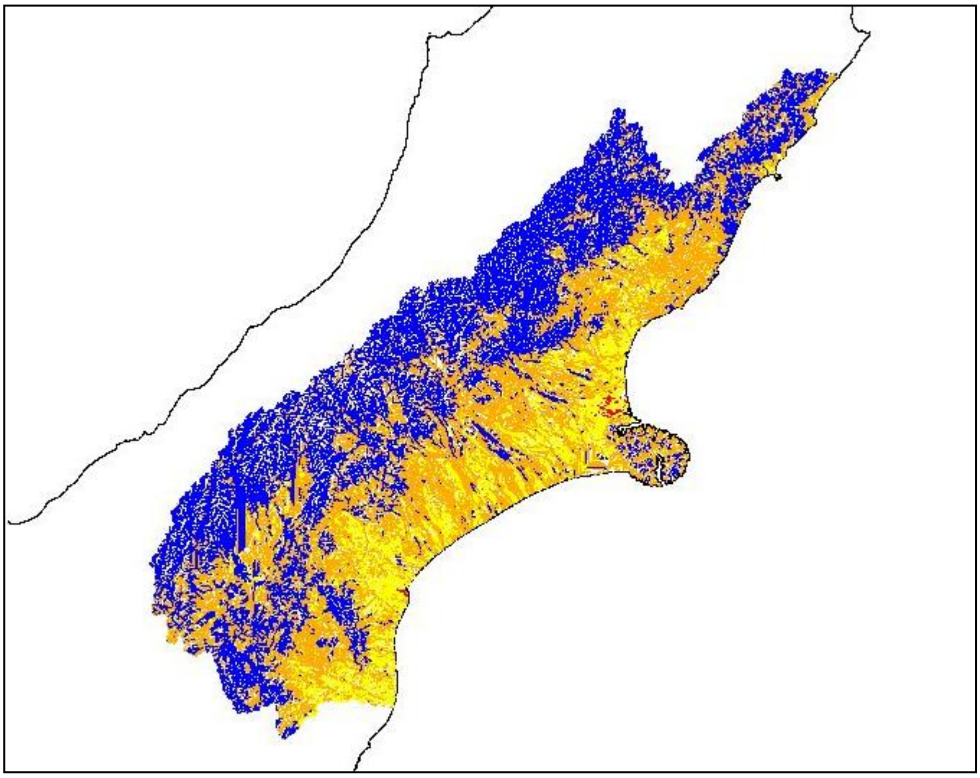


Figure 1. Macroinvertebrate Community Index for rivers and streams in the Canterbury region. Blue = clean water, Orange = doubtful quality, Yellow = probable moderate pollution, Red = Probable severe pollution.

30. The Ministry for the Environment web site presents data from NIWA monitoring of 66 rivers throughout New Zealand conducted in 2007. This data places at least two of the eight Canterbury river sites

amongst the lower decile of rivers in the country for a number of ecological health measures (Table 1).

River name	Average MCI (2005–2007)	Rank	Average % of EPT (2005–2007)	Rank	Annual maximum periphyton cover [%] (1990–2006)	Rank	Overall state ranking
Waitaki @ Kurow (A)	103.9	41	93.4	3	10	12=	14
Waimakariri @ Gorge (A)	102.7	45	74.8	12	20	20=	21
Hurunui @ Mandamus (A)	115.3	22	53.9	33	35	37=	23
Waitaki @ SH1 Br. (B)	94.4	59	47.9	37	4	4=	25
Opihi @ Rockwood (A)	108.1	37	69.5	22	37	40=	28
Opihi @ Waipopo (B)	111.3	30	70.5	21	37	40=	30
Waimakariri above old HW Br. (B)	102.3	47	38.6	46	21	22	35
Hakatakamea above MH Br. (river joins Waitaki downstream of Waitaki A)	114.1	24	73.8	14	55	54	43
Hurunui @ SH1 Br. (B)	100.5	49	12.9	58	40	45=	51
Opuha @ Skipton Br. (river joins Opihi upstream of Opihi A)	96.2	57	11.8	60	50	48	58

Table 1. Ministry for the Environment league table results for biological metrics at 66 NIWA monitor rivers throughout New Zealand conducted between 2005 and

2007(http://www.mfe.govt.nz/environmental-reporting/freshwater/river/league-table/biological-state.html).

31. There is a comprehensive body of scientific information dating from the 1970's (Hynes, 1975) that details how land use activities that occur in the catchment surrounding waterbodies have a major effect on the biological communities living in those waterbodies in New Zealand (e.g., Quinn *et al.*, 1997; Townsend *et al.*, 1997; Townsend & Riley, 1999; Quinn, 2000; Greenwood *et al.*, 2012) and mirror the findings elsewhere around the globe, reviewed by (Allan, 2004).

32. In the Canterbury region contaminants of concern from agriculture include nutrients (principally nitrogen and phosphorus), deposited and suspended sediment and faecal microorganisms. These may enter the streams directly as runoff from the surrounding land or indirectly via the groundwater and surface recharge from many of the spring-fed sources.

33. The land use activities, often associated with agriculture, if not conducted appropriately can lead to a decline in ecological health of waterbodies that occur or flow through that land. This includes an excessive increase in periphyton (Fig. 2), a change in the chemical and physical characteristics of the habitat (e.g. pH, oxygen levels, substrate composition, deposited fine sediment), a change in the aquatic invertebrate communities from the preferred mayfly, stonefly and caddisfly dominated communities to worm, snail and midge dominated communities, and a loss of terrestrial inputs of invertebrates to aquatic food webs through riparian habitat destruction.

34. Changes in the aquatic invertebrate communities can cause significant impacts on the health of aquatic and terrestrial ecosystems. Both as larvae within the river, and as flying adults, these invertebrates form an important dietary component for both aquatic (e.g., fish (McDowall, 1990) and terrestrial (e.g., birds, spiders, bats (O`Donnell, 2004; Polis *et al.*, 2004; Burdon & Harding, 2008)) food webs. Changes to the invertebrate communities can potentially have significant widespread

effects on ecosystem functioning both in the waterbody and within the wider catchment.

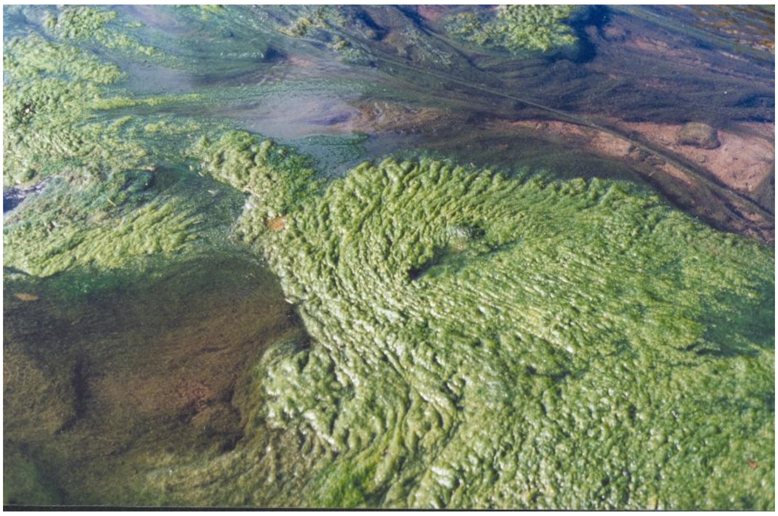


Figure 2. Excessive periphyton growth and smothered substrate.

