Review of Bay of Plenty NERMN Stream Bio-monitoring Programme

Bay of Plenty Regional Council
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NEW ZEALAND

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BAY OF PLENTY
REGIONAL COUNCIL
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Previous years' reports, Lisa Tauroa.

Executive summary

The Bay of Plenty Regional Council (BOPRC) has a Natural Environment Regional Monitoring Network (NERMN) that was implemented to monitor the state of, and trends to the region's major rivers and lakes. Results from this network are to assist in determining whether the objectives of Regional Plans and strategies are being achieved. This document reviews the river invertebrate monitoring component of the NERMN protocol, which has been running since 1992. It focuses on features of the programme such as sampling location and frequency, what indicators have been measured, and how the data is analysed and stored. It seeks to understand how the information generated by monitoring is fed back to the planning and policy staff in Council to help assess the efficiency and effectiveness of rules, methods and policy. Based on the review, 34 recommendations have been made throughout the report to improve the value of the programme to help the BOPRC meet its statutory obligations.

Freshwater monitoring within the Bay of Plenty Regional Council has been led by three environmental scientists: Rob Donald (1992-1997); Thomas Wilding (1997-2003); Matt Bloxham (2003-2011). Donald collected replicate quantitative invertebrate samples from 17 cobble-bottomed streams, 13 of which were in the eastern Bay of Plenty region, and four of which were in the Western Bay of Plenty area.

This sampling strategy continued annually until 2000, when Wilding reviewed the programme and enlarged it to a total of 118 sites spread throughout the Bay of Plenty, especially in the mid and western parts of the region. Sampling from these additional streams followed semi-quantitative methods using a kick net, which was more appropriate in these slow-flowing, soft-bottomed streams. Bloxham continued co-ordinating this monitoring programme until the summer of 2008-2009, although not all sites were sampled every year.

Despite the long duration that invertebrate sampling has been undertaken (up to 18 years), the last report summarising the monitoring findings was prepared by Wilding in 2001. In the author’s view, this information should be reported no less than once every five years.

The rationale behind site selection of the 118 NERMN invertebrate monitoring sites is unknown, with the exception of sites selected by Donald that were a subset of water quality monitoring sites from where quantitative invertebrate samples could be collected. An examination of representativeness of sites was undertaken. The River Environment Classification (REC) database was used to allocate all waterways to an appropriate source of flow (hill, lowland and lake-fed) and geology (volcanic and non-volcanic) classes. This resulted in five defined stream classes, which were examined to determine whether the current monitoring sites were representative of waterways throughout the Bay of Plenty. Preliminary results of this analysis showed that some landuse classes were under-represented in the current monitoring programme. It is recommended that consideration be given to increase the number of sites draining catchments dominated by underrepresented landuses in each of the five stream classes. It is also recommended that the REC be used to help identify potential reference sites upon which future comparisons can be made.

Features of the NERMN invertebrate sampling protocols such as sampling frequency, collection methodology, sample processing protocols, and data entry and storage were investigated. The importance of collecting consistent habitat data along with biological data was also emphasised, as habitat data has currently been collected using two different protocols. Furthermore, no habitat information has been analysed to determine how this influences invertebrate communities, or how this changes over time. A number of recommendations are made concerning how future NERMN invertebrate monitoring work is undertaken, to maximise consistency between years and minimise difficulties with retrieval of historic data.

Under the Resource Management Act (RMA), councils need to monitor the effectiveness and efficiencies of their policies, rules or methods. The Ministry for the Environment has adopted the Organisation for Economic Cooperation and Development's (OECD) Pressure, State, Response (PSR) model as a framework by which to do this. A key component of monitoring the effectiveness of policies and methods is State of Environment reporting. The NERMN Invertebrate Monitoring Programme assesses the ecological condition of waterways in the region over time. As such, it should be able to detect changes in stream health that may arise following implementation of the Council's rules and methods. However, a central part of the PSR model relies not only on the ability to monitor the state of the environment, but also to quantify the extent to which methods and rules have been implemented. If the extent to which the Council's methods and rules are being implemented throughout the region cannot be quantified, then we have no way to determine their effectiveness. Therefore it is necessary to liaise with the Council planning and policy staff, land management officers, and GIS staff to ensure that changes to environmental conditions as a result of implementation of methods and rules are quantifiable and measurable. Only then can the effectiveness of Council methods and rules in mitigating or remedying adverse effects of landuse activities can be determined.

Contents

Part 1: Introduction

The Bay of Plenty region is located in the mid-region of the East Coast of the North Island of New Zealand, running from Cape Runaway in East Cape to Waihī Beach in the west. It covers an area of 21,836 km^2, and extends inland up to 130 km to the headwaters of the Rangitāiki Stream and also includes the Rotorua Te Arawa Lakes. The region has a population of approximately 270,000 (as of June 2008), and this is expected to increase by 26% in 2021. As its name suggests, the Bay of Plenty is rich in natural resources, and has large areas of native forest and bush, plantation forestry, pasture agriculture (dairying, beef and sheep) and horticulture. Horticulture and dairying are located on fertile land in the Western Bay of Plenty and low-lying coastal plains, while forestry dominates the less fertile areas in the south and south-east. Large areas of native bush occur along the south eastern ranges, and the Kaimai Ranges to the west of Tauranga. The region is well-known and valued for its freshwater resources, particularly the Rotorua Te Arawa Lakes. For example, surveys have shown that these lakes support the most anglers for the most time of any lakes in New Zealand (Unwin 2009). The rivers are also extremely popular with anglers, who spend the most number of days fishing these rivers than other rivers within the North Island.

As with other areas throughout the country, streams within the Bay of Plenty are highly diverse with respect to their source of flow, the geology, and land cover that they flow through. Many of the larger streams originate in high hill country approximately 1,200 metres above sea level, and flow towards the coast through either large tracts of exotic pine plantation, or undeveloped native bush. The region's geology is also complex. Large areas of greywacke dominate the ranges to the south-east that run to East Cape, while the low-lying Rangitāiki Plains have a more complex geology consisting of a mixture of ignimbrite, pyroclastics, and holocene sediments dominated by pumiceous alluvium. Geology has a large influence on stream ecology in terms of influencing the erodability of the streambed and banks, substrate stability and the degree to which sedimentation occurs.

Not surprisingly, landuse activities associated with forestry, dairying and horticulture can potentially adversely affect lakes, wetlands, streams and rivers (hereafter termed ”streams”) throughout the region. These adverse effects are likely to increase with intensification of farming and the projected increase in population growth. The challenge faced by the Bay of Plenty Regional Council (BOPRC) is to allow the continued economic growth within the region whilst minimising further environmental degradation, and loss of intrinsic values that freshwater ecosystems bring to the region.

(a) The (Resource Management Act 1991) has devolved power to regional and district councils to ensure the sustainable management of each region's natural and physical resources. Under the RMA, Regional Council’s needs to prepare Regional Policy Statements (RPS). The purpose of an RPS is to provide an overview of the resource management issues in the region, and policies and methods to achieve integrated management of the natural and physical resources of the whole region. Section 62 (1) of the RMA outlines a number of requirements that a RPS needs, including but not limited to:

(b) identification of resource management **issues**, where an "issue" is defined as being a matter of concern to the region's community,

(c) the **objectives** sought to be achieved, where an "objective" is a desirable and achievable condition or position towards effort is to be directed,

(d) identification of **policies** in regard to the issues and objectives, which define the boundaries within which decisions can be made,

(e) **methods of implementation**, which are procedures, or course of action to be followed in accordance with the policies to achieve the specific objectives,

(f) any **anticipated environmental results**, which are the expected effects on the environment of implementing the policies and methods,

(g) procedures used to **monitor the efficiency and effectiveness** of methods and policies contained in the statement.

A key component of the RMA and any RPS is, therefore, the need to monitor a number of factors including the state of the environment, and the effectiveness and efficiencies of policies, rules or other methods in council policy statements or plans. The Bay of Plenty Regional Council has a Natural Environment Regional Monitoring Network (NERMN: Figure 1) that allows the Council to monitor the state of, and trends in the environment. Part of the NERMN is monitoring the freshwater ecology of the region's streams and lakes. Results from the NERMN are meant to assist in determining whether the objectives of regional plans and strategies are being achieved. To do this, it is necessary to ensure that sufficient sites are monitored throughout the region covering representative range of the region’s diverse streams. It is also necessary to sample a wide range of landuse types to ensure that the impact of landuse activities can be assessed. Furthermore, adequate mechanisms must be in place to ensure that any results of a monitoring programme are made available to planners and policymakers to aid the assessment of the effectiveness of their rules (Figure 1).

Stark and Maxted (2007) reviewed the different types of bio-assessment and bio-monitoring programmes that organisations such as regional councils undertake. In their review, they highlighted three forms of monitoring that councils are most commonly involved with:

- Compliance monitoring, which is generally focussed on specific consented activities to ensure compliance with rules. Compliance monitoring may be long or short-term, and may possibly be done with a high level of replication, at least in the short-term. If no adverse effects have been detected after a period of time (e.g. five years), then it may be practical to reduce or cease monitoring requirements.
- Assessment of Environmental Effects (AEEs), which are conducted when a new activity, or continuation of an existing activity, that may have environmental effects is proposed. An AEE will form part of the consent application process and is often done very intensively, but usually only for a short-term.
- State of Environment monitoring (SOE), which involves monitoring changes to environmental conditions that occur in the region’s environment over long-term periods. SOE programmes are ideally designed to detect underlying changes that may be occurring as a result of landuse activities placing pressures on the environment.

Figure 1 below is a conceptual flow chart showing how human activities can place pressure on freshwater resources and lower their ecological state. The current state of freshwaters is compared to the values that the community places on them. If that state is less than its values, this becomes an issue. Under the RMA, the BOPRC is responsible for producing a Regional Policy Statement (RPS), and Regional Plans that identify issues and implement processes to avoid, remedy or mitigate adverse environmental effects (yellow symbols). An important aspect of Regional Plans is to identify anticipated results of these statutory processes. The NERMN Programme (purple symbols) was developed to monitor state and trends of freshwater environments throughout the region, and to provide feedback as to the effectiveness of Regional Plans. This review examines the NERMN invertebrate monitoring protocols, including methods to ensure that adequate feedback is given to policymakers and planners. This will allow for further iterations of the RPS and Regional Plans to ensure the continued sustainable development within the region and maintenance of healthy waterways (green symbols).

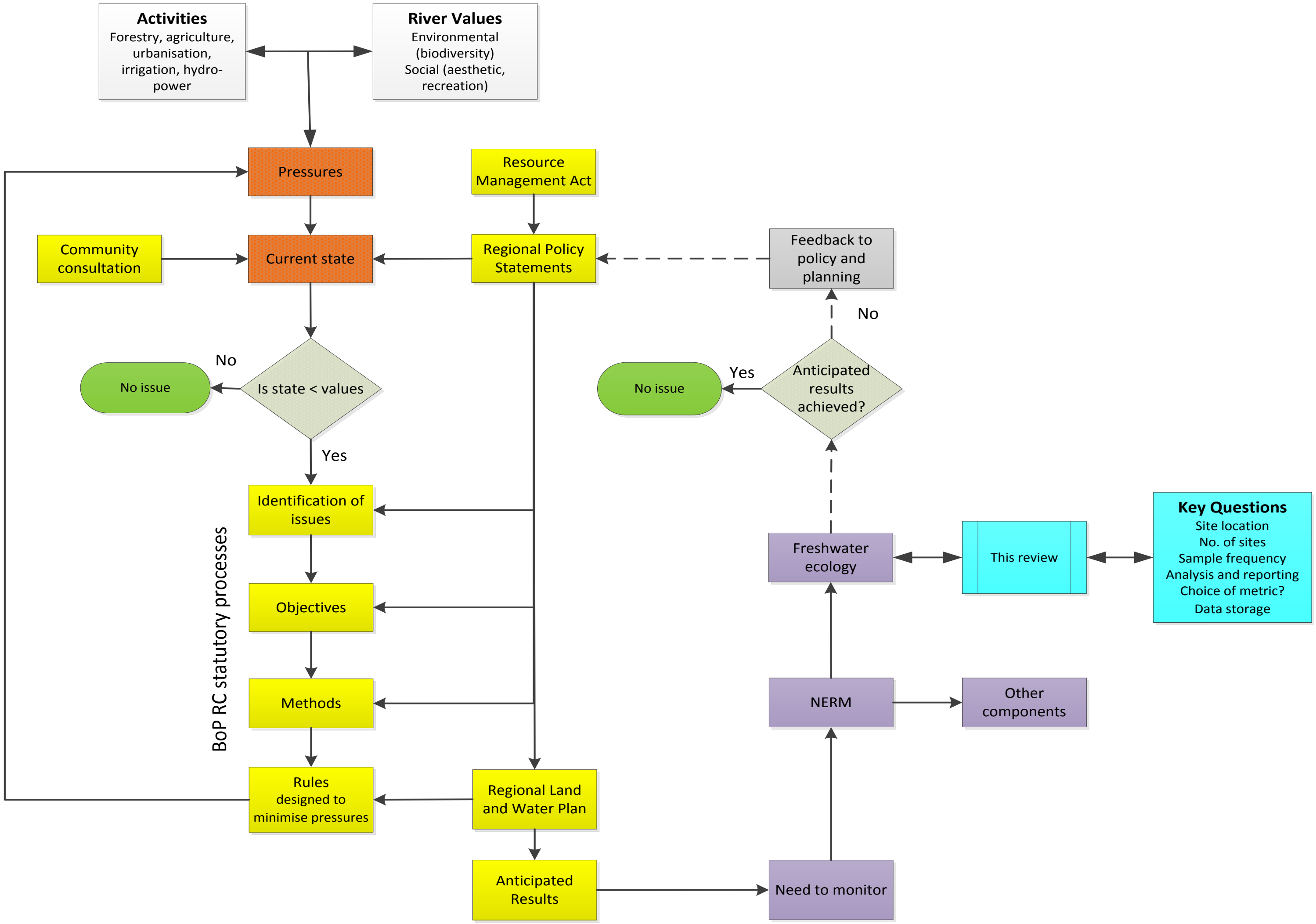

Figure 1 *Conceptual flow chart showing how human activities can place pressure on freshwater resources and lower their ecological state.*

SOE monitoring networks need to be designed with specific management objectives in mind. Stark and Maxted (2007) recommended that the following matters need to be considered when designing and planning a monitoring network:

- Where are the sites?
- Need to ensure that samples are representative in space, including both reference and impacted sites?
- How many sites can be sampled?
- What indicators need to be measured?
- What degree of change needs to be detected?
- How often should sampling be done?
- What information is required?
- How will the data be analysed?
- How much replication is needed?
- What is the cost?
- Is there a commitment to long-term funding?
- How will the data be stored?
- How will the data be translated into information for managers/council staff to use?

This document reviews the invertebrate monitoring component of the BOPRC NERMN protocol, which has been running since 1992. It focuses on many of the matters identified by Stark and Maxted (2007) in terms of sampling location and frequency, what indicators are be measured, and how the data is analysed and stored. More importantly, it seeks to understand how the information generated by the monitoring is fed back to the planning and policy staff in Council to ensure that the efficiency and effectiveness of rules, methods and policy in the RPS and Regional Water and Land Plan (RWLP) are being met. This is a requirement of the RMA, Section 35 that requires regional councils to monitor:

- the state of the environment (Section 35 (2)(a),
- the effectiveness and efficiencies of policies, rules, or other methods in their policy statements or plans (Section 35 (2)(b)),
- the results of this monitoring must be compiled, and made available to the public at least every five years.

