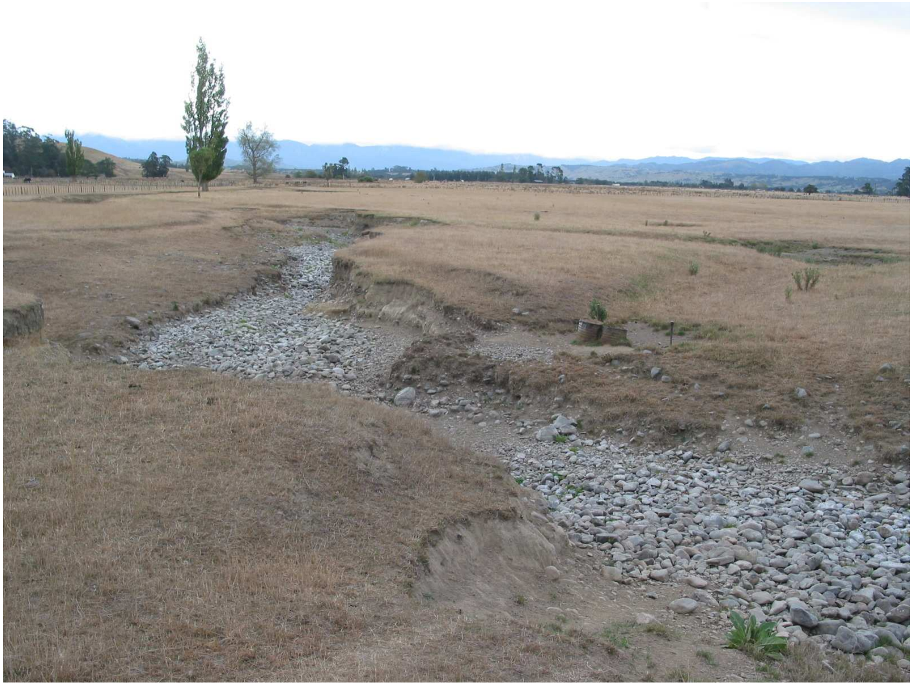
Applicability of the Stream Ecological Valuation (SEV) to intermittent streams



NIWA Client Report: HAM2010-132
October 2010

NIWA Project: ELF10205

HBRC Publication No. 4902
Report No. RM16-83

Applicability of the Stream Ecological Valuation (SEV) to intermittent streams

R. Storey

Prepared for

Hawke's Bay Regional Council

NIWA Client Report: HAM2010-132
October 2010

NIWA Project: ELF10205

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

Contents

Reviewed by:

John Quinn

Approved for release by:

Dave Rowe

Formatting checked

Executive Summary

This report describes the applicability of the Stream Ecological Valuation (SEV) (Rowe et al., 2008) to intermittent streams. Intermittent streams are defined as those that contain flowing water for most of the year, but cease flowing or dry completely for a period of days or weeks in a year of average rainfall. Though designed for small (first- to third-order) perennial streams, SEV should produce reasonable results for small intermittent streams provided that intermittent reference sites are used where reference data are needed to calculate scores, and the final scores of intermittent test sites are compared to other intermittent sites. Scores from intermittent sites may not be comparable to scores from perennial sites.

Among the 16 SEV functions, water temperature control (WTC), dissolved oxygen maintenance (DOM), decontamination of pollutants (DOP), fish fauna intact (FFI) and invertebrate fauna intact (IFI) are likely to be significantly affected by differences between intermittent and perennial streams. These will either need changes to the formulae underlying the functions, or changes to the way data is entered. Among the remaining functions, intermittent sites may operate somewhat differently to perennial streams, but the same variables influence departures from the natural (reference) condition.

Some functions may be more ecologically important in intermittent streams than in perennial streams, and others less. However, SEV assigns equal weighting to all functions, therefore no modifications to SEV are recommended in order to account for these differences.

1. Introduction

The SEV, or Stream Ecological Valuation (Rowe et al., 2008), is a functional approach to assessing the condition of stream reaches. It considers sixteen different functions that stream reaches provide to the stream network, and rates each function according to how well it is fulfilled by the particular stream reach.

The stream functions fall into four categories (Table 1). Hydraulic functions include measures of the flow regime (how close it is to the natural hydrologic regime) and measures of how well the stream is connected to groundwater, flood plains and other stream reaches. Biogeochemical functions include the ability of the stream to maintain suitable levels of oxygen, temperature and organic matter, and its ability to decontaminate pollutants. Habitat provision functions consider the suitability of the stream habitat for fish and invertebrates. Biodiversity functions measure the ability of the stream to maintain healthy fish and invertebrate fauna.