35. These biological changes are a result of a few key driving factors that can occur with land use practices. These are: increased nutrient levels (nitrogen and phosphorous) from fertiliser use and stock effluent, direct and indirect inputs to surface water from livestock, and soil erosion; increased light and temperature levels from riparian forest removal, changes to hydrology, and instream habitat; and increased deposited sediment from land disturbance including cultivation, vegetation removal and livestock access to surface waterbodies and/or riparian margins which destabilise stream banks (Allan, 2004; Matthaei *et al.*, 2006; Townsend, Uhlmann & Matthaei, 2008). The fact that the instream ecological health declines as streams in the Canterbury region move from the mountains to foothills to lowland areas (Fig. 1) strongly supports the view that this decline in ecological condition may be associated with the increasing agricultural intensity that follows the same pattern. To illustrate the effect of land use on waterbody ecological health, I have compared models of contemporary MCI (Macroinvertebrate Community Index) and MCI in the absence of land use (for details of the data and modelling approach see (Clapcott & Goodwin, 2010)). I have expressed the difference in MCI in the Canterbury Region waterbodies as a

percentage of what it would be in the absence of land use impacts and plotted it on a GIS (Geographic Information Systems) map (Fig. 3).

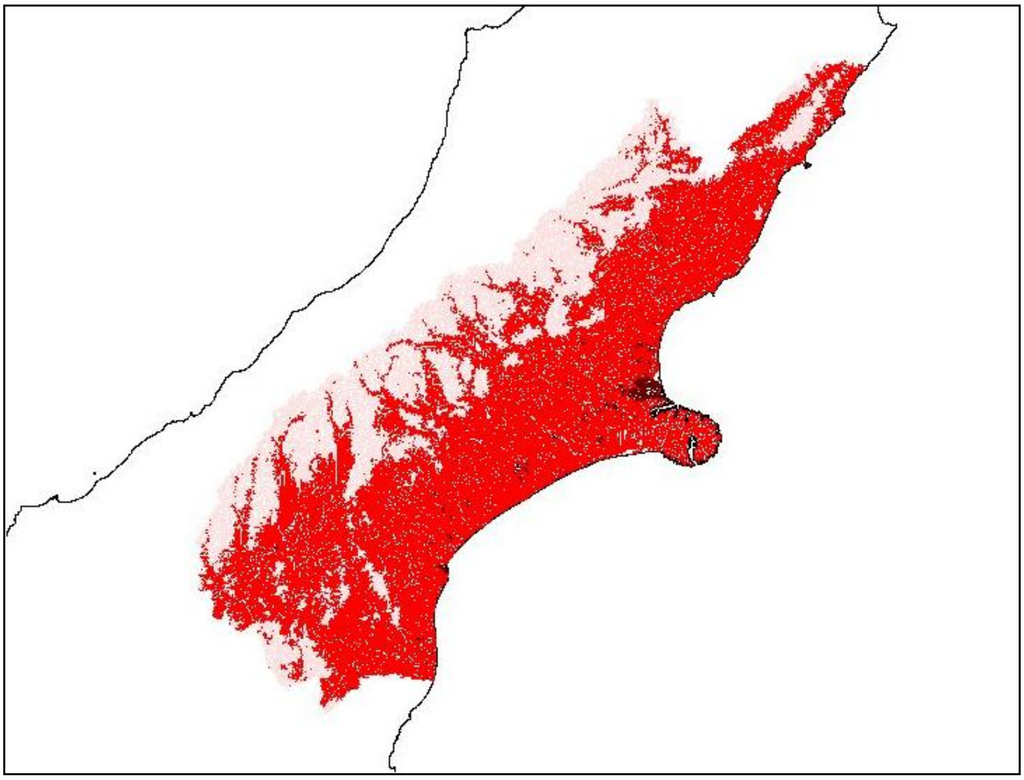


Figure 3. Percent change as a result of land use modification in Macroinvertebrate Community Index for rivers and streams in the Canterbury region. White = 0-10% decline, Red = 10 – 50 % decline, Dark brown = 50 – 100 % decline.

36. Again the decline in ecological health is greatest in the lowland and urban areas where land use is most intense.

BIOLOGICAL LIMITS TO MAINTAIN OR ENHANCE ECOLOGICAL HEALTH (TABLE 1A AND SCHEDULE 5 PCLWRP)

37. If waterbodies are to be managed to protect the values identified in the freshwater objectives (referred to in Hayward et al., 2009 as "Purposes for Management") in Table 1a (**Appendix 1**) then water quality, quantity and habitat quality must have certain characteristics. The water quality and habitat quality characteristics are set out in Table 1a (**Appendix** 1) and termed "limits" to achieve protection of the

specified values. The water quantity characteristics are set out in policy form. As I understand it, the approach Environment Canterbury is proposing in the pCLWRP is to set limits (in Table 1a and b), but they are not proposed to be enforced as bottom lines, and the limits proposed by Ecan have been set in the absence of explicitly linking those limits to identified freshwater objectives in respect of instream values. I believe that it will be difficult to identify the appropriate limits (physicochemical characteristics) based on science without specific knowledge of exactly what one is attempting to protect.

38. The difficulties of setting limits to achieve outcomes using only the management unit (as in Table 1a pCLWRP), instead of identifying objectives for particular instream values, can be found in urban spring-fed streams, the majority of which are considered to have low ecological health (Hayward *et al.*, 2009). However, some of these are trout spawning streams (e.g., Saltwater Creek) that would need to have much higher physicochemical limits, to protect this spawning, than occurs in the average urban spring-fed stream.

39. Hayward et al. (2009) carried out an assessment of the values of waterbodies in the region in reference to waterbody type (i.e., management unit) and developed purposes for management which reflected these values. In the context of Fish and Game's case Fish and Game have renamed the "Purposes for Management" classification as "Freshwater Objectives". For each of the management units and purpose for management Hayward et al. (2009) determined the critical value and set limits which were designed to represent the environmental bottom lines required to provide for these values. The pragmatic approach took into account freshwater values including native biodiversity, salmonids fishery and spawning, waterbody type, and current state of the resource. I support this approach and recommend re inclusion of the purposes for management and critical values in Table 1a and also Schedule 5 of the pCLWRP (mixing zones and receiving water quality standards). Attached as **Appendix 2** is an amended version of Schedule 5 that I support. And given the direct relevance of the Hayward et al report to

the evaluation of this approach, the full report is attached as **Appendix 3.** While the approach is coarser than the identification of values for each river reach and establishment of limits to provide for these values, it represents an improvement from what is currently in the pCLWRP.

40. Boothroyd & Stark (2000) have suggested that QMCI's above 6 represent 'clean water', those between 6 and 5 'doubtful quality or possible mild pollution', 4 – 5 'probable moderate pollution' and less than 4 'probable severe pollution'. In my opinion QMCI's of 6 and above represent good ecological health where Salmonid and native fish should prosper (Matheson, 2012). Streams with a QMCI between 5 and 6 will be of moderate ecological health and be able to support a limited trout fishery (but are unlikely to have much spawning). Streams with QMCI's lower than 5 may still have the occasional trout present but are unlikely to support a sustainable fishery or spawning. Hay and colleagues (Hay, Hayes & Young, 2006) made similar suggestions that also recommended a QMCI above 6 (indicative of clean water) for "Regionally Significant Trout Fisheries", or above 5 (indicative of possible mild pollution) for "Other Trout Fisheries".