The importance of this feedback mechanism cannot be overestimated, as there is little point in designing and implementing a monitoring programme if it doesn't adequately monitor the effectiveness of methods and rules that the Council has prepared. Finally, this document will help answer whether the invertebrate bio-monitoring component of the NERMN is delivering information that is of value to BOPRC.

Part 2: Scope and objectives

The objectives of the NERMN Programme (Wilding 1998) are to:

(i) Investigate, document and report to the BOPRC the natural resources of the Bay of Plenty region as required for the preparation and monitoring of regional plans,

(ii) faithfully maintain a programme of regional resource and environmental data acquisition, with emphasis on major areas of use or potential use,

(iii) investigate, document and report to BOPRC the effects of land-use on water quality, ecology and environmental status of the Bay of Plenty region,

(iv) provide BOPRC with information on significant environmental trends which policies or decisions of BOPRC can address,

(v) ensure that all NERMN Programmes are completed as schedule and within budget,

(vi) maintain an appropriate level of scientific support consistent with BOPRC's objectives.

In addition, the freshwater ecology monitoring network has two additional specific objectives:

(vii) provide BOPRC with reliable data regarding the ecological status of the streams and lakes in the region,

(viii) provide a basis for the reliable detection of long-term trends in ecology of stream and lake systems in the region.

Stark and Maxted (2007) reviewed bio-assessment and bio-monitoring programmes from regional councils, and highlight that SOE monitoring networks need to be designed with specific management objectives in mind. Although many of the above objectives seem appropriate in the broader multi-programme scale of the NERMN, it is suggested that more specific objectives be developed for the freshwater ecology component, and particularly for the stream ecology component. This is particularly important in light of the responsibilities of Council under the Section 35 of the RMA, and under recent governmental initiatives to ensure Council’s statutory obligation to adequately monitor environmental conditions in their region as part of the proposed National Environmental Reporting Bill (MfE 2011). Moreover, the effectiveness of any restoration activities being implemented as part of methods and rules under the RPS and Regional Plans also need to be assessed.

Recommendation 1

The following modified and additional objectives are proposed for the NERMN Freshwater Ecology Programme:

“Stream bio-monitoring is designed to:

(i) provide BOPRC with reliable data regarding the ecological status of the streams in the region at representative sites,

(ii) identify environmental factors related to stream ecological condition, to assist with developing policies that avoid, mitigate or remedy adverse effects on stream ecosystems,

(iii) satisfy the Council’s RMA section 35 responsibilities for reporting in assessing the performance of policies methods and rules,

(iv) contribute data collected as part of SOE monitoring to national reporting and monitoring initiatives (i.e. as is proposed under the National Environment Reporting Bill.)”

Part 3: History of NERMN invertebrate monitoring

Freshwater monitoring within the BOPRC has been led by three environmental scientists: Rob Donald (1992-1995); Thomas Wilding (1996-2003); Matt Bloxham (2003-2011). Donald (1992) first assessed the suitability of the then existing 41 NERMN water quality monitoring sites for invertebrate monitoring, and selected 17 of these sites that were amenable to quantitative invertebrate sampling. These were all cobble-bottomed streams, and mostly located in the Eastern Bay of Plenty region (Figure 2), although four sites were located in the Western Bay of Plenty area. At each site, seven replicate quantitative samples were collected in 1992. This number was reduced to five replicate samples from 1993, following analysis of the 1992 data that showed that collecting five replicates could still detect a 50% change in each of the biotic variables measured. Such a degree of change was considered large enough to detect any effects of human activities. Wilding (1998) reviewed the Invertebrate Monitoring Programme and made the following recommendations:

1. Change the sampling frequency from annually to once every three years,
2. Cease doing full counts on invertebrate data, and instead perform a fixed-count sample processing methodology,
3. Review the benefits of identification below generic level, as species identifications took extra effort and provided a diminishing return of information,
4. Implement a kick net sampling methodology to sample soft-bottomed sites that were currently not included in the monitoring programme,
5. Determine how many sites were required to typify conditions within a stream, how many streams needed to be sampled to represent major areas of resource use, and how many sites could be sampled each year,
6. Determine whether spatial or temporal replication was more effective in achieving the objectives of the NERMN Programme.

This sampling strategy (five Surbers from each of 17 sites each summer) continued until 2000, with the exception of 1998-1999, when only three sites were sampled.

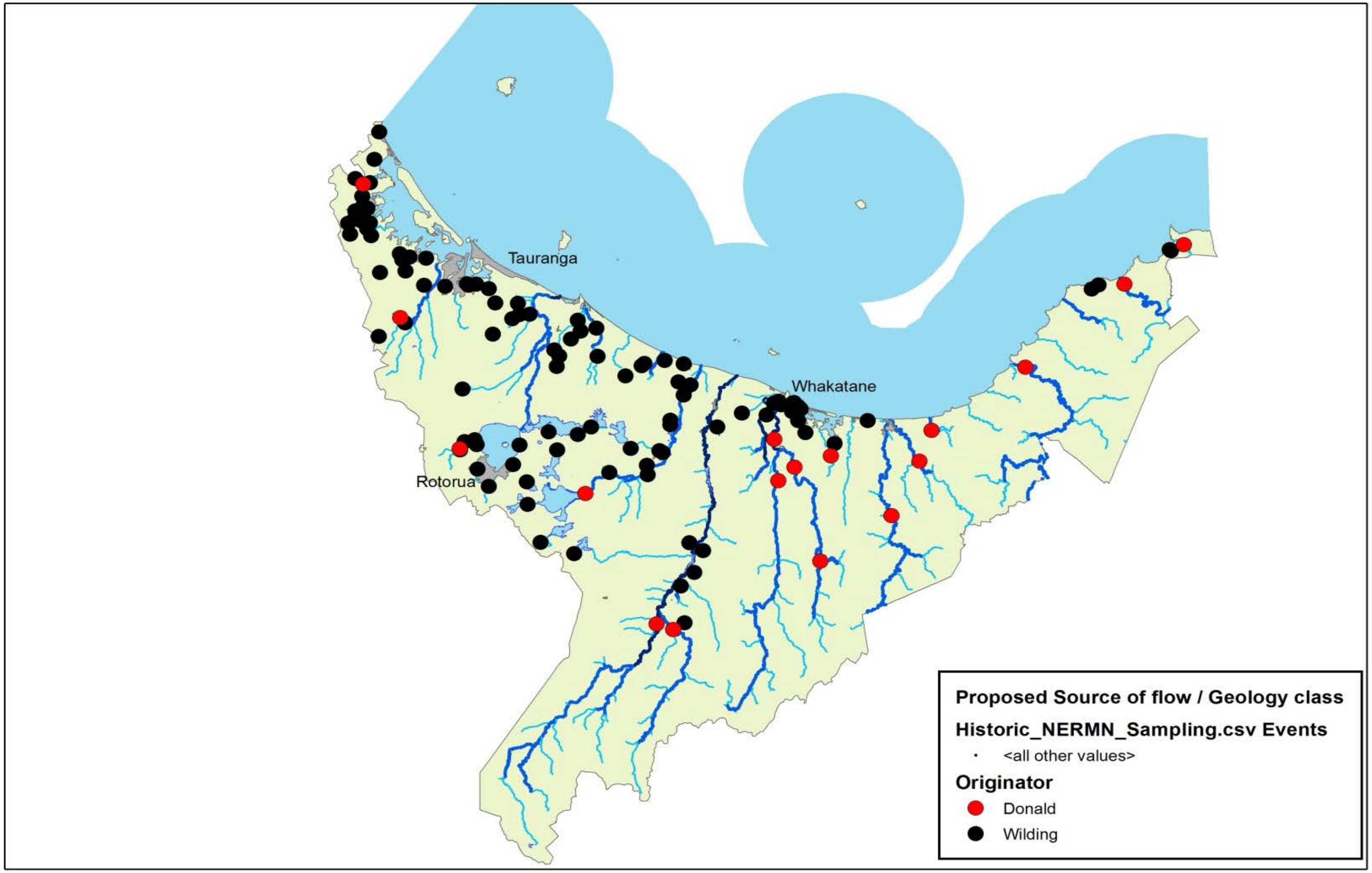

Figure 2 *Map showing the location of all NERMN invertebrate monitoring sites throughout the region, as originally collected by Donald (red symbols), and then by Wilding and Bloxham (black symbols). Note that samples are still collected from the original sites initially sampled by Donald, although not every year.*

In 2001, the invertebrate sampling programme was enlarged to a total of 118 sites, spread throughout the Bay of Plenty region, especially in the mid and western parts of the region. While some of these were still hard-bottomed streams (i.e. dominated by cobbles and gravels), many were soft-bottomed streams (i.e. had a streambed with >50% of soft sediments) which were better suited to the use of kick nets. As far as can be ascertained, no clear documentation exists as to why streams were sampled using either hard or soft bottomed techniques. For example, it is not known what sample protocol was used for a stream with a 50:50 mixture of fine substrates and gravels, or how the sampling protocol was chosen.

Wilding oversaw the invertebrate sampling component in the region from 2001-2003, and this was then continued by Bloxham, who co-ordinated the monitoring programme until the summer of 2010-2011. Not all sites were sampled every year and no samples were collected in the summer of 2009-2010. The majority of streams have been sampled for eight or nine years, while 16 streams have had samples been collected from them for 11 or more years (Figure 3). Only five streams have been sampled over a period of five or fewer years. Examination of the length of time between the first and the last sampling occasion at each site showed that 50 sites have been sampled over a nine-year period, and another 41 sites have been sampled over an eight-year period (Figure 4). Most of the 17 sites initially sampled by Donald have continued to be sampled with, at most, two years between sampling periods. This means that sampling of these sites span a period of between 16 and 18 years, representing valuable data for detecting long-term changes in ecological condition.

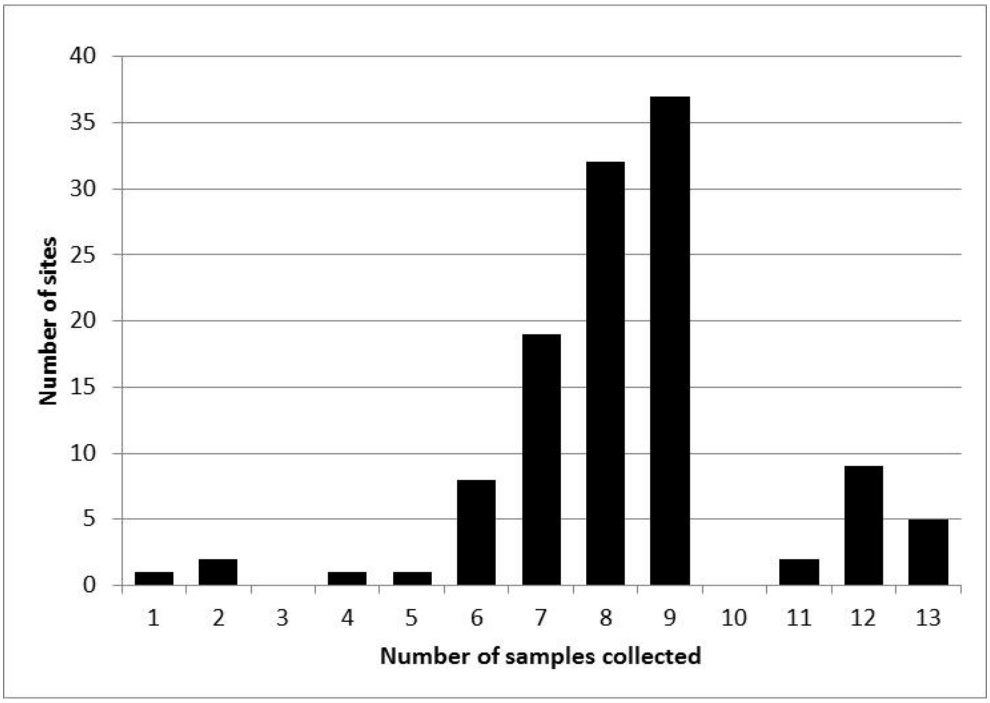

Figure 3 *Bar chart showing a frequency distribution of the number of samples collected from each site as part of the NERMN Invertebrate Monitoring Programme throughout the Bay of Plenty region.*

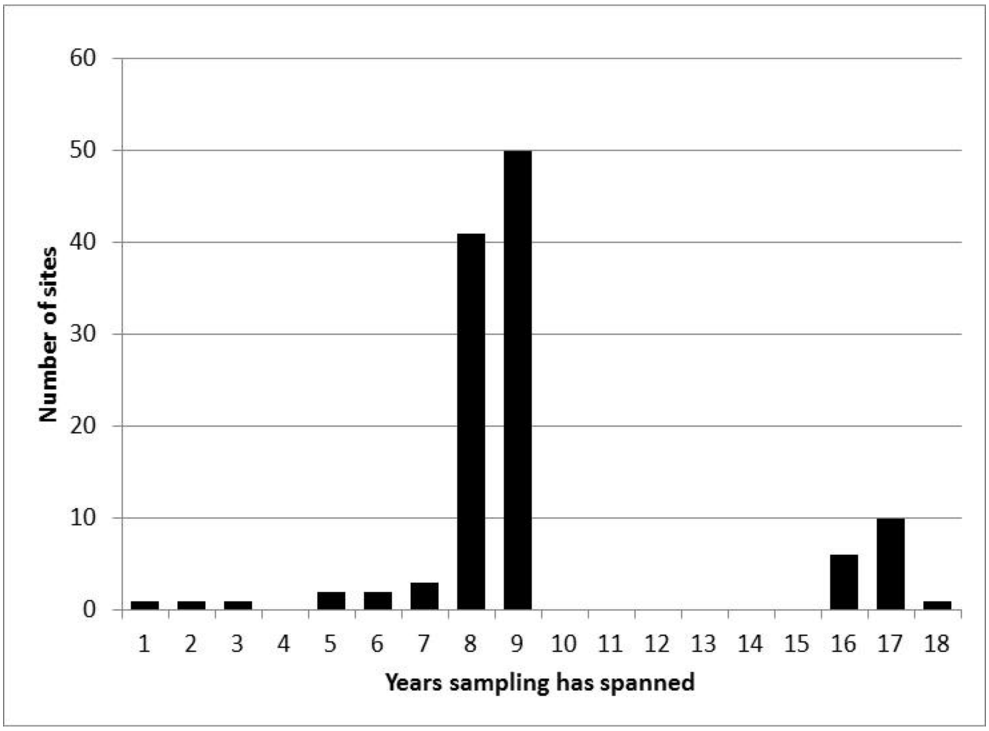

Figure 4 *Bar chart showing a frequency distribution of the number of years that sampling has spanned at each site of samples as part of the NERMN Invertebrate Monitoring Programme throughout the Bay of Plenty region.*

Despite the large volume of data now available, no further reports summarising the results of invertebrate monitoring have been published since the last report written by Wilding in 2001. In a recent report released by the Office of the Auditor General (OAG) (Provost 2011), a number of recommendations have been made concerning monitoring and reporting on the effectiveness and efficiencies of policies and methods. Recommendation 3 of the OAG is that regional councils monitor the effectiveness and efficiency of their policies, rules, or methods and policy statements and plans, and make the results of this monitoring available to the public at least every five years. Thus, for the invertebrate monitoring aspect of NERMN, this recommendation is not being met.

