Introduction to periphyton monitoring in freshwater ecosystems

Version 1.0

This introduction was prepared by Duncan Gray in 2013.

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Introduction

What is periphyton?

The periphyton community is the slimy coating that adheres to rocks and other stable substrates that comprise the stream bed. The community is made up of variable proportions of algae, fungi and bacteria as well as organic matter entrained from stream flow. The appearance of the periphyton layer can vary greatly and provides a lot of basic information about conditions within the stream. Moreover, periphyton is a fundamental component of the stream ecosystem purifying waters by absorption of metals and nutrients, and providing a significant component of the food resource to the stream food web. Correspondingly, the periphyton community is highly responsive to degradation of water quality, shifts in invertebrate consumer communities and the occurrence of floods with sufficient energy to slough algal growths. High levels of periphyton cover can have detrimental effects on stream biodiversity, trout and recreational use of waterways. Biggs & Kilroy (2000) define these nuisance growths of periphyton and provide thresholds to be avoided in resource consents and regional plans.

Periphyton community types

The species and morphologies of periphyton that are common in New Zealand streams are reasonably well understood. An in-depth discussion is beyond the scope of this protocol, but an accessible, yet comprehensive review of taxa and communities is provided by Biggs (2000a) and Biggs & Kilroy (2004). The two most common morphologies of periphyton likely to be encountered in New Zealand streams are diatoms and filamentous algae which may be readily divided according to colour and thickness/length for mats and filaments, respectively. Taxonomic surveys are possible in New Zealand, but require considerable resources, such as laboratory equipment for analysis and trained personnel (see 'Periphyton taxonomic sampling and identification'–docdm-784937). A complete review of available methods suitable for New Zealand streams can be found in Biggs (2000b).

Applications of periphyton monitoring

Periphyton sampling programmes may be used to address a number of different objectives in New Zealand streams. Inventory or resource surveys may be performed to establish general patterns in periphyton biomass or composition. This data can be applied in the ranking of conservation values of sites or comparisons of broadscale effects of land use or flow regime change. Objectives concerned with more local-scale, impact-specific effects such as the influence of restoration projects or effects of concessions on the public estate, such as mining, can also be addressed. The incursion of *Didymosphenia geminata* throughout the South Island and risk of further spread has led to a substantial increase in Didymo detection in the periphyton monitoring being conducted by DOC. More detailed monitoring of Didymo biomass to improve our understanding of its ecological effects and management implications are a further application of periphyton monitoring. Periphyton

communities can provide an effective time-integrated measure of many impacts on stream ecosystems, indicative of not only conditions at the time of sampling, but also reflecting conditions over the past weeks or months. To achieve this, clear objectives must be identified from the outset and applied in the design of an efficient sampling programme.

Primary influences on the periphyton community

Streams and rivers are regulated by a hierarchy of factors that ultimately determine the communities observed at any point in space and time (Hynes 1975; Allan & Castillo 2007). Broadly, climate, geology and human activities dictate the morphology, hydrology and physico-chemistry of stream reaches, which regulate the fundamental controllers of local stream habitats such as velocity and nutrients (Biggs 2000b). Local periphyton communities can also be influenced by grazing invertebrates, but these in turn are regulated by the hierarchical physical environment. Essentially, at any location the periphyton community will reflect the battle between forces of growth: light and nutrients; and those of loss: physical disturbance and invertebrate grazing (Biggs & Kilroy 2004).

Promoting growth

Light is a fundamental factor affecting periphyton growth, although light levels need to be unusually low before they limit growth. Most stream periphyton communities will not be limited by light until shading reaches 60% (Quinn et al. 1997). Nutrient levels, particularly nitrogen (N) and phosphorus (P), tend to be primary limiting factors for periphyton growth. Levels of these nutrients are naturally regulated by the geology of a catchment; for example, recent volcanic rocks contribute nutrients to stream waters, but of more concern is the influence of land use intensification (Biggs & Kilroy 2004). Given adequate light and nutrients, periphyton growth may be prolific and reach nuisance levels very rapidly. However, usually either N or P availability limits growth and water managers need to understand the nutrient flux or supply to streams and regulate changes in land use to prevent excessive growth. Water chemistry testing is a routine method to assess nutrient limitations and loadings, but it should be noted that nutrient concentrations may be highly variable over time and interact with periphyton biomass such that low nutrient concentrations may be a direct result of high periphyton growth rates. A useful characterisation of the nutrient status of a stream in relation to periphyton should include data collected at least monthly over a year and analysed in conjunction with discharge records (Biggs & Kilroy 2004).