41. Thus to achieve the freshwater objectives identified in Table 1a **Appendix 1** for each of the river management units the QMCI limits of Table 1a in the pCLWRP would need to be modified to those in accordance with the changes made in **Appendix 1.** A QMCI of 6 should protect a sustainable and healthy trout fishery, a QMCI of 5 a moderate, but not sustainable trout fishery and a QMCI of 4 is not suitable for any trout fishery value. This raises concerns for the few significant trout spawning rivers that occur in the Urban stream units mentioned above.

42. To assess significant adverse effects to the ecological health of receiving waterbodies the water quality standards in Schedule 5 needs to include assessment of the biological communities. Usually this would involve a statistical assessment of the potential change in QMCI

as the result of a discharge. I have found that a 20% change in QMCI is a suitable practical alternative to statistical evaluation (i.e. is equivalent to a significant effect) that many resource managers find more practical for most consent holders. Thus a limit of a 20% change in QMCI should be added to Schedule 5 as a standard (Appendix 2).

43. In my experience chlorophyll *a* levels of 200 mg/m^3, presented in Table 1a of the pCLRWP are very high and normally only occur in very eutrophic (nutrient enriched) waterbodies. Furthermore, they would also not be consistent with a filamentous algal cover of less than 30% presented alongside the 200 mg/m^3 numerics in Table 1a. In my opinion it would be more robust and consistent to have 120 mg/m^3 instead of 200 mg/m^3 as the maximum chlorophyll *a* biomass to maintain ecological health (Biggs, 2000b) (**Table 1a Appendix 1**).

44. Paradoxically there are no nutrient or flow limits in the pCLWRP Table 1a notifed by Ecan to achieve these periphyton limits. Periphyton limits are only likely to be achieved by setting nutrient concentrations and flow regimes for a waterbody. I am unaware of any way a landowner could directly meet these periphyton limits other than by maintaining nutrient and flow regime bottom lines. By managing nutrient concentrations and flow regimes, which are measurable, and controllable, by landowners then they will by default, ensure their activities do not breach the periphyton target.

45. Several other biochemical standards have been altered or excluded in Schedule 5 from those recommended in Hayward et al. (2009) without any obvious scientific justification. I would therefore also recommend a Biological Oxygen Demand (BOD) standard of 1 mg/L and the pH change standard of 0.5 be added to Schedule 5 following Hayward et al. (2009) (**Appendix 2**). The Dissolved Organic Carbon standard in Schedule 5 should also be 1 mg/l not 2 mg/l, again based on Hayward et al. (2009).

46. Water temperature can also be an important constraint on aquatic life. The productivity of a trout population will suffer as water temperature approaches and exceeds 19°C. Laboratory studies looking at the impacts of high temperatures on trout, have found that brown trout ceased feeding once temperatures climbed above 19°C and that they would die if temperatures climbed above 25°C for a sustained period (Elliott & Hurley, 2003). Similarly, 50% of Deleatidum mayflies will die after 4 days in water at 22.6°C (Quinn *et al.*, 1994). However, the thermal range for developing trout embryos, is much narrower. The preferred range for brown trout spawning is 3-20°C, with an optimum temperature of 10°C, and for hatching a preferred range of 2-11°C with a maximum of 20°C (Death, 2002). Thus for management units with high Salmonid fishery values the temperatures in Table 1a should be reduced from 20°C to 19°C, for management units with salmonid spawning values I recommend the inclusion of maximum temperature of 11°C to apply from April to October (**Appendix 1**), and for Schedule 5 standards I recommend a maximum change in temperature of 2°C (**Appendix 2**)

47. Finally, management can ensure water quantity and quality is appropriate to sustain a Salmonid fishery, but if the habitat is not of suitable condition the fishery will not be maintained. In riverine systems this is termed natural character following (Froude, Rennie & Bornman, 2010). This encompasses the geomorphological characteristics of a river reach that can be altered by engineering for flood control, protection and construction of infrastructure (e.g. roads and bridges).

48. Until recently there has not been a mechanism to manage the sometime conflicting instream habitat needs of fish and the requirement for flood engineering to protect infrastructure. However, to manage and protect a Salmonid fishery it is necessary to include this in any resource management planning.

Nutrient Limits

49. Land use activities contribute to the degradation of water quality and ecological condition in waterbodies through the run-off of nutrients. This can result in eutrophication (unnaturally high nutrient levels) that in turn can lead to excessive periphyton growth (Fig. 2). Nitrates and ammonia (NH_3) can also be directly toxic to many aquatic animals (Hickey & Martin, 2009), however declines in ecological health occur long before toxic levels of these nutrients is achieved.

50. Agricultural land use practices contribute nutrients to waterways in a variety of ways. Application of fertiliser can inadvertently end up being applied directly into waterways or be washed into them during rain events. Livestock, if given access to waterways, have a preference for urinating and defecating directly into the waterway (Bagshaw, 2002; Davies-Colley *et al.*, 2004). Finally, land erosion from landslips, livestock trampling and wallowing, or cultivation too close to waterways, will deposit sediment into streams to which phosphorous is bound. This can subsequently dissolve into the water and become available for periphyton growth.

51. Excessive periphyton growths are not only aesthetically unappealing, but they can also result in dramatic changes to the biological communities in rivers and streams. T hey lead to a change from mayfly, stonefly and caddisfly dominated communities to ones with worms, snails and midges that do not support the same abundance, biomass or diversity of fish that the former communities do. The periphyton can also build up to such a biomass that the lower layers start to rot. This can dramatically reduce the oxygen levels and change the pH of the water leading significant adverse effects on many invertebrates and fish.

52. The change to habitat structure and quality (in particular pH and oxygen levels) as a result of excessive algal growth will result in fish emigrating, growing more slowly, being more susceptible to disease,

or in the worst case dying. Large fish kills can be a result of reduced oxygen levels from excessive periphyton growth particularly on warm summer days. Changes to the invertebrate fauna as a result of excessive periphyton growths have similar but slower effects on fish. The change often results in smaller prey items such that fish have to expend more energy to consume an individual prey item. This can result in slower grow rates, reduced condition, emigration or death (Hayes, Stark & Shearer, 2000).

53. Increased nutrient levels can also result in increased abundance and/or toxicity of cyanobacteria, such as *Phormidium,* which appears to be on the increase in the Canterbury Region (e.g. Timaru Herald 'Poisons reduce rivers to drains' article 20/1/2013). Although the linkage between nutrient levels and *Phormidium* biomass and/or toxicity is not well understood (Wood & Young, 2011). They concluded it may pose a risk to drinking water supplies. They also concluded more research on the effects of the toxins for edible aquatic species (e.g., koura and trout) and potentially ecosystem health were warranted. I recommend adding another column to Table 1a to limit cyanobacteria cover to 20%.

54. Dr Mike Joy and his research team at Massey University have also shown that juvenile native fish (*Galaxias* and *Gobiomorphus*) can detect the difference between water coming from high and low level nutrient waterbodies as they migrate upstream and actively avoid the high nutrient rivers altogether. Therefore elevated nutrient levels can act as a barrier to fish migration.

55. In general the two main nutrients that can result in excessive periphyton growth are nitrogen (N) and phosphorous (P) (Biggs, 1996; Dodds, Jones & Welch, 1998; Biggs, 2000a; Death, Death & Ausseil, 2007).