Recommendation 2

Clarify and document sampling protocols to be used in each stream to ensure consistency of hard or soft-bottomed sampling.

Recommendation 3

Prepare and complete a report summarising the state of freshwater environments throughout the region, highlighting amongst other things:

1. the ecological status of the streams and lakes in the region at representative sites,
2. the effects of landuse changes on stream health,
3. any long-term trends in stream health over time in the region.

Recommendation 4

Using the results of trend analysis of suitable sites over time, determine, if possible, the effectiveness and efficiency of the Council's policies rules or methods.

Part 4: Sample location

A key part of any Invertebrate Monitoring Programme revolves around site selection. Stark and Maxted (2007) outlined three key questions that need to be considered when designing and planning a monitoring network:

1) Where are the sites?
2) Are sites representative in space, including both reference and impacted sites?
3) How many sites can be sampled?

Ideally, site selection within the Bay of Plenty region for State of Environment reporting needs to fill a number of criteria including:

1 being representative of different environmental states at various spatial and temporal scales,

2 being able to compare state and trends amongst selected environmental classes, including reference classes,

3 being able to compare selected environments with reference conditions,

4 monitoring individual impaired streams,

5 allowing assessments of policy effectiveness to be made as per RMA Section 35 responsibilities.

A recent workshop held by the Ministry for the Environment (MfE) as part of the National Environmental Monitoring and Reporting (NEMAR) Programme discussed network design principles for national freshwater monitoring (Larnard and Snelder 2012) and identified seven different approaches that could be used for establishing sites in a monitoring network:

1 environmental classifications,

2 probabilistic approaches,

3 data driven approaches,

4 geographical distributions,

5 topographic/catchment-based distributions,

6 high priority sites based on expert opinion,

7 combinations.

Of these seven approaches, five could be considered relevant as being used to assist with site selection for the NERMN Programme. Environmental classifications refer to spatial frameworks which characterise and group stream reaches, based on environmental factors such as climate, source of flow, geology and land cover, which are known to influence ecological communities. Within New Zealand, two environmental classifications exist: the River Environment Classification (REC), and Freshwater Environments of New Zealand (FWENZ). The REC was developed by NIWA for MfE to provide a spatial framework for regional (or larger) scale environmental monitoring and reporting, environmental assessment and management (Snelder and Biggs 2002). It was developed to discriminate spatial variation in a wide range of stream characteristics, including physical and biological characteristics. It is a multi-scale classification, delineating patterns at a range of scales from approximately hundreds of km^2 to 1 km^2. The REC defines a hierarchy of classes (Table 1), within which ecological similarity (e.g. water quality or biological communities) varies from general to specific, as the classification level is decreased. The highest REC classification level (climate) groups streams that are very generally similar climatically. In contrast, the fourth classification level of the REC (land cover) will group streams that are similar climatically, share similar hydrological regimes in terms of their source of flow, have a similar catchment geology and a similar dominant catchment land cover.

Thus, when we look at a specific variable for a group of sites, the variation within a group that share a similar climate class is quite large, as the sites are only 'generally' similar. As the classification level is reduced, variation within a class decreases because the number of shared controlling factors increases. These similarities are linked to spatial scales; streams may be generally similar over large areas but specific characteristics remain similar over only small scales. In contrast, FWENZ is a hierarchical multivariate classification system based on environmental factors that are correlated with aquatic communities (Clapcott, Young et al. 2011). This includes information on climate, flow, nutrient status, shade and estimated substrate size. While some of these factors (for example climate) have been obtained from actual measurements, others (for example substrate size and shade) have been derived from empirical models and extrapolated throughout the country.

Both the REC and FWENZ can be used to assign sample sites into classes. In this way, it is possible to see whether all the major environmental classes within the Bay of Plenty region are being adequately sampled. Once streams have been assigned to their appropriate classification, the next major task is to determine how many sites from each class should be surveyed, as well as the exact location of each site within a particular class.

This task can be undertaken using a probabilistic approach, where an unbiased site selection procedure is used from a larger population of sites. In its simplest form, a probabilistic approach to site selection within the region could be achieved by randomly selecting a certain number of streams throughout the region according to their reach identification code. This approach could also be used after classifying stream reaches according to either their REC class or FWENZ class, and then randomly selecting sites from within these classes. Additional criteria such as road access and land ownership could also be applied as a filter to the random selection step. Whether the REC or FWENZ is used to classify streams appears moot, as statistical comparisons of the abilities of the REC and FWENZ showed that the former performed better at discriminating patterns of fish, invertebrate, flow regimes and water quality at low levels of classification, whereas at higher classification levels, FWENZ outperformed the REC in discriminating fish and invertebrates.

When selecting sites for regional State of Environment monitoring, it is important to consider how representative the selected sites are of environmental conditions found throughout the greater region. Ideally, a monitoring programme would be comprised of the same proportion of sites in different environmental classes as are found within the region. For example, if 50% of waterway reaches within a region had a lowland source of flow, 30% had a hill country source of flow, 15% were lake-fed, and 5% were mountain-fed, then a monitoring protocol of, for example, 100 sites should ensure that these sites are spread over a similar representative range of source of flow. By ensuring that site selection is representative of the region’s underlying physical drivers, then comments about the average ecological condition within the region can be made in the knowledge that the sites sampled mirror the range of conditions throughout the region. However, ensuring a degree of representation may not be the most appropriate way to ascertain whether there are differences between streams in different classes due to the unequal number of sites within each class. Thus, sites which occur less frequently in a region may not be sampled with enough replication to draw any statistical significance from the results. A way around this is to ensure that site selection is balanced between different *a priori* defined classes. There is, therefore, an inherent conflict between selecting sites which are representative, which may lead to a very unbalanced sampling design and sites which are more balanced between different classes, but which may not fully reflect the condition throughout the region.

Recommendation 5

Implement the use of either the River Environment Classification (REC) or the Freshwater Environments of New Zealand (FWENZ) within the BOPRC to assist with spatial classification of streams into groups of similar classes.

Status

This recommendation was implemented as part of the review process into the stream bio-monitoring (see next section), where the REC was used to create four tentative stream classes, based on source of flow and geology. The validity of these is to be further examined at a later stage.

Table 1 REC classification levels, categories and their notation, mapping characteristics and class assignment criteria.

Classification level	Classes	Notation	Mapping characteristics	Original class assignment criteria	Class assignment criteria for this work
1. Climate	Warm extremely wet Warm wet Warm dry Cool extremely wet Cool wet Cool dry	WX WW WD CX CW CD	Mean annual precipitation, mean annual potential evapotranspiration, and mean annual temperature	Warm: Mean annual temperature >12°C Cool: Mean annual temperature <12°C Extremely wet: Mean annual effective precipitation >1,500 mm Wet: Mean annual effective precipitation 500–1,500 mm Dry: Mean annual effective precipitation < 500	Warm Cool
2. Source of flow	Mountain Hill Low elevation Lake	M H L Lk	Catchment rainfall volume in elevation categories, Lake influence index	M: > 50% annual rainfall volume above 1,000 m ASL H: 50% bring forward following between 400 and 100 m ASL L: 50% rainfall below 400 m ASL Lk: Lake influence index >0.033	Hill Lowland Lk
3. Geology	Alluvium Hard sedimentary Soft sedimentary Volcanic basic Volcanic acid Plutonic	Al HS SS Vb Va Pl	Proportions of each geological category in section catchment	Class = The spatially dominant geology category unless combined soft sedimentary geological categories exceed 25% of catchment area, in which case class = SS	Non-volcanic Volcanic
4. Land cover	Bare Indigenous forest Pastoral Tussock Scrub Exotic forest Wetland Urban	B IF P T S EF W U	Proportions of each land cover category in section catchment	Class = The spatially dominant land cover category unless P exceeds 25% of catchment area, in which case class = P, or unless U exceed 15% of catchment area, in which case class = U	Natural Exotic forestry Pasture Urban

Part 5: Allocation of REC classes to NERMN invertebrate monitoring sites

The rationale behind choosing the 118 NERMN invertebrate monitoring sites is unknown, with the exception of the fact that sites selected by Donald were a subset of water quality monitoring sites from where quantitative invertebrate samples could be collected. To determine whether the current invertebrate monitoring sites were representative of waterways throughout the region, the REC database was used to allocate all reaches to their appropriate climate, source of flow, geology and landuse class.

The number of reaches allocated to separate classes within each REC classification level (see Table 1) was determined, as was the percentage of reaches within the region to each class. This was then compared to the percentage of reaches within the NERMN invertebrate sampling dataset that belonged to each class. For the climate classification level, the region was characterised by three dominant classes WW (77 streams), CW (25 streams), and CX (ten streams). Two other climate classes (CX, WD) were also found in the region, but these contained only five and one stream, respectively. When compared to streams throughout the region, NERMN monitoring sites appeared to be overrepresented in the WW climate class, and underrepresented in the CW and CX climate classes (Figure 5).

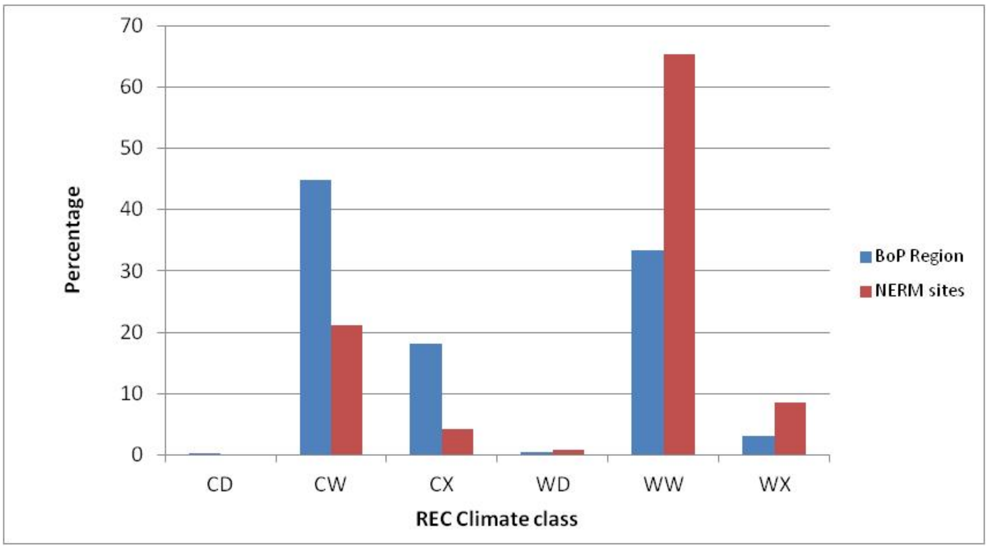

Figure 5 Bar chart showing the percentage of sites classified according to six climatic classes found within the region (blue bars) and within the NERMN Monitoring Programme (red bars).

For Source of Flow, most stream reaches (56%) within the Bay of Plenty region were regarded as hill-fed, with Lowland-fed being the next most common (39%: Figure 6). The NERMN sample sites were over-represented by lowland sites (74%), and under-represented by hill sites (22%). Mountain and lake-fed streams were uncommon in the region (<3%), and although no mountain-fed streams were sampled by the NERMN Programme, lake-fed streams had been sampled with a similar proportion as in the region. However, this amounted to only four streams, which may be too few to draw statistically valid conclusions of potential trends at the class level.

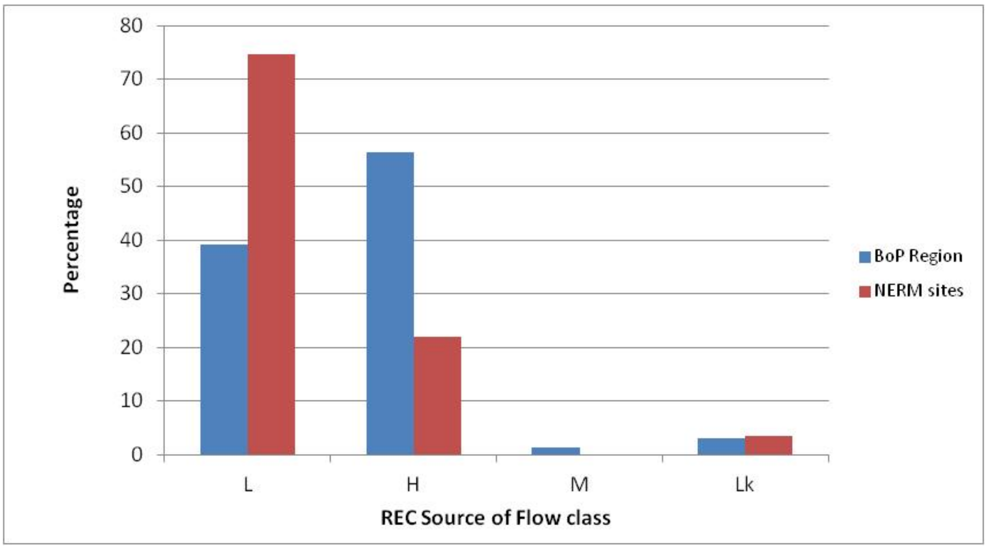

Figure 6 *Bar chart showing the percentage of sites classified according to the four different source of flow classes found within the region (blue bars) and within the NERMN Monitoring Programme (red bars).*

Geology in the region was dominated by acidic volcanic rock (69% of stream reaches), where concentration of phosphorus tends to be high, and where substrates tend to be fine (sands, silts and mud). This underlying geology appeared to be over-representative in the NERMN sampling sites (91%) when compared to what was typical in the region (Figure 7). The other dominant geology in the region was hard sedimentary, comprising 28% of stream reaches in the region. However, only 6% of reaches (i.e. seven streams) sampled by the NERMN Programme were in hard sedimentary catchments, suggesting that these stream types may also be under-represented. Even when combining the “miscellaneous” geology classification to the hard sedimentary classification to produce a non-volcanic rock category, this still ended up with only ten streams (ca. 9%). This is considered under-representative. The other three geological classes occurred only rarely in the region and were not sampled in the NERMN Programme (Figure 7).

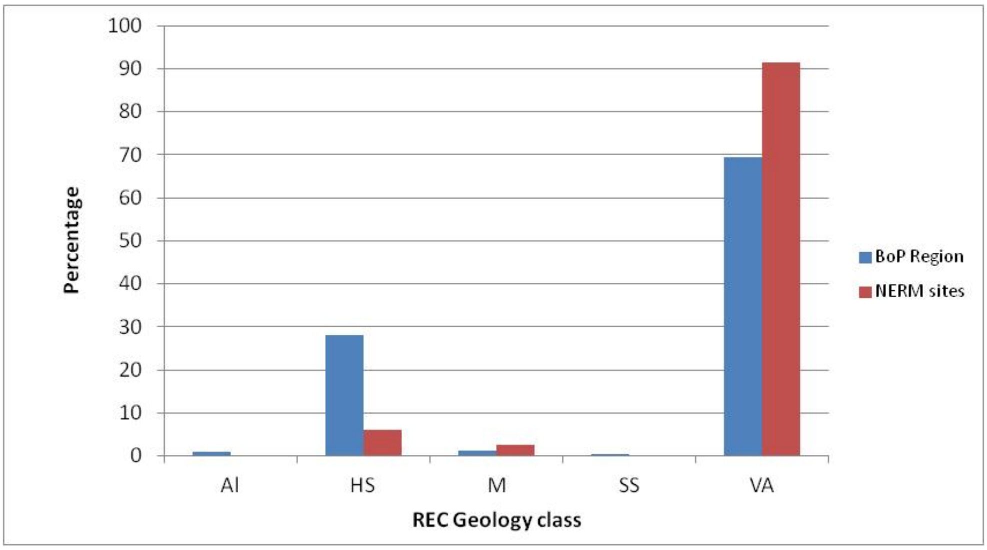

Figure 7 *Bar chart showing the percentage of sites classified according to the five different geological classes found within the region (blue bars) and the NERMN Invertebrate Monitoring Programme (red bars).*

Dominant land cover in the region was indigenous forest (51%), followed by pasture (26%), and exotic forests (20%). This trend was not represented by the NERMN sites, which were over-represented by pasture sites (52%), and under-represented by indigenous forest (38%) and exotic forests (7%) (Figure 8).