Each function is derived from one or more variables, most of which are measured in the field, though some are derived from maps. The variables are weighted and combined in a mathematical equation to produce a score between 0 and 1 for each function. The final SEV score is an average of the 16 individual function scores, and provides an overall measure of the functional health of the stream. Reference sites, considered close to pristine, are assessed to provide a measure of the maximum score that can reasonably be achieved in a particular location. The sites of interest, called "test sites", are then scored in comparison to the reference sites to assess the extent to which ecological functions have been degraded at the test sites.

The overall SEV score is useful for quick comparison of different stream reaches. However one of the main values of the SEV approach is the ability to see which functions are being performed well and which poorly. This enables resource managers to determine what management approaches are most needed and which will confer the greatest benefits to overall stream health and provision of ecosystem services. Thus it is important to consider the individual function scores as well as the overall SEV score.

Table 1: SEV functions.

Function category	Function abbreviation	Function name
Hydraulic	NFR	natural flow regime
Hydraulic	CFP	connectivity to floodplain
Hydraulic	CSM	connectivity for species migrations
Hydraulic	CGW	connectivity to groundwater
Biogeochemical	WTC	water temperature control
Biogeochemical	DOM	dissolved oxygen maintenance
Biogeochemical	OMI	organic matter input
Biogeochemical	IPR	instream particle retention
Biogeochemical	DOP	decontamination of pollutants
Biogeochemical	FPR	floodplain particle retention
Habitat provision	FSH	fish spawning habitat
Habitat provision	HAF	habitat for aquatic fauna
Biodiversity	FFI	fish fauna intact
Biodiversity	IFI	invertebrate fauna intact
Biodiversity	ABI	aquatic biodiversity intact
Biodiversity	RVI	riparian vegetation intact

SEV was originally designed for use in small first- to third-order perennial streams in the Auckland region. However, as the method has become more widely known, there has been increasing interest in understanding whether it can be used in other regions or in other stream types. The present report assesses its suitability for use in first- to third-order intermittent streams, intermittent streams being defined as those that flow for most of the year, but cease flowing or dry completely for a period of days or weeks in a year of average rainfall. The aim of this report is simply to identify aspects of SEV that may not apply as accurately to intermittent streams as to perennial streams. Recommending the appropriate changes to SEV is beyond the scope of this report, though the nature of the changes needed should be apparent from the discussion of each issue.

SEV is currently undergoing review, with the new version expected to be in use by mid-2011. Where the review involves changes that affect the comments below, I will refer to both old and new versions of SEV.

2. General principles for achieving accurate SEV scores in intermittent streams

An SEV score is a measure of how well a stream reach performs the 16 ecological functions, compared to the performance of a reference reach. That is, SEV assesses departures of a modified stream from the natural condition. The processes or seasonal dynamics involved in a particular ecological function may differ between intermittent and perennial streams. In such cases, the perennial stream SEV formulae can be used for the intermittent stream, provided that departures from the natural condition are caused by the same set of variables in the intermittent as in the perennial stream. However, two points must be borne in mind.

First, a universal rule for SEV is that the reference sites should be of the same stream type as the test sites. It is particularly important when evaluating intermittent test sites that reference sites are also intermittent. Intermittent reference sites are not necessarily easy to find, and for some streams they simply may not exist. In this case, the best solution is to bring reference data for each function in turn from the most suitable source, adjusting it, if necessary, using best professional judgment to reflect pristine condition. The most suitable source may be a relatively unimpacted intermittent stream, if the function being considered is not greatly affected by the impacts on that stream. Or it may be a pristine perennial stream, if the function being considered is not affected by the different flow type. If no suitable real data is available for a particular function, the last possibility is to imagine what a reference stream would score.

The second point is that the SEV score of an intermittent stream should be comparable to SEV scores of other intermittent streams, but may not be comparable to SEV scores of perennial streams. Therefore, the final scores must be used appropriately.

Field data for intermittent streams should be collected during the flowing-water period of the year (typically winter). To collect a representative sample of invertebrates, sampling should be done at least 2 months after flow has begun, but not after October. This is to allow invertebrate taxa with different recolonisation rates sufficient time to become established in the stream, and to capture semi-terrestrial stoneflies and early-emerging caddisflies and mayflies that leave the water in spring. In Hawke's Bay during a typical year, a suitable window for sampling is between May and October.