56. The nutrient (N or P) that is limiting periphyton growth is the one that when added to a waterbody will result in an increase in periphyton biomass. To illustrate this you could consider a pot plant that needs light and water to grow; you can grow it in the best light possible, but if you do not water it then the plant will die. Water becomes the limiting resource because it is the scarcest resource; addition of any water (as long as the plant has not died) will result in the plant growing. Thus the resource (nutrient) that is at the lowest level in the waterbody is the one that can have the biggest impact. Management of that nutrient will therefore have the biggest effect on controlling periphyton growth in a waterbody.

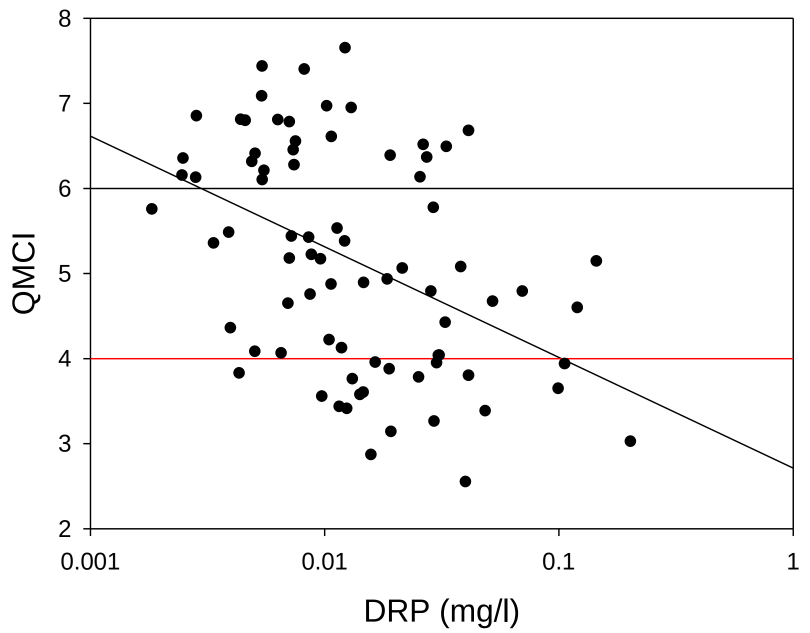
57. The molar ratio of N to P in the water, termed the Redfield ratio (Redfield, 1958), has been suggested as a benchmark for assessing nutrient limitation. Ratios greater than 20:1 are considered P-limited, those less than 10:1 are N-limited and for values between 10 and 20 to 1 the distinction is not clear (Schanz & Juon, 1983; Borchardt, 1996). (McArthur, Roygard & Clark, 2010) used Redfield ratios to show there is considerable spatial and temporal variation in the indicated limiting nutrient.

58. There is a considerable body of evidence that these ratios are not indicative of actual nutrient limitation (Francoeur *et al.*, 1999; Wold & Hershey, 1999; Francoeur, 2001; Keck & Lepori, 2012). A more effective alternative for assessing which nutrient is limiting is the deployment of nutrient diffusing substrates (Hauer & Lamberti, 1996; Biggs & Kilroy, 2000). (Death *et al.*, 2007) using nutrient diffusing substrates found nitrogen to be the limiting nutrient in summer at a number of sites in the Rangitikei River catchment despite varying Redfield ratios.

59. Integrating this information on potential limiting nutrients and periphyton growth the conclusion is that without site and season specific studies both N and P can be potentially limiting nutrients throughout the waterbodies in the Region (Wilcock *et al.*, 2007; Kilroy,

Biggs & Death, 2008). Appropriate management should be focussed on managing both nutrients, not just one or the other.

60. Biggs (2000a) from research on periphyton established nutrient and flow relationships to predict maximum periphyton biomass in New Zealand streams and rivers. However, although the pCLWRP has periphyton limits Environment Canterbury does not appear to have any mechanism to achieve or assess the attainment of those limits. They do however have QMCI limits for each river type in Table 1a. Therefore I would propose to use the relationship between QMCI and nutrient concentrations to achieve limits for QMCI and periphyton in Table 1a. (Fig. 4). This leaves aside the issue of whether those QMCI limits are appropriate for the values in each of the management units which I discussed above.



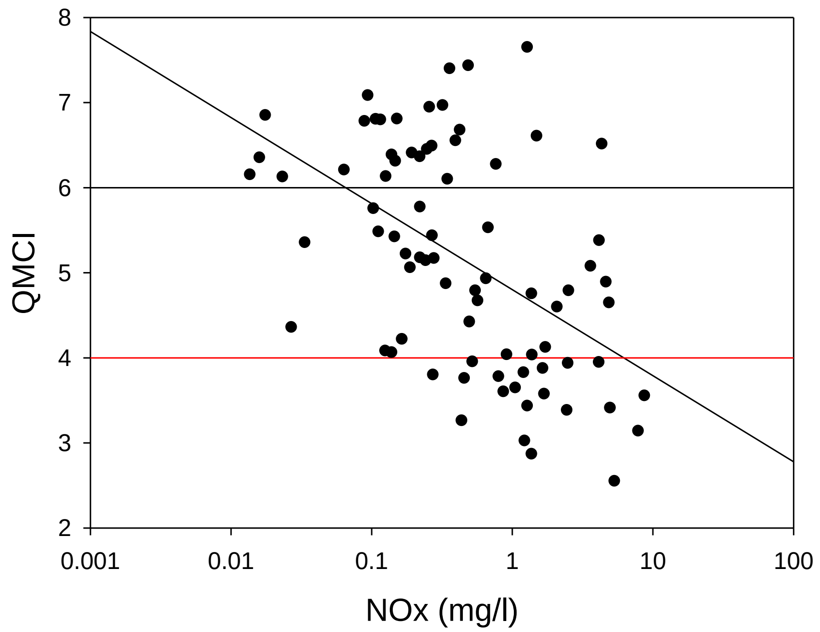


Figure 4. Water quality measured as QMCI from 80 Canterbury rivers and streams plotted against mean nitrate and dissolved reactive phosphorous levels. Data supplied Environment Canterbury.

61. The pCLWRP has water quality standards for waters not classified as Natural for dissolved inorganic nitrogen ("DIN") and dissolved reactive

phosphorus ("DRP") in Schedule 5 (p 16-9) derived from Hayward *et al.* (2009).

62. After integrating current understanding about linkages between nutrient levels and instream values for management units in Table 1a **(Appendix 1)**, the linkages and practicality of trying to manage for biological limits (e.g., periphyton and QMCI) in Table 1a presented daa in this evidence and technical analysis by Environment Canterbury (Hayward *et al.*, 2009) I conclude there is clearly a need to have nutrient limits presented in a table in the pCLWRP.

63. The nutrient quantities presented in Schedule 5 of the pCWLRP are all consistent with the above assessment. Movement of the DIN and DRP numerics from Schedule 5 (originally from Hayward et al 2009) to Table 1a (i.e., **Appendix 1**) will provide the clarity to allow landowners and managers to achieve some of the other biological limits in Table 1a and the freshwater objectives identified. I have amended Table 1a (**Appendix 1**) to my evidence to reflect my recommendations

Deposited sediment

64. Sedimentation, along with nutrient enrichment, is one of the most pervasive and detrimental effects on water quality and ecological integrity on streams and rivers in New Zealand.