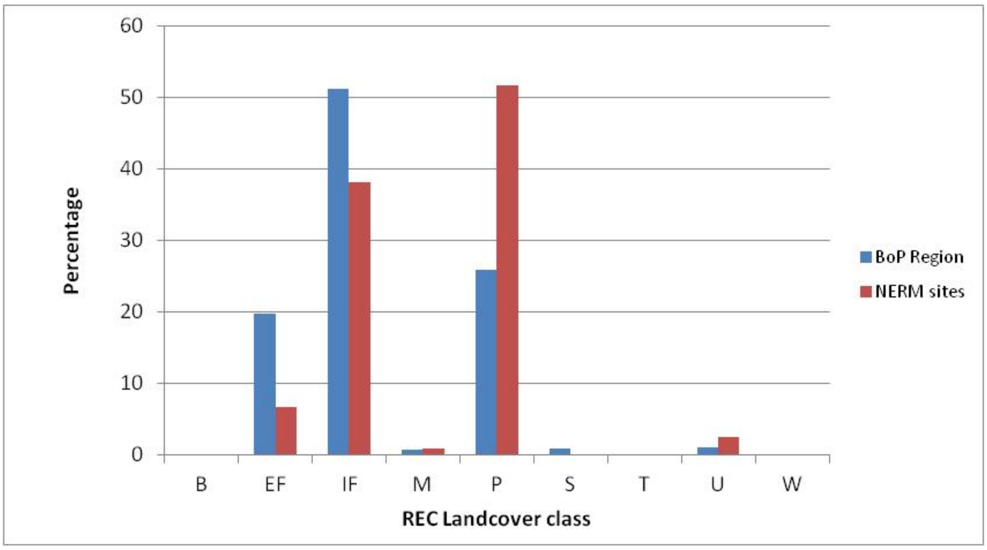

Figure 8 Bar chart showing the percentage of sites classified according to the nine different land cover classes found within the region (blue bars) and the NERMN Invertebrate Monitoring Programme (red bars).

The above analysis only looked at the percentage of stream reaches of particular classes within each classification level of the REC hierarchy. This showed that for some REC classification levels, the NERMN sampling sites were not particularly representative of the region. For example, the NERMN sites sampled proportionally more in the WW climate class, more in the volcanic geological class, and more in pasture land cover than were found in the region. A more realistic approach at examining the representativeness of the NERMN sites would be to look at the combination of REC classes in their hierarchy, and to produce a number of stream classes that could be used for future assessment.

Recommendation 6

Using the REC, develop a classification system for streams within the Bay of Plenty region that will allow streams to be grouped into similar classes based on classification levels of climate, source of flow and geology where appropriate.

Status

This recommendation has been implemented as part of the review process into the stream bio-monitoring (see below).

The REC was used to classify streams within the region to help assist with future analysis and interpretation of the NERMN invertebrate monitoring data. A fundamental part of classification is to group streams into specific classification units. Ideally, all streams within a specific classification unit will share similar characteristics. However, there is an inverse relationship between the variability of streams within a classification unit and the size of a specific classification unit. There is also an inverse relationship between the number of classification units, and the management usefulness of these units. For instance, a classification of the 118 NERMN streams to the climate level of the REC resulted in five classification units (CW, CX, WD, WW, WX), the largest class of which (WW) contained 77 streams. However, streams in this class are likely to have only a fairly low degree of within-class similarity.

Although dealing with five classification units would be efficient from a management perspective, the inherent variability within each unit would be large, potentially masking effects of human activities.

However, if the 118 NERMN streams were classified according to climate, source of flow, and geology, then 15 classification units would be created. This number of classification units is arguably too many for individual management decisions to be made about each one, despite within class similarity being higher. Moreover, the classification based on these three REC levels resulted in stream classes containing few streams.

If climate was divided into only two classes (cool, and warm), then nine classes would be created at the third REC classification (climate, geology and source of flow), dominated by W/L/VA (77 sites) and C/H/VA (21 sites). As with the initial climate, geology and source of flow classification, the other seven classes only had a few streams within them, and as such were not considered useful for planning or bio-monitoring purposes. To reduce the number of classes at different levels of the REC hierarchy, and to increase the number of streams within each management unit, the climate classification level was subsequently omitted. Within the region, source of flow was thought to play a larger role in structuring stream communities than climate. This assumption was supported by preliminary analysis of the invertebrate data collected by the NERMN Monitoring Programme, which showed that invertebrate communities appeared to be controlled more by source of flow and geology then by climate (unpublished data).

The source of flow classification level is a useful surrogate describing different hydrological regimes between the different source of flow classes, with large differences in the magnitude, duration, frequency and seasonality of floods and low flows being found in each of the classification groups. For example, hill-fed streams are often characterised by frequent, unpredictable short-lived flood events and often extended periods of low base flow. In contrast, lake-fed streams have a far less flashy hydrograph, as lakes tend to buffer and ameliorate the effects of short-term rainfall events occurring in their catchments. Moreover, lake-fed streams also have much higher base flows. A river’s flow regime thus has profound effects on the resultant biological communities that can develop there (Resh, Brown et al. 1988; Biggs 1995; Poff, Allan et al. 1997; Biggs, Duncan et al. 2001). Catchment geology also has profound effects on in-stream biota (Close and Davies-Colley 1990; Biggs and Gerbeaux 1993; Biggs 1995) by affecting factors including:

- the hydrological response to rainfall (catchments dominated by freely draining material will have fewer and smaller floods than those dominated by poorly draining material),
- nutrient regimes (rivers flowing through catchments dominated by phosphorus enriched rocks will not be as nutrient limiting as rivers flowing through nutrient poor rocks),
- substrate stability (catchments dominated by easily eroded rock will generally have smaller and more unstable substrates than those dominated by erosion resistant material).

Based on this, a *priori* classification of streams within the Bay of Plenty region was developed using source of flow and geology. For source of flow, mountain streams were grouped with hill-fed streams, reducing the number of classes to three (hill-fed, lowland and lake). The geological classes were also *a priori* grouped into two classes: volcanic and non-volcanic. Land cover was not considered for this analysis, as land cover is altered by human activities within the region. It is the effect of these activities that the NERMN Monitoring Programme is meant to be monitoring and investigating. By using source of flow and geology to classify streams, six stream classes were created within the Bay of Plenty region (Figure 9).

The percentage of sites allocated to each class within the region was compared to those within the NERMN Sampling Programme. Hill-fed streams in both non-volcanic and volcanic geologies were under represented by the NERMN monitoring, especially those in catchments of non-volcanic material (Figure 9). Within the lowland source of flow class there was a good match between the percentage of sites within the region and sampled by the NERMN Programme in non-volcanic geology, whereas the percentage of sites in the NERMN Programme in catchments of volcanic geology was more than twice that of the region. Finally, there was a similar percentage of lake-fed sites in volcanic geology, both within the region and within the NERMN Programme (Figure 9).

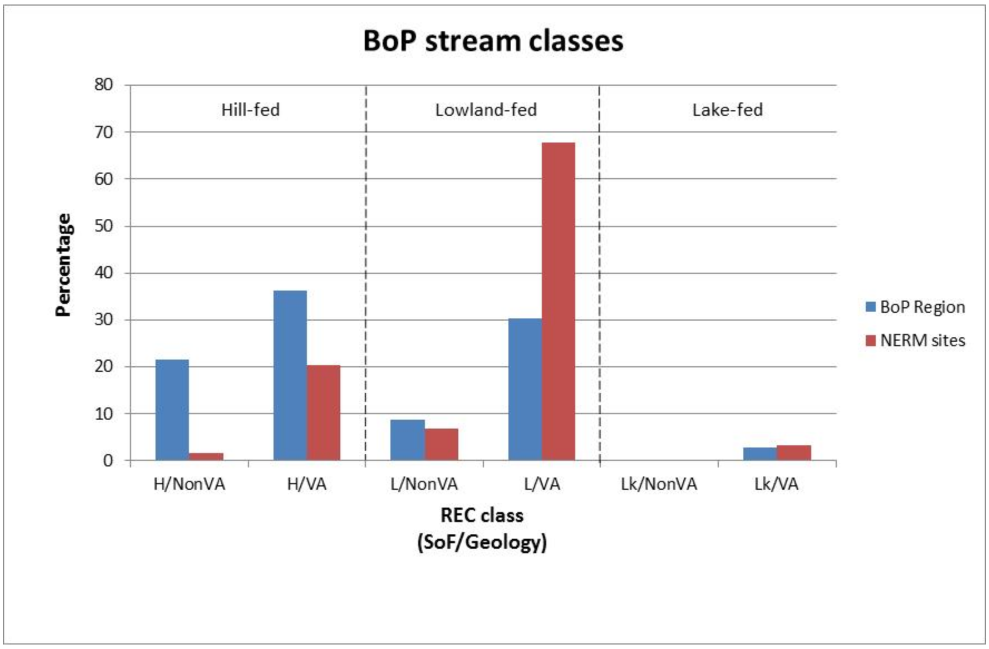

Figure 9 *Bar chart showing the percentage of sites allocated to one of six REC codes when classified according to source of flow and geology within the region (blue bars) and the NERMN Invertebrate Monitoring Programme (red bars).*

Examination of the spatial distribution of these classes showed that sites with a non-volcanic geology were found in the east of the region, draining the Raukūmara Ranges, while sites dominated by volcanic material were found elsewhere throughout the region. Lowland sites were not surprisingly restricted to the Rangitāiki Plains and areas around Tauranga Harbour, although some were found relatively far inland around the Rotorua lakes, and up the Rangitāiki Valley near Galatea. Obviously, sites with lake-fed source of flow were found on lakes Rotorua, Rotoiti, Tarawera and Rotokakahi (Figure 10).

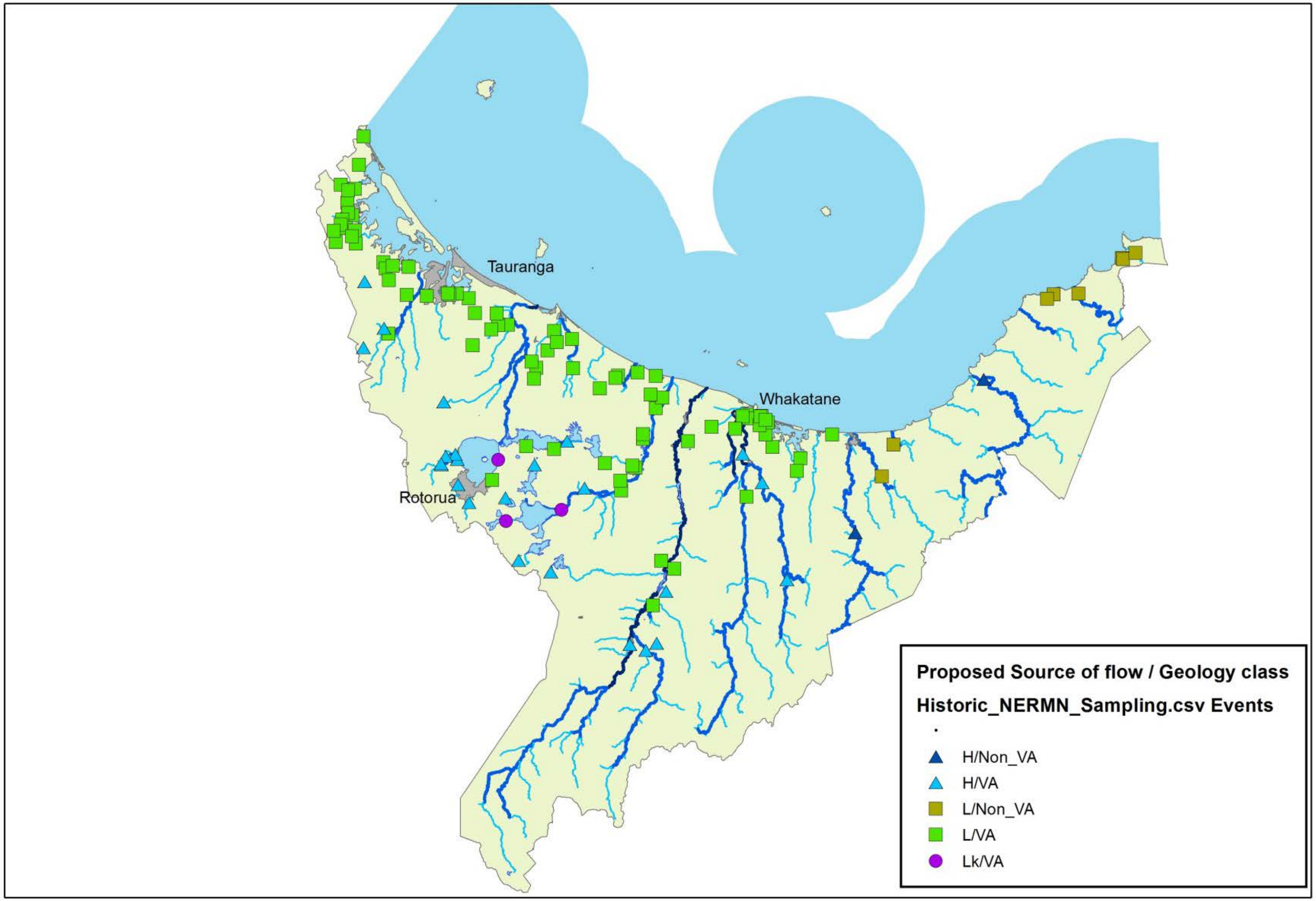

Figure 10 *Map showing a proposed classification of all NERMN invertebrate monitoring sites based on their source of flow (hill, lowland or lake) and geology (either non-volcanic or volcanic).*

Within each of the six stream classes, the proportion of waterways flowing through catchments dominated by different landuses was next determined. The percentage of sites in different landuses within the region was then compared to the NERMN monitoring sites. Prior to this analysis, landuse categories were combined into four classes consisting of "natural" (including indigenous forest, scrub, tussock and wetlands), exotic forest, pasture and urban. Un-modified natural catchments were the dominant landuse category found in hill-fed non-volcanic streams throughout the region. By comparison, this landuse type was underrepresented in NERMN sites (Figure 11). For streams flowing through catchments dominated by volcanic rocks, natural or pasture land cover appeared overrepresented in the NERMN sites when compared to the region, while those draining exotic forests were underrepresented (Figure 11). Some hill-fed sites sampled as part of the NERMN Programme had very low replication with, for example, only two streams in non-volcanic, natural catchments, and only one stream in volcanic, exotic forest catchments. This low replication is likely to limit the strength of any conclusions made, particularly in catchments draining exotic forest in volcanic areas. Given that forestry activities may adversely affect stream health, the number of sites in this stream class may need to be increased.