Loss of biomass

Grazing by invertebrates in New Zealand streams has a potentially significant influence on the composition and proliferation of periphyton communities, depending on the flow regime of the stream in question (Fig. 1). Stable streams such as springs or lake outlets tend to have invertebrate communities dominated by snails, such as *Potamopyrgus antipodarum,* which are replaced as disturbance levels increase by caddis and finally mayflies (Sagar 1986; Scarsbrook & Townsend 1993). Snails appear to be more aggressive grazers than caddisflies, and in turn mayflies, such that physical disturbance creates a gradient in invertebrate grazing pressure (Biggs, Stevenson et al. 1998). If all other conditions were constant it might be predicted that the interaction of grazing and

disturbance would maintain periphyton at similar levels in all streams; however, as with all natural systems there are important lag times and further factors to consider. For example, periphyton may accumulate rapidly in some gravel bed streams where the invertebrate community has not yet recovered from a catastrophic flood event (Sagar 1986). Similarly, if some form of pollution prevents the colonisation of invertebrates, even in stable environments, periphyton proliferation may proceed rapidly to nuisance levels where it might otherwise have been checked by invertebrates.

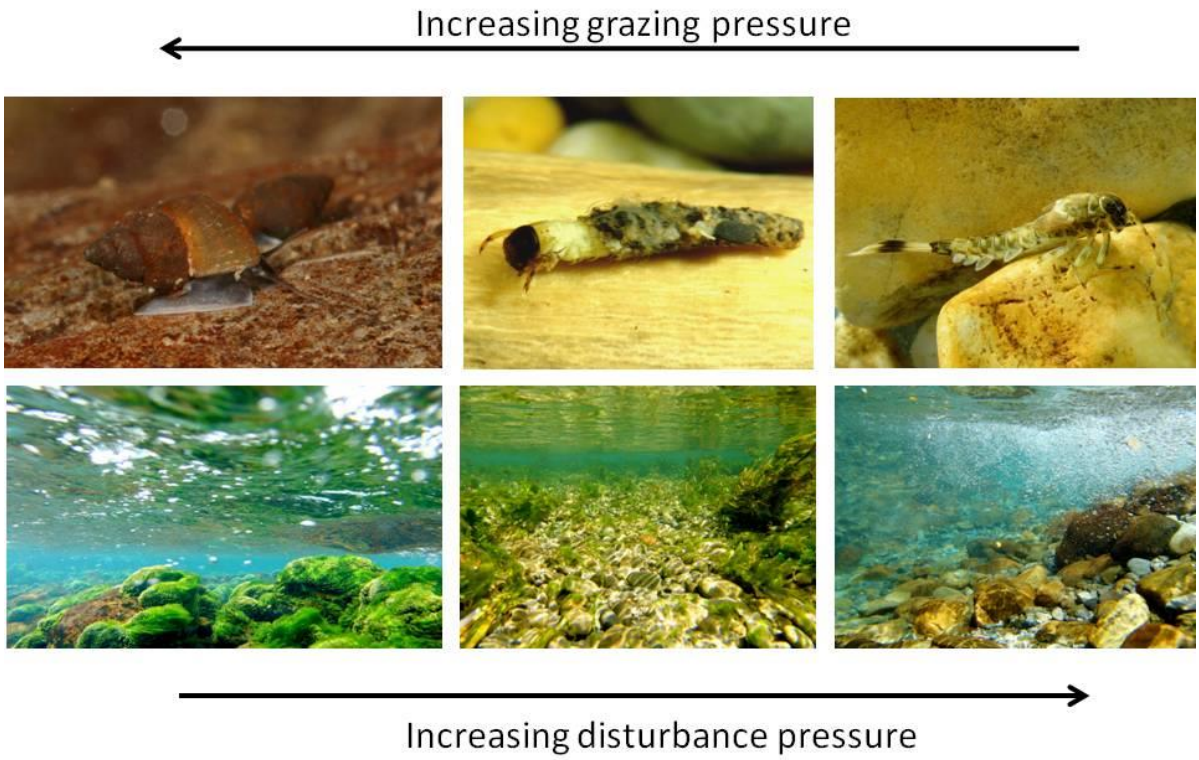


Figure 1. The opposing forces of disturbance pressure from flooding and grazing by invertebrates contributes to the regulation of periphyton communities in many streams. Top panel from left to right: the snail, *Potamoprygus antipodarum*; cased caddis *Pycnocentrodes* sp.; and grazing mayfly *Nesameletus* sp. Bottom panel from left to right: typical stream bed scene from a stable spring-fed stream; intermediately disturbed lowland stream bed; and highly disturbed alpine river. Photos: Jens Zollhoeffer.