65. Sedimentation is critically important for many aspects of ecosystem health such as trout spawning and the protection of native fish communities. Again sedimentation is often associated with agriculture. There is often a loss of productive soil to the streams and rivers of the region from activities like vegetation clearance and livestock access to waterways.

66. To illustrate this (Clapcott *et al.*, 2011) have modelled deposited sediment in Canterbury streams and rivers both with and without the influence of land use change from agriculture and urbanisation (Fig. 5).

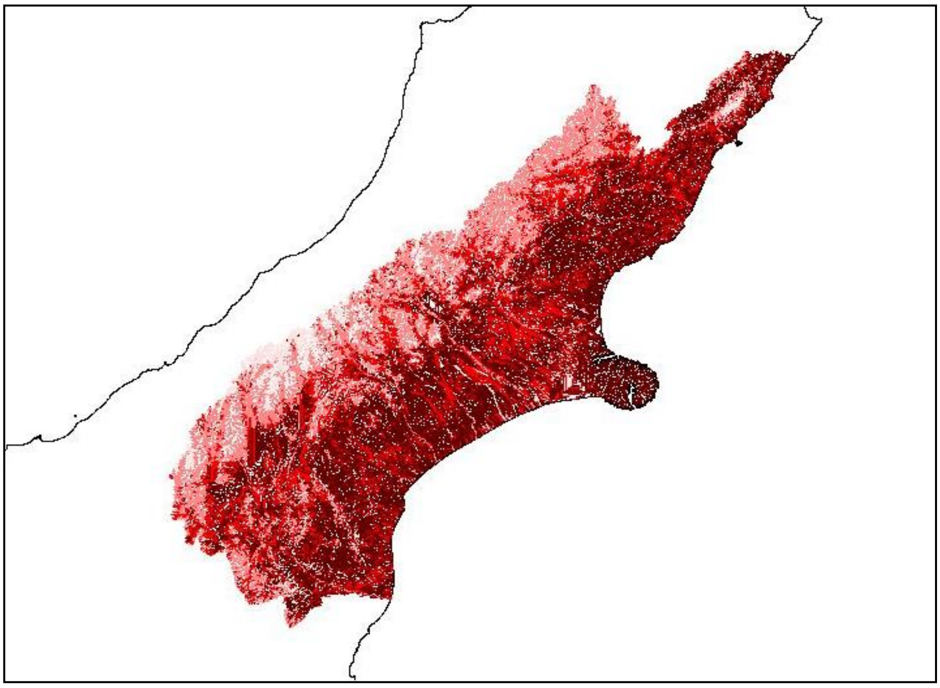


Figure 5. Percent increase in sediment as a result of land use modification for rivers and streams in the Canterbury region. White =no change, Pink = 0-100% increase, Red = 100 – 500 % increase, Dark red = 500 – 1000% increase, Very dark red = > 1000% increase.

67. Deposited sediment can smother animals directly (Fig. 6A and 6B) and/or motivate them to leave. It can also smother and bind with the periphyton on rock surfaces that is the food for many aquatic invertebrates and lower the nutritional quality of this food. It fills in the interstitial spaces between rocks (Fig. 6C) where many of the fish and invertebrates live during the day (most are nocturnal) or during flood events. Stream invertebrates and many fish (e.g., eels) can live at least up to a metre under the stream bed if there are suitable interstitial spaces (Williams & Hynes, 1974; Stanford & Ward, 1988; Boulton *et al.*, 1997; McEwan, 2009).

Figure 5A. Koura struggling in deposited sediment**.**

Figure 4B. Banded kokopu struggling in deposited sediment.

Figure 5C. Stream substrate with interstitial spaces partly clogged with deposited sediment.

68. Sediment occurs as a natural component of many natural aquatic systems, which is transported as suspended sediment and bedload, mostly at times of high river flows and floods. Small particles, such as clay and silt, are generally transported in suspension, whereas larger particles, such as sand and gravel, usually roll or slide along the riverbed. However, erosion from land use activities greatly enhances sediment supply both during low and high flow events. Sediment levels during floods are considerably higher in agricultural catchments than similar catchments with native vegetation.

69. Increased levels of suspended and deposited sediment can have dramatic effects on stream ecosystems. Increased sediment loads can:

a. smother natural benthos;

b. reduce water clarity and increase turbidity;

c. decrease primary production because of reduced light levels;

d. decrease dissolved oxygen;

e. cause changes to benthic fauna;

f. kill fish;

g. reduce resistance to disease;

h. reduce growth rates; and

i. impair spawning, and successful egg and alvein development.

(Ryan, 1991; Waters, 1995; Matthaei *et al.*, 2006; Townsend *et al.*, 2008; Clapcott *et al.*, 2011; Collins *et al.*, 2011).

70. Trout can be especially sensitive to increased suspended and deposited sediment. They require cold, well oxygenated water with low sedimentation levels. This is especially important during the trout spawning period, where cold, well oxygenated water and gravels and minimal sedimentation are essential to spawning success and egg survival. Direct impacts include: mechanical abrasion to the body of the fish and more significantly its gill structures, death, reductions in growth rate, lowered resistance to disease, prevention of successful egg and larval development, and impediments to migration. Indirect impacts include: displacing macroinvertebrate communities that provide food, and reducing visual clarity so finding prey is more difficult (Peters, 1967; Acornley & Sear, 1999; Argent & Flebbe, 1999; Suttle *et al.*, 2004; Hartman & Hakala, 2006; Fudge *et al.*, 2008; Scheurer *et al.*, 2009; Sternecker & Geist, 2010; Collins *et al.*, 2011; Herbst *et al.*, 2012).

71. A number of fish species, particularly trout, are visual feeders, thus any increase in suspended sediment or corresponding reduction in water clarity reduces their ability to feed efficiently. The reduced water clarity results in visual feeding fish spending more time and energy foraging which in turn reduces growth rates, general heath, and causes potential reductions in reproductive fitness (Kragt, 2009).

72. Increases in suspended sediment have the potential to adversely affect macroinvertebrate communities. Reductions in water clarity can cause reductions in primary production, periphyton biomass and food

quality. Invertebrate community composition may be altered as a result of sedimentation generally with a loss of stonefly and mayfly species, and an increase in chironomids and oligochaetes that can burry into silt. Sediment may also cause a reduction in dissolved oxygen by clogging substrate interstices leading to a reduction in gas exchange with more oxygenated surface water.

73. Fish, such as salmonids, that lay their eggs in the substrate of the stream are also particularly sensitive to deposited sediment. The sediment can smother eggs directly or reduce oxygen levels in the area directly below the stream bed dramatically (Olsson & Persson, 1988; Crisp & Carling, 1989; Weaver & Fraley, 1993; Waters, 1995). Generally less than 20% sediment cover is considered good for trout spawning and no sediment is optimal (Clapcott *et al.*, 2011).

74. In light of these concerns and facts, Table 1a provides for a deposited sediment limit for streams and rivers in each management unit (of, 15, 20 or 30%). I support limits below or equal to 20% in Table 1a but 30% is above that established in the national protocols (Clapcott *et al.*, 2011). Thus the 30% limit in Table 1a should be modified to 20% (**Appendix 1**).