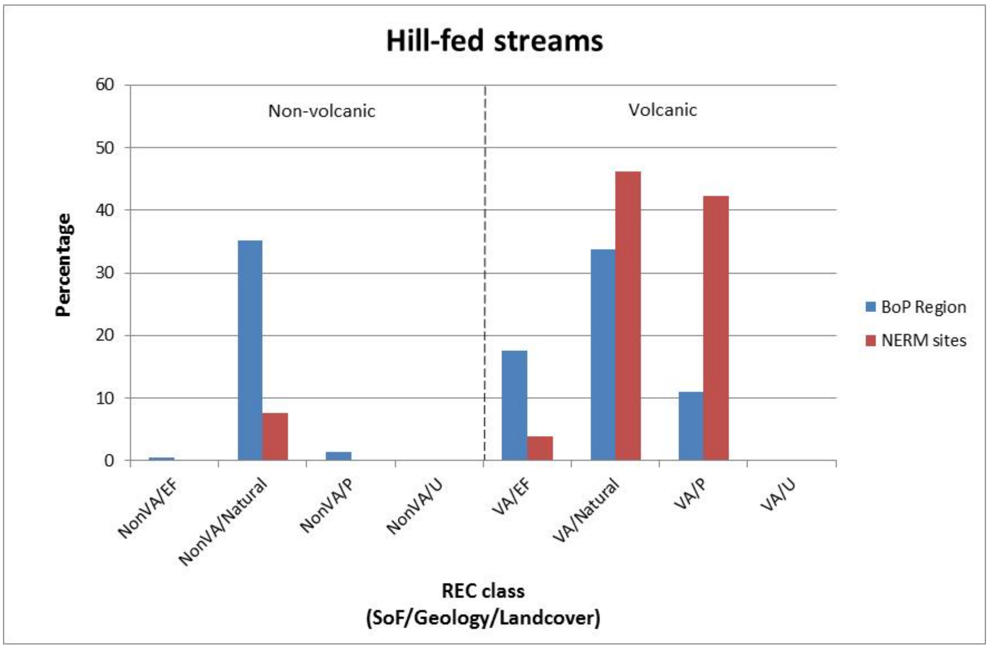

Figure 11 Bar chart showing the percentage of hill-fed streams in each of the four landuse classes within the region (blue bars) and the NERMN Invertebrate Monitoring Programme (red bars).

A similar lack of replication was observed for some of stream classes within the lowland stream source of flow (Figure 12). Here, only three and two sites have been sampled from non-volcanic, pasture streams, or volcanic urban streams respectively. Of interest was the observation that the percentage contribution of these classes was similar between the NERMN sites and those found throughout the region. This highlights the difficulty between ensuring a representative sampling regime (where sites sampled in proportion to their occurrence in the region) versus a balanced sampling regime (where sufficient sites are sampled to ensure a minimum degree of replication is achieved). Within volcanic lowland streams, the NERMN sites were overrepresented in catchments dominated by either pasture or natural vegetation, and underrepresented by catchments dominated by exotic forest (Figure 12).

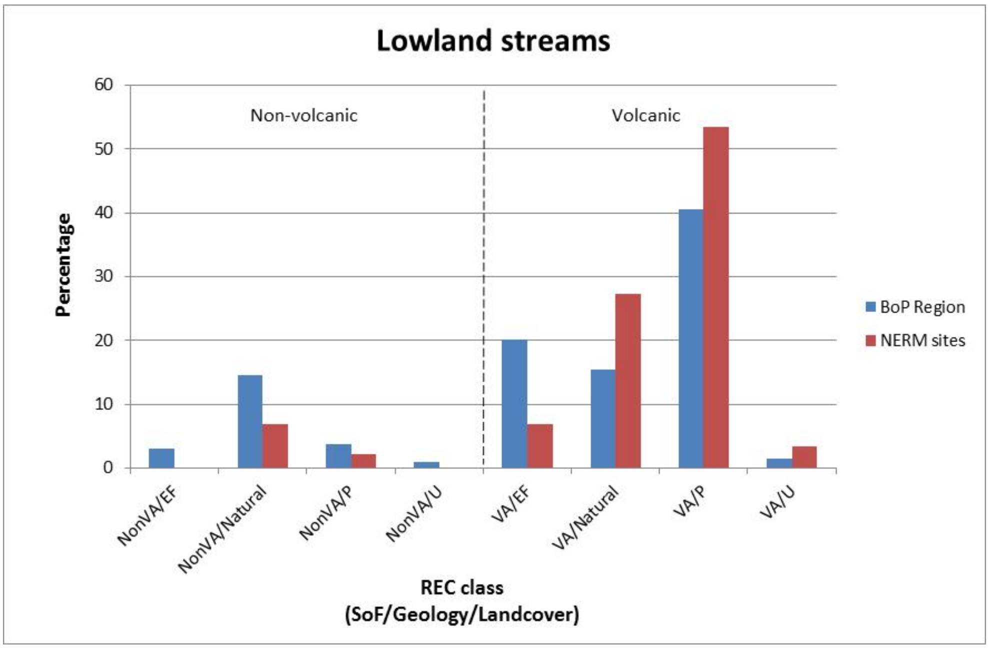

Figure 12 *Bar chart showing the percentage of Lowland-fed streams in each of the four landuse classes within the region (blue bars) and the NERMN Invertebrate Monitoring Programme (red bars).*

The percentage of lake-fed streams draining catchments in volcanic areas and dominated by natural vegetation in the region was similar to that in the NERMN Monitoring Programme (Figure 13), while NERMN sites appeared overrepresented for the exotic forestry size, and underrepresented for pasture sites. However, only four lake-fed streams were sampled as part of the NERMN Programme (two in catchments dominated by natural vegetation, and one each in pasture and exotic forestry catchments), again greatly limiting the amount of analyses and conclusions that could be drawn from this data. The number of lake-fed streams in these different landuse categories should be increased if possible.

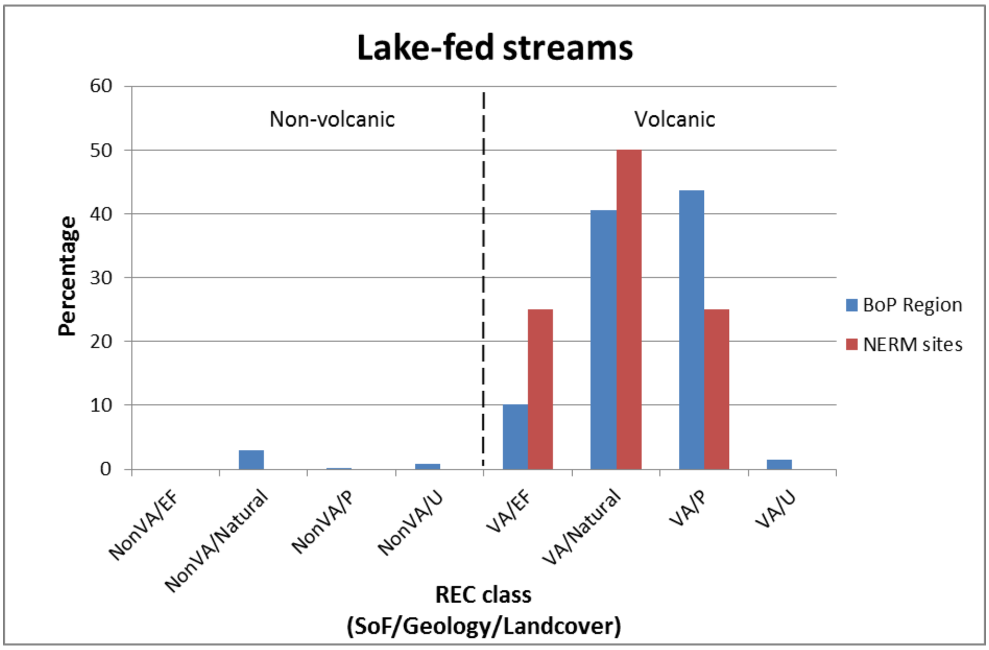

Figure 13 *Bar chart showing the percentage of lake-fed streams in each of the four landuse classes within the region (blue bars) and the NERMN Invertebrate Monitoring Programme (red bars).*

The effects of landuse activities on stream ecosystems are well documented (Scott, White et al. 1994; Quinn and Cooper 1997; Quinn 2000). Generally, as landuse activities intensify, stream health declines. There is thus an increasing decline in stream health in catchments dominated by exotic forest, pasture, dairy and urban development. An important part in assessing the effects of landuse activities involves comparing stream health in a particular stream with that in a similar stream where landuse activities are minimal – i.e. a reference stream where human impacts are negligible. The initial REC classification only assigns different land cover classes based on the percentage of dominant land cover within a catchment, unless P exceeds 25% of catchment area (in which case class = P), or unless U exceeds 15% of catchment area (in which case class = U (see Table 1)). Given this coarse classification, it could be difficult to properly assign a stream to the reference condition, as stream is assigned to the "natural" class may indeed include significant areas of modified landuse. To better characterise and identify reference condition streams, and to examine relationships between increasing land cover intensification, it is necessary to obtain data showing the percentage of different landuses in streams. Such quantitative data is found as part of the FWENZ classification system. This uses the same river network as the REC, but instead of assigning individual reaches to a particular landuse or geology category, the FWENZ database contains quantitative information on factors such as the percentage of a particular catchment covered by different landuses. By interrogating this database, it is possible to obtain quantitative information as to the percentage of every sub-catchment and catchment with different geological material and land cover. Such an approach was successfully used by (Collier, Haigh et al. 2005) in finding suitable reference streams in the Waikato region.

Recommendation 7

Assess the variation of invertebrate communities found within the 118 streams currently surveyed and determine the appropriateness of the proposed REC source of flow/geology classification.

Recommendation 8

Where possible, increase the number of streams in under-represented REC classes for future monitoring, such as:

(i) For hill-fed streams, increase the number of sites draining exotic forests in volcanic catchments, and the number of sites draining natural areas in non-volcanic catchments, while possibly reducing the number of pasture streams in volcanic catchments,

(ii) For lowland streams, increase the number of sites draining pasture or urban areas in non-volcanic catchments, and increased the number of sites draining exotic forests and urban areas in volcanic catchments,

(iii) For lake-fed streams, increase the number of streams draining exotic forests, pasture and natural areas in volcanic catchments.

Recommendation 9

Determine whether the spatial distribution of sites is appropriate given the issues, methods and rules currently in place, and whether enough sites are being sampled where land management officers are implementing methods such as riparian fencing and planting to help determine the effectiveness of these.

Recommendation 10

Obtain quantitative data from the Freshwater Environments of New Zealand (FWENZ) database showing the percentage of different land cover within a particular stream catchment at a NERMN monitoring site.

Recommendation 11

Use data obtained from FWENZ to select appropriate reference sites on which to make further comparisons, using protocols similar to those as outlined by Collier et al.

In their discussion of network design principles for national freshwater monitoring, Larned and Snelder (2012) suggested that water quality and ecological monitoring sites be integrated. Larned and Snelder emphasised that some councils (e.g. Greater Wellington Regional Council) conduct both ecological and water quality monitoring at most or all SOE sites, while other councils (e.g. Environment Canterbury) have partially overlapping ecological and water quality networks. They also highlighted a fundamental difference between water quality and biological monitoring sites. Most water quality monitoring is conducted on fifth order reaches or larger, whereas most ecological sites are on fourth order reaches or smaller (Davies-Colley, Verburg et al. 2012). One of the reasons for the disparity between site locations may reflect the fact that water quality conditions and ecological conditions may vary at different spatial scales. Water quality is affected primarily by catchment scale factors such as climate, source of flow, geology and land cover. Ecological communities, however, are affected by both catchment scale factors, as well as by reach scale factors such as substrate size, depth and velocity regimes, canopy cover, the presence or absence of aquatic plants etc. If this is true, then a good argument can be made for locating water quality sites in higher order reaches and biological monitoring sites on the lower order reaches.

Examination of the NERMN invertebrate monitoring sites showed that 86% of the 118 sites are monitored were from fourth order rivers or smaller, whereas only 60% of the 81 water quality sites were from fourth order rivers or smaller (Figure 14). Although the NEMAR panel supported integration of ecological and water quality monitoring sites, they also identified a number of disadvantages with this approach including the fact that proper integration between the two monitoring programmes may be costly and may require significant shifts in the operations of some councils, and the fact that protocols for sampling aquatic invertebrates have not yet been developed for non-wadeable streams. The latter issue means that future invertebrate monitoring may need to be limited to fourth order sites or lower until the development of ecological sampling protocols for larger streams.

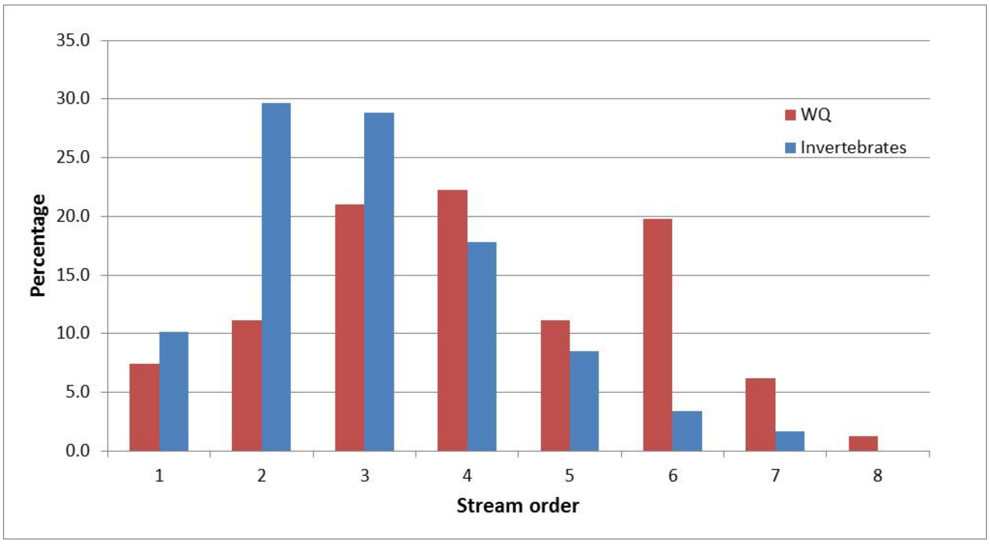

Figure 14 *Bar chart showing the percentage of streams of different order surveyed as part of the NERMN water quality (Red bars) or Invertebrate Monitoring Programme (blue bars).*

Of the 118 invertebrate monitoring sites, 52 were located upstream of water quality monitoring sites. Of these 52, 19 sites were within 500 m of each other (Table 2), and as such could be considered as paired water quality and biological monitoring sites.

Table 2 Names and locations (NZMS 260 series eastings and northings) of sites that shared similar locations for both invertebrate and water quality sites monitoring.