In most of New Zealand's rivers and streams the hydrological regime sets the primary template for periphyton growth. Severe disturbance by floods reduces periphyton biomass by instigating sloughing of individual growths from the substrate, abrasion by suspended particles and, at greater flows, movement of the substrate itself. Long-term discharge monitoring by regional councils and the National Institute of Water and Atmospheric Research (NIWA) (and its predecessors) has allowed rivers to be characterised according to the magnitude and regularity of flood events (and many other features of flow). Several studies have found a strong relationship between flooding and periphyton biomass (Biggs & Close 1989; Biggs 2000a). Each periphyton community is adapted to the antecedent (preceding) flow regime to which it has been exposed; thus communities in regularly

flooding rivers tend to be a low-growing abrasion-resistant form as opposed to those longer, less adherent forms which occur in stable streams subject to minimal flooding. Therefore, it is not only the velocity of flow in a flood which is of particular importance, but the flood magnitude and velocity relative to previous floods (Biggs & Kilroy 2004).

Various methods have been developed to describe relative flood magnitude, such as that required to generate a specific threshold velocity or the stream-specific magnitude required to move a percentage of bed substrates. However, the frequency of flooding events is also important and these two factors—relative magnitude and frequency—are elegantly combined in the FRE suite of metrics. FRE or frequency is always followed by a number representing the degree by which the current flow exceeds the median flow, thus FRE3 refers to the annual frequency of flows which exceed three times the median flow of any river. A low FRE3 number indicates a stable flow regime with few floods, such as the lake/spring-fed Tarawera River, Bay of Plenty, which experiences an annual average FRE3 of zero. A high number indicates a flashy hydrological regime, such as the alpine-sourced Hokitika River, with a FRE3 of 18.7.

The FRE3 statistic has been shown to be related to both periphyton and invertebrates across a number of New Zealand streams (Clausen & Biggs 1997). Three times the median flow may therefore be considered an ecologically relevant indicator of flood disturbance, although the actual magnitude of flood disturbance required to slough algae will vary amongst rivers, depending on factors such as channel gradient, substrate size and preceding flow conditions. Thus, depending on preceding conditions, flows less than three times median may also be ecologically significant.

The time since the last FRE3 event is also of interest. This accrual period between floods may be related to periphyton biomass on specific dates and also used to predict biomass for a river of known hydrological regime and nutrient status (Biggs 2000b). Figure 2 illustrates the general relationship between nutrients and accrual period in relation to maximum biomass criteria for the protection of benthic diversity (50 mg/m^2) and trout angling/habitat (200 mg/m^2) in New Zealand streams.