75. Since trout are visual predators and drift feeding is the predominant foraging behaviour in most rivers (especially those of moderate to steep gradient). Increasing algal growth and decreasing water clarity will adversely affect the ability of trout to “sight feed” on high quality drifting macro-invertebrates such as EPT taxa (mayflies, stoneflies and caddisflies), as it will reduce their ability to detect and intercept drifting prey. The strength of this effect depends on trout size and prey size, but will start to have an effect once water clarity drops below 4 m (Hayes *et al.*, 2000). Generally maintaining clarity levels of 3.5m - 5m, as measured by black disk, are required to maintain reaction distances of drift feeding trout at appropriate levels (Hay, Hayes & Young, 2006). Thus I recommend the inclusion of visual clarity limits in Table 1a as proposed by Hayward et al. (2009) which take into account the freshwater objectives and waterbody type (management unit) to represent pragmatic environmental bottom lines (**Appendix 1**).

76. Imposing a limit on the allowable water clarity reduction caused by a discharge is also necessary to reduce the risk of increasing deposited sediment levels as suspended sediment eventually settles out. It is also important in its own right to protect the recreational, aesthetic, trout fishery, and native fish, values associated with surface waterbodies. I consider that a maximum water clarity change of 20 to 30% dependent on the geology of the river is appropriate, and that this limit should apply year-round to protect the life supporting capacity of freshwater ecosystems. Also, the 20 – 30% change in visual clarity standard is the numerical equivalent to the narrative within s70 and s107 in the Resource Management Act 1991 ("RMA"): "*no conspicuous change in colour or visual clarity*". I therefore consider reference to the change in visual clarity in Schedule 5 would be appropriate for permitted and controlled activities, as it addresses the issue of subjective assessments in regards to "*visual change*", and ensures that the effects of the activity in the freshwater environment are unlikely to be significant.

IMPACTS OF STOCK ON ECOSYSTEM HEALTH & RIPARIAN SETBACKS

77. Riparian buffer zones can range from a simple strip of vegetation from which livestock or other agricultural activities are excluded to a completely vegetated native forest riparian strip. The principal effect of the riparian buffer is to act as a barrier to nutrients, sediment, pathogens and other potential contaminants running off the land and to prevent it entering the waterway and consequently flowing downstream to lakes and estuaries. It will also stabilise stream banks and limit erosion and undercutting. The vegetation can also take up some of the nutrients. If a forested riparian zone exists this can also serve to limit light reaching the stream bed (which can also exacerbate periphyton growth) and water temperature (most aquatic animals have an upper threshold for survival which can be comparatively low, e.g., 19°C for stoneflies).

78. The riparian buffer zone can also provide suitable habitat for the adult stages of many aquatic invertebrates (the in water life stage of many aquatic animals is the juvenile form with winged adults emerging from

the water to mate and reproduce) (Collier & Scarsbrook, 2000; Collier & Winterbourn, 2000; Smith *et al.*, 2002; Smith & Collier, 2005). Terrestrial insects and mammals from riparian zones often form a major component of the diet for many native and sport fish at certain times of the year (Main, 1988; McDowall, 1990). Thus riparian buffer zones also serve to maintain the proper ecological functioning of instream ecosystems.

79. Riparian buffer zones, particularly those with forested vegetation, are also important for providing instream habitat for native fish and trout by enhancing habitat diversity (e.g., overhanging branches, bank under cutting), creating pools and areas of day time and flood refuge. Grassy or forested river banks and lake shores also provide spawning habitat for Inanga and other Galaxias species, respectively. Thus riparian buffer zones also serve to maintain the proper ecological functioning of instream and lake ecosystems.

80. Livestock access to waterways results in the loss or destruction of the riparian buffer zone, significantly compromising its ecological function (Osborne & Kovacic, 1993; Quinn, Cooper & Williamson, 1993; Davies & Nelson, 1994; Weigel *et al.*, 2000; Kiffney, Richardson & Bull, 2003; Parkyn *et al.*, 2003; Yuan, Bingner & Locke, 2009; Weller, Baker & Jordan, 2011). Cattle and dairy cows, if given access to waterways, have a preference (in one study up to 50 times greater) for urinating and defecating directly into the waterway that will contribute to elevated levels of nitrogen and microbial contaminates (Bagshaw, 2002; Davies-Colley *et al.*, 2004). Livestock (principally cattle, dairy cows and deer) trampling (Fig. 7A and 7B) and wallowing can result in sediment deposition into streams, rivers and lakes. This can result in increased levels of deposited fine sediment with the direct detrimental ecological effects highlighted above. P hosphorous is also bound to the sediment and this can subsequently dissolve into the water and become available for periphyton growth. Finally livestock grazing will remove or degrade any riparian vegetation that might provide stream cover (to reduce light and temperature), stabilise banks, and provide habitat for aquatic and terrestrial invertebrates which are part of the aquatic food web, along with instream and lake habitat for fish.

Figure 7A. Stock damage to stream (Photos courtesy Kate McArthur, Catalyst Group)

Figure 7B. Stock damage to streams (Photos courtesy Kate McArthur, Catalyst Group)

81. In the only published study of pathogenic organisms in New Zealand waterways I am aware of (McBride *et al.*, 2002), catchments classed as dairy were the second most contaminated (after bird catchments)

with pathogenic microorganisms. Contamination of water bodies by pathogenic organisms such as bacteria (e.g.,*Escherichia coli*), viruses (e.g., norovirus) and protozoa (e.g.,Giardia and Cryptosporidium) from stock and other sources can be reduced by riparian buffer strips and denying stock direct access to streams (Winkworth, Matthaei & Townsend, 2008b; Winkworth, Matthaei & Townsend, 2008a; Winkworth, Matthaei & Townsend, 2010). For example (Winkworth *et al.*, 2008b) found a 26% reduction in Giardia flowing into waterways when planted riparian buffers are present, and this reduction was greater with native versus exotic vegetation (Winkworth *et al.*, 2010).

82. Riparian buffer setbacks from land use activities will assist with managing both sediment and nutrients and promote ecological health. In establishing the appropriate width of riparian buffer zones consideration must be given to surrounding land use activity, soil type and catchment slope, and the goals of the set back (e.g., ecological health versus limiting contaminant runoff). Even in situations where it may not be possible to have riparian setbacks then exclusion of stock from those waterways would be the best alternative for attempting to manage waterway ecological health.

Small and ephemeral streams

83. Considerable focus in water quality management in agricultural land focuses on larger waterbodies. For example the Clean Stream's Accord refers to streams that are "larger than a stride and deeper than a red-band". Assuming this description only applies to third order or greater streams this would exclude a large portion of stream length from any management (Fig. 8).