Site name	Easting	Northern	Invertebrate site number	Water quality site number
Te Pohue	2818170	6345944	NERM_012	BOP120112
Ōkāreka Tributary	2803497	6332456	NERM_015	BOP120060
Waingaehe (SH 30)	2800332	6336748	NERM_016	BOP120005
Okaro Tributary	2806577	6317592	NERM_018	BOP110155
Mangakino	2814262	6314878	NERM_020	BOP120101
Pongakawa (SH 2, Pukehina)	2819407	6370260	NERM_033	BOP110030
Ngongotahā (Hamurana Road)	2792025	6341682	NERM_036	BOP110013
Waitetī	2791581	6342869	NERM_037	BOP120003
Waiohewa	2801803	6341578	NERM_047	BOP120006
Waitekohe (upstream of SH 2 Bridge)	2767718	6396108	NERM_065	BOP710023
Waipapa Tributary (Waipapa Block Road)	2774592	6388608	NERM_086	BOP710011
Raukōkore	2939921	6380835	NERM_110002	BOP110002
Otara	2893071	6337461	NERM_110005	BOP110005
Nukuhou	2872906	6338732	NERM_110007	BOP110007
Whakatāne	2860898	6332653	NERM_110010	BOP110010
Whakatāne	2859978	6342854	NERM_110011	BOP110011
Whirinaki	2836808	6296170	NERM_110014	BOP110014
Rangitāiki	2833141	6297542	NERM_110015	BOP110015
Tarawera	2816832	6329609	NERM_110020	BOP110020

Recommendation 12

Further compare and contrast locations of the NERMN invertebrate monitoring sites and the water quality monitoring sites, and investigate the implications of further integrating the two programmes. Part of this investigation would include examining relationships between changes to invertebrate communities over time and changes to water chemistry.

Part 6: Sampling frequency

Invertebrate data is currently collected annually from the selected NERMN sites, generally in summer. Annual summer sampling is the most common sampling regime for regional councils, being done by 13 of the 15 councils (Davies-Colley, Verburg et al. 2012). Summer sampling is regarded as being a period of highest stress on streams in terms of low flows, highest water use, time of most intense landuse activities, and times when the stream may be at its lowest available dilution or assimilative capacity (Meredith, Cottam et al. 2003). The only caveat to sampling for the NERMN Programme was that no sampling be done within six weeks of a significant "flood", where a flood was defined as one exceeding three times the median flow. Unfortunately, the actual date of sampling was not recorded for the majority of samples, although it was possible to determine which month samples were collected from, especially between the summers of 2001-2002 and 2007-2008. Some of this information may be present in habitat field sheets (see section 9), but to date this has not been established.

During this seven-year period, January was the most common month for sampling (six of the seven years), followed by November and December (four of the seven years). Samples were collected during February in three of these years, while samples were collected from some sites in 2003-2004 as late as April and May. The combined NERMN invertebrate data set therefore consists of samples which had been collected over a seven-month period. This is not ideal in terms of our ability to detect long-term temporal trends in the data as a result of landuse changes, as sampling over such a wide seasonal time frame would undoubtedly add more variability to the data. However, work by Scarsbrook (2002) and Winterbourn (1997) have shown that invertebrate community composition in unmodified streams generally varies around a relatively stable state, so that although the relative abundance of taxa may change, the species composition changes to a much lesser extent. Thus, any differences to the invertebrate community composition arising from normal seasonal variation within a site are expected to be much less than the changes associated with changes in water chemistry, or in stream health arising as a result of landuse changes.

Recommendation 13

Continue the NERMN invertebrate sampling protocol on an annual basis. If more sites are to be added to these sampling network as per Recommendation 8, it may be necessary to consider some form of rotational sampling, as done by Waikato Regional Council (Collier and Hamer 2010).

Recommendation 14

Ensure that invertebrate sampling is restricted to as short a time window in summer as possible (i.e. January to March). If the nominated sites cannot be sampled due to recent floods, then other non-nominated sites could be sampled instead.

Recommendation 15

Ensure that all future sampling records the actual data of sampling on the Excel spreadsheet, and ensure that this is written into any future protocols.

Part 7: Sample collection

A fundamental part of any biological sampling programme is determining where within a river reach to sample (Meredith et al. 2003). Invertebrate communities can differ greatly between habitats such as riffles and runs (e.g. Pridmore and Roper 1985), reflecting differences in factors such as water velocity and substrate size, and the fact that different invertebrates have different preferences for either fast flowing (e.g. mayflies and stoneflies) or slow flowing (e.g. snails and worms) habitat. Historically, most bio-monitoring programmes that have attempted to minimise variation between sampling sites by sampling predominantly stony riffle areas, characterised by large substrate, in shallow, fast-flowing waters. These habitats persist under most flow or climatic regimes, and are also generally areas of high biological diversity. However, stony riffles are not found in all streams, and particularly in meandering lowland streams, or streams straightened by channelization. Most of these streams have streambeds dominated by fine substrate such as sand and mud, and the dominant flow pattern consists of slow-flowing runs and pools. Stony fast-flowing riffles are rare or absent. There is a wide variety of streams throughout the Bay of Plenty region, ranging from swift hard-bottomed mountain-fed streams flowing from the inland ranges through to slow-flowing soft-bottomed lowland streams, and channelised streams running through the Rangitāiki Plains. Runs, therefore, appear to be the most common and abundant habitat across all stream types within the Bay of Plenty region. As such, it could be argued that these habitats should be the focus of all invertebrate sampling within the region.

Initial sampling conducted by Donald from 1992 to 1995 involved collection of replicate quantitative Surber samples from stony riffle areas. This sampling strategy gave good information as to stream variability, as well as allowing total invertebrate density to be calculated. Although a useful strategy for more detailed impact assessments, collecting replicate Surber samples from streams was thought to be too detailed for state of environment reporting (Wilding 1998). Wilding highlighted the fact that many of streams in the western region of the Bay of Plenty were soft-bottomed, where techniques such as Surber samples would not work. He consequently recommended the use of kick nets to sample more of these soft-bottomed sites in areas previously unsampled.

Stark, Boothroyd et al. (2001) presented clear guidelines for the collection of samples from both hard-bottomed and soft-bottomed streams. They also presented guidelines for semi-quantitative data (as recommended for State of Environment reporting) and quantitative data (for compliance or AEE studies). Protocol C1 was developed for hard-bottomed streams, and is considered the most appropriate for riffle habitats. However, this method is easily used in run habitats, as done by Environment Canterbury for their SOE monitoring (Beech, Meredith et al. 2007). The basic concept behind protocol C1 involves disturbing an area (0.1-0.2 m^2 in area) of substrate upstream of a collecting net by using the feet to dislodge the upper layer of cobbles or gravels. Any dislodged invertebrates and other material is caught in the downstream nets, which should be placed in no further than 0.5 m away from the net. This process is repeated at or five different locations within the stream to sample the total area of 0.6 to 1.0 m^2. Although no explicit documentation on sampling from cobble-bed streams has been found, it appears as if this protocol was used by both Wilding and Bloxham (Matt Bloxham pers. comm., May 2012).

Protocol C2 has been developed for soft-bottomed streams, where there is no suitable hard-bottomed streambed to disturb in order to collect invertebrates. In some soft-bottomed streams, woody debris, submerged logs and aquatic macrophytes support diverse invertebrate assemblages (Stark et al. 2001, Collier 1995; Collier, Champion et al. 1999; Collier 2004), and so these habitats should be sampled wherever possible. Similarly, overhanging bank vegetation on bank margins can represent important habitats for invertebrates. Stark et al. recommend sampling all of these habitats in soft-bottomed streams, in proportion to their percentage of occurrence. In each of the habitats, the kick net can be jabbed or swept through vegetation and around debris jams, collecting any dislodged invertebrates. Invertebrates can also be brushed from large woody debris and into the collecting net held downstream. Stark et al. recommend collecting approximately 3 m^2 of substrate in soft-bottomed streams, with each sampling unit being approximately 0.3 m^2 in area. It appears as if this protocol was also used by both Wilding and Bloxham (Matt Bloxham pers. comm., May 2012).

Recommendation 16

Clearly identify field methods by which the different stream types in the region have been sampled, and produce clearly defined up protocols for students and others to follow in future sampling.

Recommendation 17

Where possible, ensure maximum consistency in how samples are collected over time from each site.

Part 8: Biotic indices

8.1 Invertebrate monitoring

Freshwater invertebrates are commonly used to determine the ecological condition of waterways throughout the world, including New Zealand (Rosenberg and Resh 1993; Barbour, Gerritsen et al. 1996; Stark, Boothroyd et al. 2001). These animals generally comprise the larval (and occasionally adult) stages of insects, along with molluscs (snails, bivalves), crustaceans (e.g. koura, shrimp, water fleas etc.), and worms, and are a vital component of foodwebs in streams. Aquatic insects represent the most diverse and most abundant of the freshwater invertebrate groups, followed by crustaceans and snails. The importance of these animals lies in their role of transferring plant-based organic carbon (e.g. leaves, wood, periphyton) into animal-based organic carbon, which is then available to higher predators such as fish and birds. Unlike algae, freshwater invertebrates are relatively long-lived, and can spend months to years living in streams. They are also not washed away by small floods as easily as algae are. They are not as mobile as fish, making it possible to characterise their population densities in streams with a certain degree of accuracy. They are also relatively easy to identify, and the ecological tolerances of different invertebrates are relatively well known. Thus, the presence or absence of different invertebrates in a stream tells us a lot about its ecological condition.

Monitoring freshwater invertebrates in streams has been used extensively to determine effects of catchment development (Lenat and Crawford 1994; Quinn, Cooper et al. 1997; Hall, Closs et al. 2001), and the effects of point source and diffuse run-off (e.g. Rosenberg and Resh 1993; Winterbourn, Alderton et al. 1971). Stark et al. (2001) published New Zealand-based protocols for sampling and processing stream invertebrate samples and this has further increased the attractiveness of using these organisms to assess the ecological condition of waterways. A central assumption underlining the use of invertebrates to monitor the ecological condition of streams is that the community present at a particular site is a product of its current and antecedent environmental conditions. Thus, it is assumed that communities found in polluted waters will differ to those found in unpolluted waters as a result of different tolerances or habitat preferences of each individual invertebrate species. In this way, aquatic invertebrates are used to assess overall stream “health", where the term "health" is analogous to that of human health. Healthy streams most commonly contain a diverse assemblage of invertebrates that are intolerant of activities associated with landuse change, while degraded streams are mostly dominated by only those organisms which can tolerate those conditions. It is also important to realise that ecosystem health can be affected by many different stressors associated with human induced landuse activities.

Traditionally, most emphasis has been placed on environmental monitoring programmes to detect organic enrichment (Meredith et al. 2003), yet it is important to realise that there are other types of environmental stresses which can affect aquatic biota. For example, altering a stream’s dominant energy source can have profound effects on the invertebrate communities. Forested headwater streams are heavily shaded, and have low algal biomass. Their dominant energy source comes from falling leaf litter, and from bacterial layers that develop on the stream bed. The invertebrate communities in these streams will be dominated by a mixture of "shredder" type invertebrates that consume leaf litter, and "browser" type invertebrates that consume the organic layers on cobbles (Rounick and Winterbourn 1983; Winterbourn 2000). In contrast, small streams flowing in tussock or scrub country are generally unshaded, and the dominant energy source comes from algal film growing on rocks in the stream bed.

The invertebrate communities in these streams will be dominated by grazing animals that consume algae and these communities will be very different from those in shaded streams (Rounick, Winterbourn et al. 1982; Lambeti and Moore 1984; Hall, Likens et al. 2000). Consequently, removal of forest cover associated with harvesting pine trees will have a very large impact on the invertebrate communities within streams flowing through pine forests. These changes are occurring over and above those caused by nutrient enrichment (e.g. Karr, Fausch et al. 1986). Even the introduction of exotic species can have dramatic effects on ecosystem health. This means that it is important when setting up a biological monitoring programme to make sure that the potential adverse effects of different types of stressors can be detected. This is best done by monitoring more than one aspect of the invertebrate community composition.

8.2 Assessing stream health

A major problem and challenge in using invertebrates to indicate stream health is the need to convey the somewhat complex community composition information into a series of easy to understand measures that can summarise certain attributes of the invertebrate community to obtain an overall index of stream health. A number of such metrics have been developed in New Zealand to help transform the often complex ecological data into simple numbers, which are more understandable by managers.

The first of these metrics is the Macro-invertebrate Community Index (MCI), which is commonly used as an indicator of water quality in stony streams (Stark 1985). This metric was developed by assigning tolerance values to a range of invertebrates found in stony-bottomed streams in the Taranaki Ring Plain exposed to organic enrichment from dairy sheds. Taxa which were intolerant of enriched conditions were assigned high tolerance scores, while taxa which were tolerant of such conditions were assigned low scores. Tolerance scores range from 1 to 10. The MCI is calculated is as follows:

$$\mathrm{MCI} = 20 \times [\Sigma\, a_i / S]$$

where a_i = tolerance score for the i^{th} taxon, S = total number of taxa (Stark 1993). Calculated MCI scores can theoretically range from 20 (i.e. only one taxa with a tolerance score of 1) to 200 (only one taxa with a tolerance score of 10). Calculated MCI scores above 120 are considered to represent streams in excellent condition, whereas scores below 60 are considered to indicate streams in highly degraded conditions.

The MCI score relies purely on the presence or absence of invertebrates in a stream and so can often provide only a relatively coarse indication of stream health. Thus, a healthy stream supporting large numbers of taxa with high tolerance scores (e.g. mayflies and stoneflies), and low numbers of taxa with low tolerance scores (e.g. worms) will have the same MCI score has a more degraded stream which supports the same species composition, but which has reduced densities of mayflies and stoneflies, and increased densities of worms (see Table 3). In this regard, the MCI is not particularly sensitive to the changes in the relative abundance of different taxa, which is arguably one of the first signs that a particular environment is under stress. These sites will only display a different MCI score when some of the taxa indicative of healthy environments disappear from a stream.

Table 3 *Calculated MCI and QMCI scores from two hypothetical sites showing how they can have the same taxon richness, number of individuals, and MCI score, but have a very different QMCI score due to the reduced densities of pollution intolerant organisms. From (Stark 1998).*

Taxon	Taxon score	Site A	Site B
Mayflies			
Coloburiscus	9	100	3
Deleatidium	8	250	15
Nesameletus	9	15	2
Stoneflies			
Zelandoperla	10	15	2
Beetles			
Elmidae	6	3	15
True flies			
Maoridiamesa	3	2	100
Orthocladiinae	2	2	250
Caddisflies			
Beraeoptera	8	50	2
Helicopsyche	10	60	1
Oxyethira	2	2	60
Worms	1	1	50
Number of taxa		11	11
Number of individuals		500	500
MCI		**124**	**124**
QMCI		**8.44**	**2.54**

Because of this concern, the quantitative variant of the MCI (i.e. the QMCI) is also used to describe the health of a particular waterway. This score is calculated as:

$$\text{QMCI} = \Sigma\,(n_i \times a_i)\,/\,N$$

Where n_i = the number of individuals in the i^{th} taxon, where a_i = tolerance score for the i^{th} taxon and N = the total number of individuals. Calculated QMCI scores range from 1 to 10. Streams having scores >7 represent streams in excellent condition, and streams having scores <2 represent highly degraded streams. Note that the QMCI requires either numeric or percentage data, which can be more costly to obtain than simple present absence data. However, this extra cost needs to be balanced with the increased information that this index can convey.

Because of the extra costs associated with quantitative data, Stark (1998) developed and recommended the use of the semi-quantitative MCI (SQMCI). Here, invertebrate abundance is assigned to a 1 to 5 scale corresponding to rare (1 to 4 individuals), common (5 to 19 individuals), abundant (20 to 99 individuals), very abundant (100 to 499 individuals) and very, very abundant (500+ individuals). These estimates are based purely on a visual observation of invertebrates spread out in white trays.