3. SEV functions

It is acknowledged that certain ecological functions are not as important in some stream types as in others (e.g., connectivity to floodplains is more important in lowland floodplain reaches than in upland V-shaped valleys). However, for simplicity, SEV assigns equal weighting to all functions, regardless of their relative importance in different stream types. Therefore, although some stream functions may not be as important in intermittent streams as in perennial, down weighting of those functions will not be considered in this report.

3.1 Natural flow regime (NFR)

The most obvious feature of intermittent streams is that their flow regime differs from that of perennial streams. However, NFR makes no assumptions about the type of natural flow regime, but rather measures the ability of a stream reach to maintain whatever flow regime is natural. Human modifications that impair this ability (e.g., channel straightening and lining) are expected to affect intermittent streams in a similar way to perennial streams. Therefore, this function should not require modification for use in intermittent streams, neither in its current form nor in the revised SEV.

3.2 Connectivity to groundwater (CGW)

It may be argued that this function is typically more important for intermittent streams than for perennial, for two reasons. First, it is widely believed that the hyporheic zone (deep stream bed sediments) provides a refuge for stream invertebrates during the dry season. In many Hawke's Bay intermittent streams, stream flow continues beneath the stream bed surface after surface water has disappeared, potentially providing a steady supply of oxygenated water to support invertebrate life beneath the stream bed. Second, whereas most streams constantly receive groundwater from the underlying aquifer throughout the year, intermittent streams receive groundwater during the wet season and lose water to the aquifer during the dry season. Depending on the size of the stream, this vertical loss of water may be important for recharging aquifers.

The factors that enhance or reduce connectivity to groundwater, however, are similar in both perennial and intermittent streams. Therefore, this function should not require modification for use in intermittent streams.

3.3 Water temperature control (WTC)

Moderating water temperature is critical during mid-summer, when water temperatures are most likely to exceed the tolerance levels of stream biota (Rowe et al., 2008). This is the time of year when intermittent streams are most likely to be dry or to contain only remnant pools.

Remnant pools are likely to be more susceptible to warming than are flowing waters, as the water is potentially exposed to sunlight for a longer time. However, deep pools, particularly those with macrophytes, may stratify, creating cool thermal refuges near the bottom. Furthermore, if the pools are connected to subsurface water flow, they may be buffered against warming to some extent by the constant flushing of cool groundwater. Whether intermittent streams are more or less susceptible to warming than perennial streams, maintaining cool water temperatures remains an important function. As for perennial streams, WTC will be determined mostly by the amount of shading, with water depth and velocity (if any) modifying the effect of exposure to sunlight. In remnant pools, however, the total surface area of pools, rather than the reach length, is the relevant length variable. The presence of aquatic plants, which shade the pool bed and keep it cool, is also relevant. With these minor modifications, the WTC function should be applicable to intermittent streams. Note, however, that in the current version of SEV, the formula for WTC does not perform well for streams with low shading. In the revised version, WTC does not include the variables depth, length and velocity, as these were shown in practice to have little influence on the WTC scores of perennial streams. In intermittent streams, these variables may be more important because interstitial flows are usually slower than surface flows. Therefore it may be appropriate to retain these variables when assessing intermittent streams with pools connected by subsurface flow.

In streams that have no remnant pools during summer, there is no active aquatic community requiring cool water temperatures. However, many aquatic invertebrate species survive the dry period *in situ* by maintaining drought-resistant stages (such as eggs or pupae) in stream bed sediments. Some evidence (Storey unpubl. data) suggests that exposure to midsummer sun may cause the temperature of bed sediments to exceed the tolerance limits of these resting stages, and reduce invertebrate recolonisation of the stream bed after water returns. Therefore, even in stream reaches where no surface water remains, shading of stream channels is important for temperature control of the stream bed.

3.4 Dissolved oxygen maintenance (DOM)

In perennial streams, maintenance of dissolved oxygen is critical during the summer period, when water temperatures are highest and macrophyte growth is greatest. In intermittent streams, dissolved oxygen maintenance is clearly not an issue during the dry phase when surface water is absent. However, dissolved oxygen levels do become critical during the drying phase, when water flow has ceased but isolated pools remain. In forested intermittent streams, pools accumulate leaf litter, which decomposes and consumes oxygen. Dissolved oxygen levels in forested pools may decline to less than 2 mg/L (Storey and Quinn, 2008), and many aquatic invertebrate taxa that had been found during the flowing water period are not found in isolated pools during this time. In open pasture streams, remnant pools are quickly colonised by thick macrophyte and algal growth after flow ceases. Due to daily cycles of respiration and photosynthesis, dissolved oxygen levels in these pools may fluctuate between super-saturated during the day and less than 2 mg/L at night (Storey, unpubl. data). Many open pasture streams are accessible to stock, which tend to eat the macrophytes and deposit faecal material in pools. Removal of macrophytes may reduce the daily fluctuations in dissolved oxygen, but the decomposing organic matter in faeces will keep oxygen levels low.