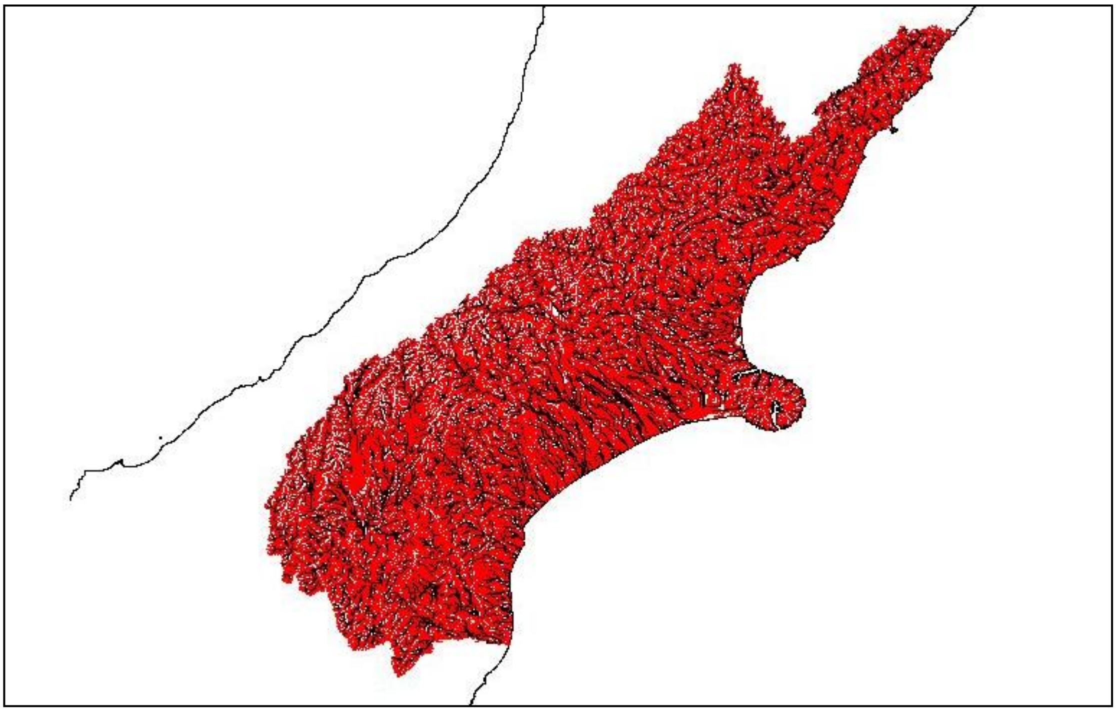


Figure 8. Streams protected by the clean streams accord (in black) and those that are too small for protection under this criteria (in red) for the Canterbury region.

84. As water runs downhill if these streams are not managed/protected then the sediment and nutrients entering them will flow down into the larger streams. A variety of studies have shown that riparian management of water bodies is strongly affected by the condition of the upstream environment (Storey & Cowley, 1997; Scarsbrook & Halliday, 1999; Parkyn *et al.*, 2003; Death & Collier, 2010).

85. Furthermore recent research has found that both small (Heino *et al.*, 2003; Clarke *et al.*, 2008; Clarke *et al.*, 2010) and ephemeral (Storey & Quinn, 2008) streams can have very high biodiversity, often greater than in larger streams. Figure 9 below show that for 960 streams and rivers sampled in the lower North Island that the highest diversity occurs in the smaller streams. The same will apply in Canterbury.

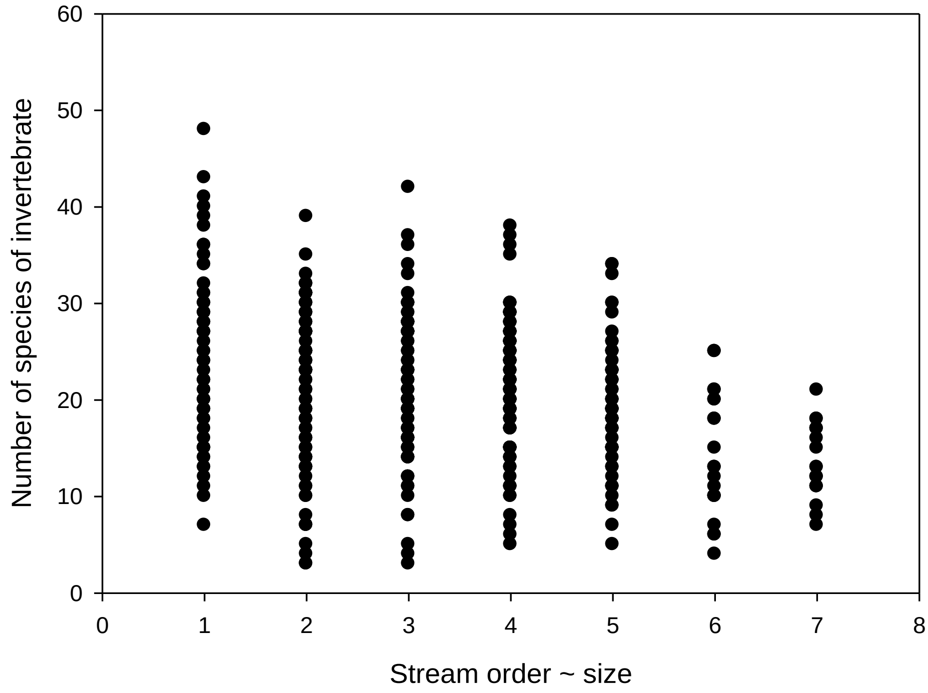


Figure 9.Number of taxa collected in 5 Surber samples in 960 streams and rivers in the lower North Island as a function of stream order (this provides a good approximation to stream size as higher order streams are larger).

86. Equivalent protection and management needs to be given to all ephemeral streams greater than 1m and all permanently flowing streams.

CONCLUSION

87. There is a considerable body of evidence that land use activities if not managed appropriately can and do have significant adverse effects on the ecological health of waterbodies in the Canterbury Region.

88. Ecosystem health in many of the lowland and urban waterbodies in the Canterbury region is extremely poor. Although waterbody ecosystem health is still moderate to high in the region's mountains, high country and hill regions scenarios of increasing agricultural intensification in these areas has the potential to result in significant adverse effects if not managed carefully. The pCLWRP does not

seem to provide adequate guidance or mechanism for that management.

89. The principal driving factors for these adverse effects are predominately increased nutrient levels, changes in flow regimes and increased deposited sediment.

90. Agriculture, particularly on highly erodible land results in increased levels of deposited fine sediment that smother plants and animals, buries habitats and changes the composition of fish and invertebrate communities, in turn reducing ecological health. The pCLWRP needs minor amendment to provide adequate guidance on limits of deposited sediment more consistent with national approaches (see Table 1a).

91. Similarly management of both nitrogen and phosphorus in all waterways is important to avoid the adverse effects of nutrient enrichment from increasing agricultural intensification. While it is laudable to have periphyton limits in Table 1a, it seems pointless if there is no mechanism to monitor or achieve these limits. I would propose that nutrient limits are the only practical mechanism for achieving the outcomes for periphyton and QMCI in Table 1a. If nutrients are not managed below certain thresholds this results in cascading affects through riverine food webs that result in degraded water quality and ecological health. The concentrations of nutrients presented in Table 1a (**Appendix 1**) from Hayward et al (2009) are highly likely to lead to maintained or improved ecological health if concentration is restricted to those levels.

92. Healthy ecological systems require the appropriate chemical, physical and biological conditions. Both excess nutrients and sediment can detrimentally alter this environment. Improved ecological health will only result from managing both sediment and nutrients.

93. To achieve protection of the Salmonid fishery in each of the river management units the QMCI limits of Table 1a in the pCLWRP would need to be modified to those in **Appendix 1**. A QMCI of 6 should

protect a sustainable and healthy trout fishery, a QMCI of 5 a moderate, but not sustainable trout fishery and a QMCI of 4 is not suitable for any trout fishery value.

94. Chlorophyll *a* values in Table 1a of 200 mg/m^2 should be reduced to 120 mg/m^2 to be consistent with the percent filamentous algae cover column and to provide for the values in Table 1a.

95. There is convincing evidence that the ecological health of hill and lowland streams and rivers is moderate to poor and would be unlikely to assimilate increased detrimental effects that may result from unmanaged increases in agricultural intensification or less environmentally focused agricultural practises. It is possible that any increased agricultural intensification would result in even more dramatic declines in ecological health. – Significant adverse effects on life supporting capacity.