Stark (1998) found that care was needed when assigning dominant taxa to the abundance classes, as they had the greatest influence on the SQMCI. Stark also found that the SQMCI provided a similar assessment of a streams invertebrate community as the QMCI but with 40% less effort. However, Duggan, Collier et al. (2003) compared the performance of a fixed count sub-sampling (100, 200, and 300 individuals) to that of coded abundance, and found that coded abundance estimates resulted in much greater variability and potential loss of information in the data. This was attributed in part to the ranges assigned to each of the abundance levels, particularly to the dominant taxa. These dominant taxa had very wide abundance ranges, whereas less dominant taxa had much narrower ranges, and thus gave little weighting to the final index value. Based on their results, Duggan et al. concluded that a fixed count methodology gave superior results to the SQMCI. As with any monitoring, the final choice of index will reflect both the objectives of the study, as well as financial and practical constraints. The NERMN invertebrate sampling protocol to date includes a mixture of both full counts from Surber samples, and a 300 fixed count methodology (see Section 9).

Stark developed the MCI tolerance scores for stony-bottomed streams, and recognised that these scores do not work well in soft-bottomed streams. In response to this, Stark and Maxted (2007) developed tolerance values for invertebrate taxa inhabiting soft-bottomed streams. In doing so they created the soft-bottomed versions of these metrics (MCI_sb and QMCI_sb). These are calculated in the same way as the hard-bottomed metrics, and have the same scoring bands.

Two other commonly used metrics to describe the invertebrate communities is the number and percentage of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa in a sample. These metrics convey useful information about overall invertebrate community composition and condition, as many species of these insect groups are sensitive to pollution, and show reductions in density at sites affected by contamination such as excess nutrient enrichment or heavy metals. Furthermore, as sediment loads, or algal biomass, increase, the number or % of EPT taxa often declines. The exception to this is for the two hydroptilidae caddisflies *Oxyethira* and *Paroxyethira*, which are common in streams dominated by high algal biomass, and are generally regarded as being highly tolerant of organic enrichment. As such, the number and percentage of EPT is often calculated without these animals (commonly referred to as EPT* and % EPT*).

Although the MCI and QMCI have been used extensively by ecologists throughout New Zealand, these metrics cannot always detect changes in stream health caused by some pressures. A notable example of this was found by Hickey and Clements (1998), who investigated the effects of heavy metals from current and closed goldmines on Coromandel Peninsula. Here, they sampled invertebrate communities above and below mine discharges. They showed that the abundance and species richness of mayflies, the number of EPT taxa, and total taxonomic richness were the best indicators of heavy metal contamination in New Zealand streams. Of interest was the finding that the MCI and QMCI did not differ significantly in samples collected above and below areas receiving mine drainage. Hickey and Clements thus recommended that these metrics not be used, or be used with great caution when assessing the effects of metal contamination on streams.

There is therefore a trade-off in using metrics; they need to be easy to calculate and understand, but they also need to be sensitive enough to a wide range of stressors to show a change. Collier (2008) recently developed a new metric - the Average Score Per Metric (ASPM) that amalgamates the different behaviours of individual metrics into a new confined metric. This was shown to perform better than either the individual metrics alone. Whether the ASPM metric is applicable for Bay of Plenty streams is presently unknown.

Donald (1992 and 1995) calculated a number of metrics including taxon richness, total abundance (density), MCI and EPT richness. He also looked at differences between 1994 and 1995 using pairwise t-tests. Because he collected replicate samples, he was able to assess the within river variability of different biotic measures, expressed as the coefficient of variation. Based on data collected from 1992 to 1995, Donald found downward trends in MCI scores in the Whangaparaoa and Waiaua Rivers, suggesting a decline in river health at these sites.

Wilding (2001) took over monitoring the same sites as Donald, from 1995 until 1998. He presented MCI and QMCI values, taxon richness, and the number of EPT taxa. Wilding also presented pie charts showing invertebrate community composition in for stream types that had previously been identified based on an ordination of the invertebrate data collected by Donald (1992). Wilding also introduced the concept of comparing the results of each stream against reference sites, and calculated a percentage reference for each index. Although he acknowledged that the monitoring programme was not set up for this approach, he identified two East Cape sites as representing reference conditions based on the fact that 95% of their catchment was native forest or scrub. By comparing the number of EPT taxa, and MCI scores, Wilding was able to assign impairment categories (no impairment, slight impairment, moderate impairment or heavy impairment) to the sites that had been sampled.

Comparison of different metrics those derived from reference condition sites is regarded as a powerful technique to describe the ecological health of waterways, and has been used widely by regional councils such as Environment Waikato (Collier 2005; Collier and Kelly 2006), and the Canterbury Regional Council (e.g. Meredith, Cottam et al. 2003) for their State of Environment monitoring and reporting. The only challenge with this method is defining what is meant by the "reference condition", and in deciding which sites are representative of reference conditions. When using the reference condition approach, the need for some form of classification is obvious, as there is little point in comparing the condition of a particular stream to a reference stream if the two streams are inherently different. Based on the REC analysis above, a logical classification scheme of streams in the Bay of Plenty was based on source of flow and geology. Within each of these stream classes, suitable reference conditions could be identified, and other sites compared to these (see Recommendations 10 and 11).

Recommendation 18

Undertake a comparison of metrics such as EPT, percentage of EPT, MCI and QMCI, and the ASPM to determine what is best for summarising waterway health throughout the region, to assess their ability to discriminate between the five different derived stream classes, and to show temporal trends.

Part 9: Sample processing

All material collected in the sample nets is placed into appropriately labelled plastic bottles and preserved (either with iso-propyl alcohol, or ethanol) prior to processing. Stark et al. (2001) outline a number of laboratory processing methods that range in complexity and cost effectiveness. The simplest method (Protocol P1) uses coded abundance, whereby the relative abundance of invertebrates are assigned a 1 to 5 coded abundant scale. The second method (Protocol P2) is a fixed count method, whereby samples are processed and counted until a predetermined number (usually 200) is reached. The third protocol (Protocol P3) represents a full count method which can provide a direct measure of abundance. In this method, all invertebrates collected from a known area are counted. Although Donald (1992) originally followed a full count processing methodology, Wilding (2001) reviewed the NERMN Monitoring Programme and recommended introducing sub-sampling or fixed count methods to increase the efficiency of sample processing. The current sample processing methodology used in the NERMN Programme is based on the Protocol P2 (see Appendix 1 for details).

All three protocols described in Stark et al. (2001) involve sieving the original sample through a series of nested sieves, placing the contents of each sieve into white trays, and ensuring that this is spread evenly throughout the tray. For the fixed count method, the tray is marked with grids (approximately 6 cm x 6 cm), one of which is randomly selected. This randomly selected square is then examined by eye, and all invertebrates within it are removed and placed into a separate container. Sample sorting ceases if a total of at least 200 (or, in the case of the NERMN Programme, 300) organisms have been removed from this randomly selected square. If, however, less than 300 organisms have been counted, another square is randomly chosen, and the process repeated until at least 300 animals have been counted and placed into the separate container. This container is then observed under the microscope where all invertebrates are identified and counted. With the full count protocol, the sample is spread evenly throughout the white tray, and the sample processor works systematically across the tray, removing all the organisms found. These are then placed into a separate petri dish to confirm identifications by microscopic examination if necessary.

Note that all these protocols involve a degree of double handling. The sample is initially sieved, and then each site fraction is spread (supposedly evenly) throughout a white tray. This material is then scanned and any animals found are removed and placed into a separate petri dish. Following removal of either a fixed amount (300 for NERMN monitoring) or all the invertebrates in the tray, the contents of the petri dish are examined microscopically where animals are identified and counted. An alternative method, and one which is used by Environment Canterbury and by NIWA Christchurch, is to sieve the contents through a series of nested sieves, and then place these directly into a small Bogorov tray (see Winterbourn, Gregson et al. (2006) for further information). This material is spread evenly throughout the channels in the tray, and then microscopically examined where invertebrates are both identified and counted at the same time. For large amounts of material trapped on a sieve, sub-sampling can be used. In this way, there is no double handling of invertebrates as the sample from the sieve is examined and invertebrates identified and counted at the same time.

Finally, Stark et al. (2001) emphasised the importance of performing proper QA/QC checks on the invertebrate data as samples are processed. Quality control requirements are designed to focus on the two most likely sources of error: sorting and identification (i.e. taxonomy). In general, Stark et al. recommend QC procedures that involve the re-examination of 10% of sample selected at random. A second sample processor is provided with the results obtained by the original processor, and checks on both the identification and count of relative abundances.

Given the extra time and resources required to QA/QC checks, Stark et al. emphasises that such checks do not necessarily have to be carried out on the wall sampling occasions. Instead, they suggest that QC efforts be implemented for SOE monitoring once every three years or, in case of using casual personnel for sorting and identification, a QC report would be expected for each significant project. Given the implications of feeding the results of SOE monitoring back to the policy and planning team, the importance of ensuring that accurate and consistent data is collected over time cannot be under-emphasised.

Recommendation 19

Investigate the most cost-effective processing methodology for invertebrate samples to see if cost savings can be made between the P2 and P3 protocols currently being used, and the Bogorov tray protocol as outlined above.

Recommendation 20

Investigate the possibility of using students for both sample collection and sample processing, if given enough training. This recommendation is made in the knowledge that the fauna is numerically dominated by a range of invertebrates that are easy to identify (the freshwater snail *Potamopyrgus antipodarum*, the mayflies *Deleatidium*, *Zephlebia* and *Austroclima*, black flies (Austrosimulium), the common shrimp *Paratya*, chironomid midges, and the caddisflies *Aoteapsyche*, *Pycnocentrodes*, and *Triplectides*). Central to this recommendation would be the caveat that students would pick out any animals they couldn't properly identify for future identification by a trained ecologist, and that appropriate QA/QC protocols be used. It may also be possible to create a photographic image library of different organisms encountered, as well as a reference collection. Note that high-quality photos of invertebrates are currently available from organisations such as Landcare Research and EOS Ecology (a private Christchurch consultancy), and so may not need to be reproduced.

Recommendation 21

Following from recommendations of Stark et al. (2001), ensure that at least 10% of samples collected and processed as part of their SOE monitoring are retained for independent QA/QC purposes.

Part 10: Assessment of habitat quality

A key part of biological monitoring often involves some form of habitat assessment. This is useful, as in-stream habitat conditions can potentially have large effects on invertebrate community composition and abundance. Moreover, assessing habitat conditions can often provide information highlighting potential causes of observed changes in ecosystem health as a result of habitat changes (see Section 7.1). There are a number of habitat assessment techniques that are used to describe components of stream habitat known to influence invertebrate communities (e.g. Harding, Clapcott et al. 2009). Such components often describe the:

1. nature of the streambed in terms of size, compactness, angularity (and, by default, assessment of stability as constantly moving stones are generally more rounded),
2. nature of the dominant flow characteristics (i.e. riffle, run, pool, backwater etc.),
3. nature and severity of any bank erosion,
4. presence of aquatic plants in the stream,
5. amount and nature of riparian vegetation.

Some councils (e.g. Environment Canterbury, Environment Waikato) allocate different habitat factors to a scoring system, following methodology derived from the USEPA (Plafkin, Barbour et al. 1989). These habitat scores can then be used to determine any relationship between habitat quality, and invertebrate community health, and to determine any changes in habitat quality over time that may be caused by human activities, and which may be responsible for changing in-stream health.

Habitat variables had been collected since the inception of the NERMN surveys in 1992 (Donald 1992). Here, variables such as substrate size (expressed as a substrate index (Jowett 1993)), and percentage periphyton cover of mats, green and brown filaments, and green and brown films, were assessed. Data from the NERMN Water Quality Monitoring Programme (nutrients measures, dissolved oxygen, temperature, BOD_5, conductivity, pH, suspended solids and turbidity) was also included in the habitat variables. Wilding continued collecting similar habitat and water quality data until 2000. Following the commencement of sampling in soft-bottomed streams, Wilding and Bloxham collected other habitat variables such as adjacent landuse, description of riparian vegetation, stream shading, presence of aquatic plants, bank and channel stability, hydraulic variability and substrate conditions. This other data appears to have been first collected in the summer of 2003-2004, and appears to have been collected annually since then. As far as can be ascertained, all this information is presently stored on the original field sheets, and none has been entered into spreadsheets. As such, neither the spatial coverage, nor temporal nature of this habitat data is known.

Unfortunately, large differences exist in the types of habitat data collected. For example, surveys in 2003-2004, and in 2005-2006 collected quantitative data of 17 different habitat factors (Table 4).

Table 4 List of measured habitat factors measured in earlier NERMN invertebrate surveys prior to 2006-2007.

Habitat type	**Measured habitat factor**
In stream habitat	Percentage substrate size
	Percentage organic substrate within the stream bed
	Average reach velocity
	Dominant topography
	Channel realignment
	Canopy cover
	Nuisance algae
	In-stream disturbance
Classification	Average width
	Riffle depth
	Average depth
	Percentage pool, riffle, run, chute
Adjacent landuse	Percentage of nine different categories
Riparian zone	Percentage of different riparian vegetation types
	(Left and right banks)
	Extent of buffer zone
	Bank stability

In the summer of 2006-2007, there was a large switch from collecting quantitative data to collecting semi-quantitative data, whereby different habitat factors were *a priori* coded to different classes, and these were allocated a habitat score (Table 5). For example, the type of streamside vegetation was *a priori* divided into six classes, with streamside vegetation dominated by native trees scoring a 30, while streamside vegetation dominated by pasture grasses was scored a 1. These habitat sheets were based on a system developed by Hawke's Bay Regional Council, and which focused primarily on riparian vegetation (Matt Bloxham pers. Comm. May 2012). The idea behind this was to develop some form of riparian habitat scoring system.

Table 5 List of measured habitat factors measured in latter NERMN invertebrate surveys post 2006-2007. Also showing are the maximum values that could be scored each measured habitat factor.

Habitat type	Measured habitat factor	Maximum habitat score
Adjacent landuse	Dominant landuse beyond the stream	40
Vegetation	Width of stream and bankside vegetation	30
	Structure of the stream side vegetation	20
	Type of streamside vegetation	30
	Age (height) of trees and vegetation	10
	Streamside shading	20
	Completeness of buffer	30
	Periphyton cover	20
	Macrophyte abundance	20
Stability	Bank stability	20
	Channel stability	20
Disturbances caused by stock	Stock access	20
	Stock damage	20
Other external disturbances	Potential for sediment inputs	20
	Potential for contaminant inputs	20
	Presence of artificial drainage networks	20
	Natural drainage pathways	20
Stream habitat diversity	Hydraulic diversity	20
	Stable bottom substrate availability	20
	Embededness	20

This system places a lot of emphasis on riparian vegetation and adjacent landuse. For example, vegetation variables give a total score of 160, whereas variables describing bank and channel stability only have a weighting score of 40. Considering the importance of stream bed instability in structuring invertebrate communities (Scarsbrook and Townsend 1993; Biggs, Scarsbrook et al. 1997; Biggs, Duncan et al. 2001), it is surprising that there are only two habitat factors measuring this and that its weighting score is ¼ that of riparian vegetation. Its relevance to stream health at the reach scale in streams sampled as part of the NERMN Programme is therefore unknown.

Recommendation 22

Examine the existing habitat data collected as part of the Bay of Plenty NERMN sampling protocol and develop appropriate spreadsheets to allow this data to be electronically stored.