During the drying phase, riffle sections of intermittent streams are dry, and taxa that cannot tolerate low oxygen take refuge in these dry sediments in the form of eggs or other drought-resistant stages (Storey, unpubl. data). If, due to human modification, dissolved oxygen levels in an intermittent stream became critically low before the drying phase began, the refuge quality of riffle sediments may be compromised, with a consequent impact on the stream biota. In this case, the DOM function of intermittent streams may be degraded by the same human impacts as perennial streams, and the perennial stream SEV could be used without modification. However, in general, when assessing DOM in intermittent streams, it must be noted that pools in both natural and human-modified intermittent streams will experience critically-low dissolved oxygen levels during part of the summer period.

3.5 Organic matter input (OMI)

The dynamics of organic matter input in intermittent streams differ from those in perennial streams due to its accumulation during the low flow and dry phases in intermittent streams. In Mediterranean and Australian intermittent streams, the standing stock of benthic organic matter (BOM) typically is greatest during the low flow and dry phases (Boulton and Lake 1992, Ylla et al., 2010), such that when water returns, a large volume of BOM is exported downstream early in the flow period. The BOM also releases highly labile dissolved organic compounds, thus dissolved organic carbon levels in stream water may reach their maximum annual levels shortly after the first rains (Romani et al., 2006). The sudden availability of labile particulate and dissolved organic matter stimulates a pulse of high microbial activity that may last for up to a week (Acuna et al., 2004, Ylla et al 2010). The seasonal dynamics of benthic organic matter may also be correlated with abundances of detritivorous macroinvertebrates (Boulton and Lake 1992).

Although the dynamics of organic matter input are different, intermittent stream ecosystems depend on organic matter input just as perennial stream ecosystems do. Therefore, this function should not require modification for use in intermittent streams, but it would be appropriate to acknowledge in an SEV report that the organic matter dynamics in intermittent streams are somewhat different from those in perennial streams.

3.6 In-stream particle retention (IPR)

As outlined above, streams retain leaves and other particles more effectively during the period of low or zero water flow. Particles accumulating on the dry stream bed will be retained, with minimal loss of nutritive quality (Romani et al., 2006) until autumn rains produce surface pools. In isolated pools (during the period before and after water begins flowing each year), leaves and other particles will be processed as during the flowing water period. If IPR is measured once during the flowing water period, it will underestimate average annual IPR, as it will not include periods of low and zero flow when organic matter accumulates and is processed in surface pools.

Human modifications to streams that reduce IPR are expected to affect intermittent streams in the same way as perennial streams. Therefore, this function should not require modification for use in intermittent streams, but it would be appropriate to acknowledge in an SEV report that the in-stream particle retention dynamics in intermittent streams are a little different from those in perennial streams.

3.7 Decontamination of pollutants (DOP)

Decontamination of pollutants is assumed in SEV to be largely due to microbial biofilms growing on hard surfaces in streams (Rowe et al., 2008). Therefore, in SEV, DOP is a function of surface area available for biofilm growth (Rowe et al., 2008).

Microbial biofilms in intermittent streams have been little studied, and their composition, in relation to perennial stream biofilms, is not well known. However, it is known that intermittent streams have active biofilms, and that sufficient numbers of bacterial and algal cells remain viable on dry stone surfaces to recolonise those surfaces after rewetting (Robson and Matthews 2004, Amalfitano et al., 2008). Biofilms develop rapidly after water flow returns to intermittent streams, and rates of microbial production and activity in rewetted stream bed sediments have been observed to return to pre-drying rates within days of rewetting (Marxsen et al., 2010). Therefore, when wet, biofilms in intermittent streams are expected to be similar to those in perennial streams in terms of their potential to decontaminate pollutants.