96. Stock access to waterways will increase stream bank erosion, sediment deposition, nutrient enrichment, pathogenic organism abundance in waterways, instream habitat destruction, and if riparian buffer zones are also open to stock access, greatly exacerbate the detrimental effects of land use activities that can potentially be ameliorated by the buffering ability of streamside vegetation. In my opinion the single best management practise that could be implemented to improve ecological condition of waterways is to exclude all stock.

97. As water runs downhill, management of small and ephemeral streams is critical to the management of larger downstream waterways and biodiversity. For that reason, this protection and management also needs to be given to all ephemeral streams greater than 1m, and all permanently flowing streams.

98. As aquatic ecological communities are complex ecosystems that are affected by multiple interacting stressors, the effects for ecological communities of specific management practices that focus on

controlling only one of these stressors is difficult to predict. Improvement in the ecological health of these waterbodies will require the management of all the interacting stressors, as proposed by the Fish and Game rules of Phillip Percy. However, any reductions in nutrients, deposited sediment, and restriction of stock access to waterbodies, will improve the current poor state of many of the region's waterbodies.

Associate Professor Russell George Death

4 February 2013

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APPENDIX 1 – Table 1a

Management Unit	Subunit	Purposes for Management	Critical Values	QMCI [minimum score]	Dissolved oxygen [minimum saturation] (%)	Temperature [max] (°C) to apply from October to April inclusive	Temperature [max] (°C) to apply during May to September inclusive	Emergent Macrophytes [Max. cover of Bed](%)	Total Macrophytes [Max. cover of bed](%)	Chlorophyll a [max. biomass](mg/m²)	Filamentous algae >20mm [max. cover of bed](%)	Benthis Cyanobacteria [max cove of bed] (%)	Fine Sediment <2mm diameter [max. cover of bed](%) All Values	Suitability for Contact Recreation [SFRG*] Value 8	pH	Nitrate & Other toxicants (Protection level)	DIN	DRP	Clarity black disk (m)
Natural State				Rivers are maintained in a natural state															
Alpine – Upland*		1,2,3,4,6, 7	High biodiversity Salmonid Fishery	~~5-6~~ 6		~~20~~ 19	11			50	10	20	10	Good		99%	0.08	0.005	1.6
Alpine – Lower*		1,2,3,4,6, 7,8	Salmonid Fishery Amenity							120	20	20		Good to Fair		99%	0.18	0.007	1.6
Hill-fed Upland*		1,2,3,4,6, 7	High Biodiversity Salmonid Fishery		90			No Set Value	No Set Value	50	10	20	15	Good		99%	0.21	0.006	4
Hill-fed Lower*		1,2,3,4,6, 7,8	Salmonid Fishery Amenity Contact recreation							~~200~~ 120	30	20		Good to Fair	Maintain between 6 and 8.5 [no greater than 0.5 change]	95%	0.47	0.006	4
	Urban	1,2,3,5,6, 7,8	Amenity	~~3.5~~ 4		20	20			~~200~~ 120	30	20	20	No Value Set		95%	0.47	0.006	4
Lake – fed*		1,2,3,4,6, 7	Salmonid Fishery High Biodiversity	6		20	20			~~200~~ 120	30	20	10	Good		99%	0.21	0.003	3
Banks Peninsula*		1,2,3,4,6, 7,8	High Biodiversity	~~4 – 5~~ 5		20	20			120	20	20	20	No Value Set		99%	0.09	0.025	2
Spring-fed Upland*		1,2,3,4,6, 7	High Biodiversity Salmonid Spawning	6		~~20~~ 19	11	20	30	50	10	20	10	Good		99%	0.10	0.007	3
Spring-fed lower basins*		1,2,3,4,6, 7	High to moderate Biodiversity Salmonid	5		20	11	30	30	~~200~~ 120	30	20		Fair		95%	0.47	0.010	3

			Fishery																
Spring-fed – plains*		1,2,3,4,6, 7,8	Moderate Biodiversity Salmonid Fishery	~~4.5 – 5~~ 5	~~70~~ 80	20	11	30	50	~~200~~ 120	30	20	20	No Value Set		95%	1.5	0.016	3
	Urban	1,2,3,5,6, 7,8	Moderate Biodiversity Amenity	~~3.5~~ 4		20	11	30	~~60~~ 50	120	30	20	~~30~~ 20	No Value Set		95%	1.5	0.016	2

Freshwater Objectives
1 Ensure diverse and abundant aquatic ecosystems of indigenous flora and fauna
2 Protect habitat of salmonids (trout or salmon)
3 Maintain amenity values
4 Ensure water quality is safe for contact recreation
5 Ensure water is suitable for secondary contact recreation
6 Safe guard Ngai Tahu cultural values including; mauri, mahinga kai, wahi tapu and wahi taonga
7 Ensure water is suitable for stock drinking water supply
8 Support the functioning and health of estuaries and coastal lagoons

APPENDIX 2 – Water Quality Standards for waters not classified as Natural from Schedule 5

Water quality class	Purposes for Management	Critical Values	QMCI	BOD	DOC	Temperature	pH	pH	Visual Clarity	Colour	DIN	DRP	E. coli*	Nitrate & Other toxicants (Protection level)
			Change shall not exceed (%)	Change shall be less than mg/l	Change shall be less than mg/l	~~Average~~Change shall not exceed (°C)	Shall be between (no units)	Change shall not exceed (no units)	% change shall not exceed	% change shall not exceed (Munsell units)	Shall be less than (mg/l)	Shall be less than (mg/l)	95% of samples shall be less than (E.coli per 100ml)	Shall not exceed the concentration specified in Table WQL17 for rhe relevant level of protection (see note below)
Alpine – Upland*	1,2,3,4,6,7	High biodiversity Salmonid Fishery	20	1	~~2~~ 1	2	6.5 – 8.5	0.5	20	5	0.08	0.005	260	99%
Alpine – Lower*	1,2,3,4,6,7,8	Salmonid Fishery Amenity									0.18	0.007	550	~~95%~~ 99%
Hill-fed Upland*	1,2,3,4,6,7	High Biodiversity Salmonid Fishery							20	5	0.21	0.006	260	99%

Hill-fed Lower	1,2,3,4,6,7,8	Salmonid Fishery Amenity Contact recreation									0.47	0.006	550	95%
Hill-fed Lower urban	1,2,3,5,6,7,8	Amenity									0.47	0.006		~~90%~~ 95%
Lake – fed*	1,2,3,4,6,7	Salmonid Fishery High Biodiversity							20	5	0.21	0.003	260	99%
Banks Peninsula *	1,2,3,4,6,7,8	High Biodiversity							~~35~~ 30	10	0.09	0.025	550	99%
Spring-fed Upland*	1,2,3,4,6,7	High Biodiversity Salmonid Spawning							20	5	0.10	0.007	260	99%
Spring-fed lower basins*	1,2,3,4,6,7	High to moderate Biodiversity Salmonid Fishery							~~35~~ 30	10	0.47	0.010	550	95%

Spring-fed – plains	1,2,3,4,6,7,8	Moderate Biodiversity Salmonid Fishery							~~35~~ 30	10	1.5	0.016	550	95%
Spring-fed – plains urban	1,2,3,5,6,7,8	Moderate Biodiversity Amenity	~~3.5~~ 4						20	5	1.5	0.016	550	~~90%~~ 95%