Recommendation 23

Compare and contrast the value of collecting quantitative data (up to 2005-2006) with categorical data (post 2006-2007) to see which is the most appropriate form to collect for future surveys.

Recommendation 24

Analyse both types of habitat data to see whether any relationships exist to the invertebrate data.

Recommendation 25

Finalise a new habitat data collection protocol for upcoming surveys, as well as create consistent Excel spreadsheets for all future habitat data to be entered into. Furthermore, investigate the possibility of using electronic data capture methods to minimise time in transcribing paper-based field sheets into Excel.

Part 11: Data entry/storage

A large proportion of time for this review was spent in data discovery, as well has combining the different datasets collected over time. The original data collected by Rob Donald was archived on the Bay of Plenty R: drive, and as such had little in the way of formal backup. This data was saved as individual years in separate Excel workbooks, although a combined workbook containing separate worksheets for each year from 1992 to 1995 was found. This data was saved in a typical "full matrix" format, with sites as columns, and species as rows. Species were denoted by usually a four letter abbreviation, where the first two letters represented a major taxonomic group (e.g. Trichoptera = TR; Ephemeroptera = EP), and the second two letters represented genera and species. A similar data matrix was used by Wilding from 1996 until 2000, with the exception that the full taxonomic name was used instead of species codes. As with the Donald data, all the Wilding data was simply saved on the R: drive.

A recurring problem with these two data sets was the fact that different numbers of species were found in each year, meaning that the order of taxa (as columns) can vary considerably between years. For example, the number of taxa from 1992 to 1995 varied from 47, 41, 54 and 61 respectively. This made it difficult to easily combine the datasets over this four-year period, as for example, column 13 in 1992 had different taxa to column 13 in 1995. Furthermore, there was inconsistent use of abbreviations in the early datasets, and inconsistent use of all taxa names in the latter datasets. Again, this presented problems when combining data between years, which is necessary when conducting long-term monitoring.

Post-2001, a totally new different set of sites were sampled, and these are stored in the Council’s Objective file storing system. The advantage with this is that it is in theory both discoverable, and recoverable: two essential characteristics of data, especially when considering its economic value. This data has been stored in the same format as before, namely a matrix of sample units (in this case a site and a date) and species. Some additional columns such as sample number, eco-region, landuse, and photo/sites location number have also been added. Quick examination of the data revealed many inconsistencies and inaccuracies that increased the difficulty of merging datasets. The most pronounced inconsistency was with the site information, where the same site often had more than one name, or spelling. For example, “Aongatete”, “Aongatete[space]”, and “Aongatete 14/12/04” are all fields describing the same site. Another problem with the data is that no specific date information had been given except for the year (e.g. 2003-2004). This meant that there will be no easy way to examine the data to filter out potential climatic events which may have happened on particular dates. For example, a large flood event may have occurred on 23 November 2003, which may have affected the results of any sampling done on 5 January 2004. Because there is no date information, future analyses done on historic data has no way of building in potentially useful information such as time since last flood.

An example of a better data storage system will include three individual worksheets:

1 the first worksheet gives information on site details. This includes a master site code, the site name, GPS Eastings and Northings, and potentially the REC reach number,

2 the second worksheet gives information on the samples collected at a site. This includes the master site code, date, whether replicate samples were collected, and can store information on the protocol used,

3 the third worksheet is a simple list of different animals found at a particular site. This will include the master site code, the names of individual taxa encountered, and a count value (either abundance, density, percentage, or coded abundance).

Any new samples collected in future years are simply added to these three worksheets, creating effectively very long thin files. Using a combination of the Excel functions "Pivot tables" and "VLookups", full data matrices are more easily created for future analyses.

Furthermore, any invertebrate samples collected by the BOPRC as part of consent or compliance work should also be saved into the same database, as it will increase the spatial coverage of sites sampled throughout the region. Unless data is both discoverable and accessible, there is little point in having it.

Recommendation 26

Ensure that a consistent terminology is adopted for entering sites names into an invertebrate dataset. Investigate the use of drop-down menus of site names to minimise spelling mistakes, or insertion of accidental characters.

Status

The current combined dataset has ensured consistency among site names. Use of predictive text or drop-down menus to be investigated at a later date.

Recommendation 27

Ensure that the sampling date is accurately and adequately recorded on both the individual sample container, and any dataset sheets associated with the sample, and this date information is entered into the appropriate database

Recommendation 28

Adopt a "single source of truth" taxonomic list of all taxonomic identities. Consider linking this list to the standard in NIWA taxonomic list, which in turn is linked to the New Zealand Organisms Registrar (NZOR) database currently being created by Landcare.

Status

All taxonomic identities identified by the NERMN invertebrate surveys have been made compatible with the NIWA Master taxonomic list.

Recommendation 29

Ensure that any new data entry be done in a more efficient and user-friendly format that avoids many of the pitfalls associated with a full data matrix format.

Recommendation 30

Consider utilising the Freshwater Biodata Information System (FBIS) database storage system currently being developed by NIWA. FBIS has been designed to house all of NIWAs freshwater biological data, and is designed for geospatial searches. It is also being developed to interrogate other databases held by other organisations such as regional councils and other consultancies via web service protocols so that end users can obtain data via the FBIS portal from multiple organisations. Liaise with NIWA as to the best way to ensure interoperability between any future Bay of Plenty invertebrate datasets, and FBIS. The benefit of this is that any data collected by NIWA as part of the National Water Quality Monitoring Network can easily and seamlessly be obtained from the Bay of Plenty region, and added to the existing data from the NERMN Programme.

Status

An Excel spreadsheet consisting of all invertebrate data collected as part of the NERMN sample protocol has now been created and has been saved in Objective. This could form the basis of any web service protocols developed by NIWA for FBIS.

Recommendation 31

Liaise with BOPRC consents and compliance staff to ensure that any invertebrate monitoring conducted by the Council, or for the Council, is entered into the appropriate spreadsheets in a consistent manner.

Part 12: Linking the NERMN Programme to Council's policy statements and plans, and ensuring feedback

There is a clear expectation under Section 35 (2)(b) and Section 35 (2A) of the RMA 1991 to monitor the effectiveness and efficiencies of Council policies, rules, or methods. State of Environment reporting is a key component of this. When developing monitoring programmes, local authorities should "*emphasise measuring indicators that enable assessment of Regional Policy Statement objectives and anticipated environmental results*" (Part 4, proposed Bay of Plenty RPS, November 2010). A central theme of the RMA is around the concept of sustainable management, and indeed councils own RPS and Regional Plans are all about promoting the sustainable management of the region's natural and physical resources.

The effectiveness of achieving sustainable management can be measured through frameworks such as the Pressure-State-Response (PSR) framework, based on the concept of causality; human activities exert pressures on the environment, altering the quality and quantity of environmental resources that lead to responses in human behaviour, which in turn are meant to minimise the magnitude of adverse effects (Figure 14). The OECD has suggested using this framework to measure sustainability, and MfE has also adopted this framework.

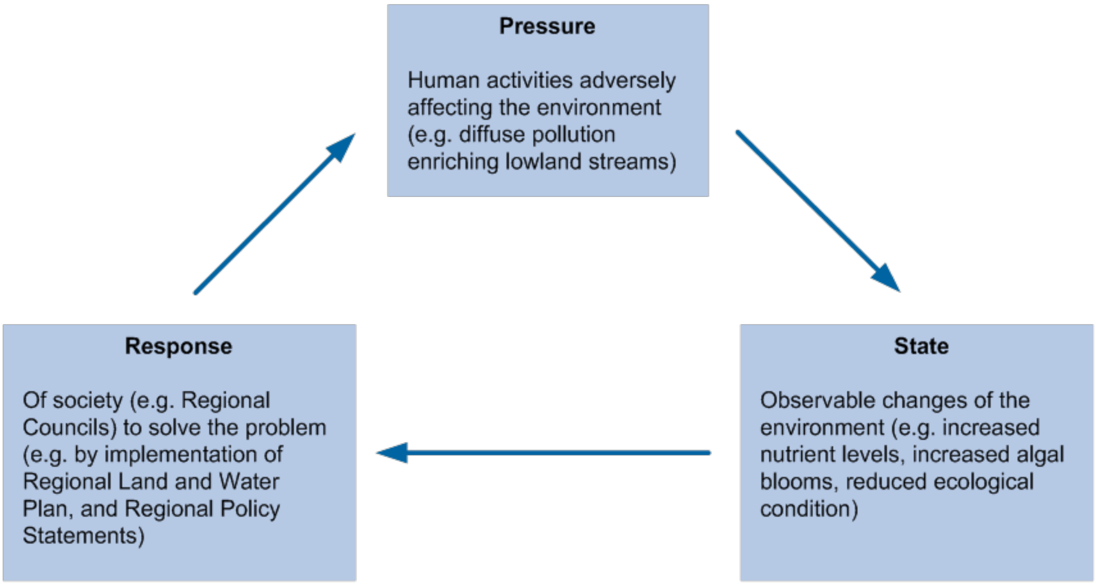

Figure 14 *Example of the pressure State response model that sets the framework under which councils are meant to operate to ensure reduced pressure on environmental services as a result of implementation of methods and rules.*

In this example, pressures are placed on surface waters as a result of landuse intensification, leading to increased nutrient run-off through diffuse non-point source pollution. The NERMN Invertebrate Monitoring Programme, as well as the Water Quality Programme, can assess the current state of surface waters throughout the region.

As part of the Council's RLWP and RPS, specific responses (i.e. rules and methods) are implemented to reduce environmental pressures. For example, Methods 24, 26 and 27 of the RWLP refer explicitly to the need for riparian planting, and Methods 36, 37 and 45 refer to reducing the potential for nutrient inputs into streams. Method 78 also explicitly states the need to monitor "*the effectiveness of riparian management and plantings on water quality and in stream biota using a programme that is consistent with national guidelines*".

The NERMN Invertebrate Monitoring Programme is able to assess the ecological health of waterways in the region over time. The results from this should, in theory, be able to detect if stream health is maintained throughout the region if the rules and methods developed by BOPRC are indeed having the desired effect. Moreover, there should, in theory, be an observable improvement to stream health as adverse effects of landuse intensification are minimised by implementation of the methods and rules. However, a central part of the PSR model relies on not only the ability to monitor the state of the environment, but also to quantify the extent to which methods and rules have been implemented. If we have no way of quantifying the extent to which the Council's methods and rules are being implemented, we have no way of being able to determine their effectiveness. For example, the NERMN monitoring may have shown that the ecological health of a particular stream may not be improving over time, or may be continuing to decline. Without knowing whether any riparian management activities have occurred in the catchment, or knowing about the spatial and temporal extent of these management activities, it is impossible to determine the cause of this continued decline. It is only with detailed information as to the spatial extent of riparian protection and how this has increased in stream length throughout the catchment, that the effects of riparian planting on stream health can be determined. If stream health increases, it suggests that the methods and rules are effective, whereas if stream health continues to decline, it suggests that another environmental parameter may be responsible for this decline. This will need to be identified, and steps taken to avoid, mitigate, or remedy any further adverse effects.

Indeed, this is specified in the regional plan, whereby Method 70 states:

"Use of the results of NERMN monitoring to assess the effects of land-use activities and changes in landuse patterns on surface water and groundwater quality and quantity. With regards to water quantity, climatic variations, re-vegetation and other natural events will be taken into account."

Although information on climate and river flow is relatively accessible, there needs to be clearly defined data source for activities such as catchment re-vegetation in order for this method is to be successfully implemented.

Recommendation 32

Better understand how the information generated by the NERMN Invertebrate Monitoring Programme is fed back to the planning and policy staff in Council to ensure that the efficiency and effectiveness of rules and methods in statutory documents are being met.

Recommendation 33

Liaise with the Council planning and policy staff, land management officers, and GIS staff to ensure that changes to environmental conditions as a result of implementation of methods (e.g. Method 70) and rules are quantifiable, measurable, and are recorded in a consistent manner, and which is easily discoverable. It is only by providing this data can future analyses assessing the effectiveness of Council methods and rules be made.

Recommendation 34

Ensure that the current monitoring strategy meets the needs of the land management officers, policy analysts, and planners to ensure that the effectiveness of their methods and rules are measured.

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Appendices

Appendix 1 – Invertebrate processing protocol (2003-2011)

The following Memo was written by Matt Bloxham (BOPRC's Ecologist from 2003-2011) outlining the process that the summer students used each year for the annual SoE invertebrate monitoring survey.

Important point: Many of the animals we are dealing with in this region are small and once they have been in alcohol for a while are very brittle and easily broken (legless and tailless specimens are difficult to identify and headless ones cannot be used). So the emphasis through this entire process should be on thoroughness (so we don't miss the smallies) and a tender touch (so we don't damage the brittlies).

1 Take a sample over to the sink and carefully empty contents into a half millimetre mesh sieve (making sure all animals are transferred, you can rinse the jar to ensure they are transferred).

2 Now gently rinse the sample with flowing water (the idea is we are trying to rinse out any remaining alcohol and some of the fine particulate to make sorting easier).

3 If there are still large leaves or sticks left in the sample, this is a good opportunity to carefully rinse anything clinging to them into the sieve and discard.

4 Now transfer the sieve contents into one of those large white trays with the grids, being careful to insure all insects left in the sieve are transferred to the tray (you may use a pair of tweezers or a paint brush to help transfer insects from the sieve to the tray).

5 Now add a little water to the tray, not so they are absolutely swimming but enough to cover the samples and prevent them from drying out.

6 Make sure the contents are evenly distributed across all the grids in the tray (this is quite important).

7 General: What we want to do now is extract approximately 300 animals from the tray in a random fashion. We do this by randomly picking the grids (using the random number sheet) and carefully extracting all the animals from each grid. You should use one of those bright desk lamps to illuminate the sample and to prevent you from straining your peepers. There is also a flimsy wee square you could use to help better define your square and the samples within, whatever works best for you.

8 How do we do it: Take a random number sheet and pick a row of numbers (start from the top if you wish and work your way down). Use the first number to find your first location on the tray e.g. "B4".

9 Once you have moved to the first numbered square on the tray grid, remove all the animals from that square (keep a count of the animals extracted using one of those clicker counters as you go, i.e. you will count every animal transferred to the vial for the entire random grid search) and place these into a vial (filled two thirds full with 70% alcohol).

10 Once you have removed all the animals from the square, select your next random number (next row down) and move to that square and repeat the process. You will keep doing this until your clicker says you have removed 300 animals, though often you will go over 300 as the last square (which again you will remove all animals from) will often take your total number to well over 300.

11 Now scour the remaining contents of the tray for any unusual invertebrates that you have not already encountered in the random grid search and place these into a separate vial (you won't need to count these but you will need to label these as fully as the random search vial).

12 On waterproof paper, include all the information you need to enable the person identifying the invertebrates to trace it back to an exact site. You will for example include information on the total number of insects counted (in the main vial), the site number, the sample number, the type of sample (DNS = dip net soft substrate, and DNH = dip net hard substrate), the date and of course the site name. If you use more than two vials, you should also add "one of three vials" etc.

13 Complete the sample register and move on to your next sample.

14 We will only collect invertebrate samples if there have been no significant rainfall events leading up to the sample. The general rule of thumb is that if rainfall exceeds median flows for that stream by three times, then one should wait for between 4-6 weeks for invertebrates to re-colonise a stream before it is sampled.