The surface area available for biofilm growth may differ between intermittent and perennial streams, due to the contribution of instream plants. In perennial streams, the biomass of algae and macrophytes typically is greatest during summer. In intermittent streams, however, macrophytes and long algal filaments die during the dry period, and may take some time to regrow after water begins flowing. Thus, in the early part of the flowing-water period, intermittent streams may have less surface area for biofilm development than equivalent perennial streams. Some smaller intermittent streams however, accumulate soil, and can be invaded by terrestrial plants during the dry period. Until the terrestrial plants die as a result of being submerged, they may provide surface area for growth in place of aquatic macrophytes. The dynamics of instream plant growth have not been well studied in intermittent streams, but it appears that the average amount of instream plant surface area for biofilm growth may be overestimated by a single site visit during winter. In contrast, the average amount of instream plant surface area in perennial streams may be underestimated by a single site visit during winter. Therefore, DOP may not be strictly comparable between perennial and intermittent streams, unless some correction for season has been applied.

The dynamics of contaminant input also may differ between intermittent and perennial streams. In intermittent streams, contaminants (such as animal dung, or urban runoff) are likely to be deposited during the dry period, though possibly to a lesser extent than during the flowing water period. These contaminants may accumulate on the stream bed until water begins flowing in the channel, at which time they may be flushed out of the reach *en masse*, undergoing less processing than in a perennial stream. Furthermore, intermittent streams experience a pulse of nitrogen and phosphorus on rewetting, due to nutrients released from biofilms during both drying and rewetting processes (Marxsen et al., 2010). For these reasons also, DOP in intermittent streams may not be strictly comparable to that in perennial streams, though comparisons between intermittent streams should be valid.

In summary, the seasonal dynamics of contaminant input, available surface area and microbial growth are expected to differ significantly between intermittent and perennial streams. Therefore, caution is recommended in comparing DOP scores between intermittent and perennial streams. Despite these differences, the main factor influencing the potential of a stream to decontaminate pollutants (available surface area) should affect intermittent streams in a similar way to perennial streams, and therefore require no change to the formula for DOP.

3.8 Fish Fauna Intact (FFI)

Little is known regarding the use of intermittent streams by New Zealand native fish. One study (Davey et al., 2007) has shown that three native fish species move into intermittent reaches at different rates and to different distances from perennial refugia. Thus, species richness and density decreased linearly from 3 species and 1.0 fish m^{-2} at 100% flow permanence to 0 species at 30% flow permanence. Fish density was significantly lower 6 km from the nearest perennial reach to 3 km from the perennial reach. FFI is based on the Fish Index of Biotic Integrity (IBI) (Joy and Death 2004), which calculates ratio of observed:expected fish species present in the test reach. Therefore, an accurate score for an intermittent reach depends on knowing the fish assemblage to expect in an intermittent stream. An intermittent stream Fish IBI is likely to be needed, but otherwise, the formula for FFI should not require any other modifications.

3.9 Fish spawning habitat (FSH)

To our knowledge, no research has determined whether native fish spawning is affected by stream intermittency. One might expect that species such as torrentfish and common bully that spawn during summer (McDowall 2000) may be affected by summer stream drying, whereas those that spawn in spring or autumn (e.g., bluegill bully and banded kokopu, respectively), or have a long spawning season (e.g., common bully), may not be greatly affected.

If native fish do spawn in intermittent streams, one would assume that the same characteristics of the stream bed and floodplain provide suitable spawning habitat in intermittent and in perennial streams. Therefore, if this function is relevant to intermittent streams, there is no obvious reason to change the formula.

3.10 Habitat for aquatic fauna (HAF)

HAF is the average of $V_{physhab}$ (physical habitat in the stream reach), $V_{watqual}$ (the temperature of inflowing water) and V_{imperv} (the percent impervious area of the catchment, a surrogate for water quality in the stream reach). Of these, water temperature is less relevant in intermittent than in perennial streams. This is because in many intermittent streams, water will only enter the reach from upstream during cooler times of year when water temperature is less likely to limit survival of invertebrates or fish. The temperature of remnant pools and dry stream bed sediments is likely to affect survival of invertebrates, but these are controlled by shading within the reach, rather than upstream shading as described in the SEV manual. Therefore, the formula for HAF may require a minor change, either to remove $V_{watqual}$ or to measure it as shading within the reach rather than shading upstream.

3.11 Invertebrate fauna intact (IFI)

IFI is the average of MCI (macroinvertebrate community index) and EPT (richness of Ephemeroptera, Plecoptera and Trichoptera). In the revised version of SEV, it will likely also include V_{invert}, a comparison of the taxa list in the test site to that in several reference sites.

The invertebrate fauna of intermittent streams is significantly different to that of perennial streams, due mainly to the absence of many EPT taxa. Therefore, to obtain meaningful IFI scores for intermittent streams, the invertebrate assemblage of the test site must be compared with that of an intermittent reference site. In the current version of SEV, V_{MCI}, V_{EPT} and V_{invert} are all calculated or scaled relative to reference site scores, therefore no change to the formula for IFI is needed. In the new version of SEV, however, V_{MCI} probably will be calculated based on absolute scores. Intermittent streams will inevitably score poorly using that method, therefore it is recommended that for intermittent streams, V_{MCI} should be scaled relative to reference site scores. V_{EPT} and V_{invert} in the revised version of SEV incorporate an estimate of species richness and a taxa list, respectively, from a number of perennial Auckland reference sites. In order to correctly scale or calculate V_{EPT} and V_{invert} for intermittent streams, reference site data derived from local intermittent streams must be used in place of the values supplied with the SEV calculator.

4. Research questions emerging from this report

In assessing the applicability of SEV to intermittent streams, it has become apparent that several important gaps exist in our understanding of the ecological functions of intermittent streams. In order to apply SEV to intermittent streams with greater confidence, I recommend research in the following areas:

1. The seasonal dynamics of particulate organic matter in intermittent streams. How do the standing stock and export of leaves and wood change over the hydrologic phases of an intermittent stream, and how do they compare with those in a perennial stream? In pasture streams, living plant matter (algae and macrophytes) also should be considered.

2. The seasonal dynamics of nutrient and dissolved organic matter export from intermittent streams compared with perennial streams.

3. The use of intermittent streams by native fish for habitat and spawning, considering the effect of stream size and distance from perennial streams.

5. References

Acuna, V.; Giorgi, A.; Munoz, I.; Uehlinger, U.; Sabater, S. (2004). Flow extremes and benthic organic matter shape the metabolism of a headwater Mediterranean stream. *Freshwater Biology 49*: 960–971.

Amalfitano, S.; Fazi, S.; Zoppini, A.; Caracciolo, A.B.; Grenni, P.; Puddu, A. (2008). Responses of benthic bacteria to experimental drying in sediments from Mediterranean temporary rivers. *Microbial Ecology 55(2)*: 270–279.

Boulton, A.J.; Lake, P.S. (1992). Benthic organic matter and detritivorous macroinvertebrates in two intermittent streams in south-eastern Australia. *Hydrobiologia 241(2)*: 107–118.

Davey, A.J.H.; Kelly, D.J. (2007). Fish community responses to drying disturbances in an intermittent stream: a landscape perspective. *Freshwater Biology 52(9)*: 1719–1733.

Joy, M.K.; Death, R.G. (2004). Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. *Environmental Management 34(3)*: 415–428.

Marxsen, J.; Zoppini, A.; Wilczek, S. (2010). Microbial communities in streambed sediments recovering from desiccation. *FEMS Microbiology Ecology 71(3)*: 374–386.

McDowall, R. (2000). The Reed Field Guide to New Zealand Freshwater Fishes. Reed Books, Auckland. 224 p.

Robson, B.J.; Matthews, T.G. (2004). Drought refuges affect algal recolonization in intermittent streams. *River Research and Applications 20(7)*: 753–763.

Romani, A.M.; Vazquez, E.; Butturini, A. (2006). Microbial availability and size fractionation of dissolved organic carbon after drought in an intermittent stream: Biogeochemical link across the stream-riparian interface. *Microbial Ecology 52(3)*: 501–512.

Rowe, D.; Collier, K.; Hatton, C.; Joy, M.; Maxted, J.; Moore, S.; Neale, M.; Parkyn, S.; Phillips, N.; Quinn, J. (2008). Stream Ecological Valuation (SEV): a method for scoring the ecological performance of Auckland streams and for quantifying environmental compensation - 2nd edition. *Technical Publication No. 302*. 85 p.

Storey, R.G.; Quinn, J.M. (2008). Composition and temporal changes in macroinvertebrate communities of intermittent streams in Hawke's Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research 42*: 109–125.

Ylla, I.; Sanpera-Calbet, I.; Vazquez, E.; Romani, A.M.; Munoz, I.; Butturini, A.; Sabater, S. (2010). Organic matter availability during pre- and post-drought periods in a Mediterranean stream. *Hydrobiologia 657(1)*: 217–232.