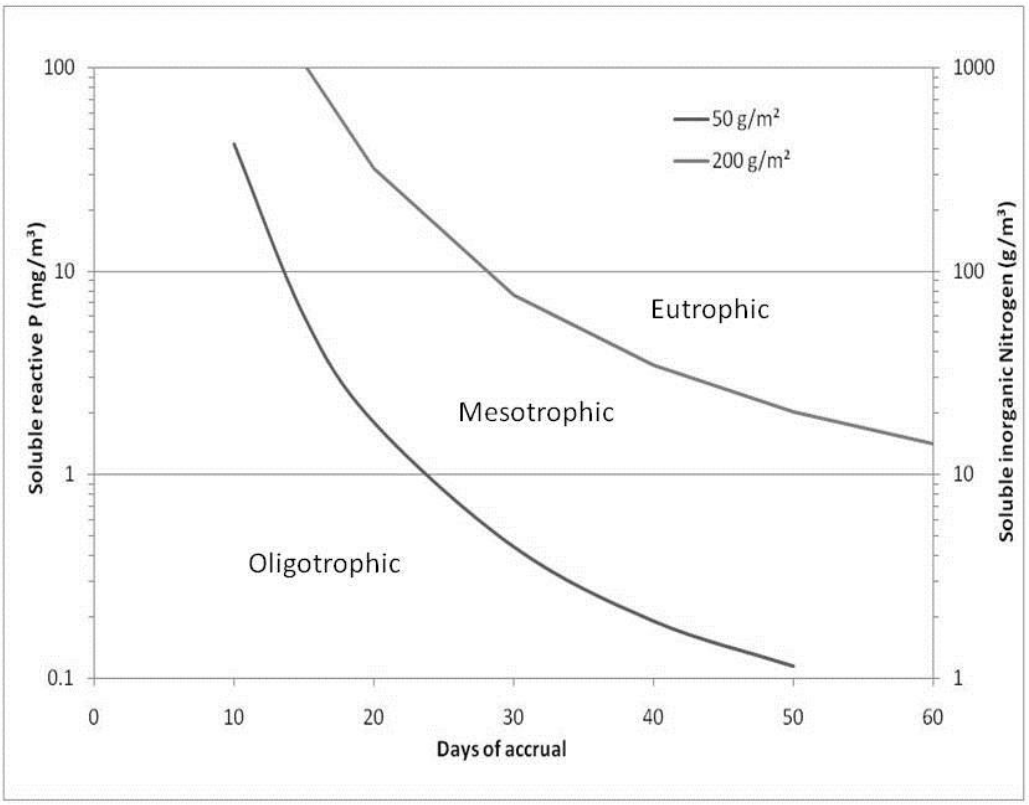


Figure 2. Mean monthly soluble nutrient concentrations (P and N) predicted to result in maximum benthic algal biomass in a gravel/cobble-bed stream for varying days of accrual, from Biggs (2000a). Boundaries and trophic status equate to maximum biomass criteria for the protection of benthic diversity (50 g/m^2) and trout angling/habitat (200 g/m^2) in New Zealand streams. The accrual period is generally calculated as times since 3× median flow event (Clausen & Biggs 1997).

Overall, despite the various factors which combine to regulate periphyton growth at any point and time it has been shown to be sufficient to characterise a system according to disturbance and nutrients. This is a particularly useful approach for monitoring the outcomes of management intervention as these two factors are often those readily impacted by human activities.

Nuisance growths and guidelines

A number of stream resources and ecosystem services can be compromised by proliferation of periphyton (Table 1). These events tend to be sporadic and dictated by the occurrence of low flows, but, while subjective values like angler enjoyment or aesthetics are difficult to quantify, these values and other more accepted uses such as irrigation that may be compromised by periphyton growth will continue to compete with increasing intensity for remaining water resources.

Table 1. Instream values that may be compromised by proliferations of periphyton (from Biggs 2000b).

Instream value	Issue
Aesthetics	Degradation of scenery, odour problems
Biodiversity	Loss of sensitive invertebrate taxa through habitat alteration, possible reduction in benthic biodiversity
Contact recreation	Impairment of swimming, odour problems, dangerous for wading
Industrial use	Taste and odour problems
Irrigation	Clogging intakes
Monitoring structures	Fouling of sensor surfaces, interferes with flow
Potable supply	Taste and odour problems, clogging intakes
Native fish conservation	Impairment of spawning and living habitat
Stock and domestic animal health	Toxic blooms of cyanobacteria
Trout habitats/angling	Reduction in fish activity/populations, fouling lures, dangerous for wading
Waste assimilation	Reduces stream flow, reduces ability to absorb ammonia, reduces ability to process organics without depletion of DO
Water quality	Increased suspended detritus, interstitial anoxia in the stream bed, increased ammonia toxicity, very high pH
Whitebait fishing	Clogging nets

Biggs (2000b) suggests limits for periphyton growth in relation to amenity values (a combination of contact recreation and aesthetics), biodiversity and trout angling/habitat. Beyond these limits periphyton biomass is defined as a nuisance growth, which is a condition to be avoided if possible. Whilst regarded as provisional, these guidelines and thresholds are in common usage in New Zealand, although in some places they are superseded by plans and regulations reflecting specific local conditions and needs. Guidelines usually present both a periphyton cover and biomass threshold to allow for variation in study format; cover data is quicker and cheaper to collect allowing greater spatial coverage while biomass data requires greater time and resources, but provides a higher resolution data set. The Inventory and Monitoring Toolbox provides protocols to suit both scenarios. Periphyton communities are also divided into mat-forming communities and filamentous taxa.

Table 2. Biomass and cover guidelines for periphyton growths in gravel/cobble-bed streams for three primary instream values. Note: Regional differences in thresholds may have been established since the publication of Biggs (2000b). Always consult the most recent regional plans or regulations. (AFDM = ash-free dry mass)

Instream value/variable	Diatoms/Cyanobacteria	Filamentous algae
Aesthetics/recreation (1 November–30 April)		
Maximum cover of visible stream bed	60% > 0.3 cm thick	30% > 2 cm long
Maximum AFDM (g/m^2)	N/A	35
Maximum chlorophyll *a* (mg/m^2)	N/A	120
Benthic biodiversity		
Mean monthly chlorophyll *a* (mg/m^2)	15	15
Maximum chlorophyll *a* (mg/m^2)	50	50
Trout angling and habitat		
Maximum cover of whole stream bed	N/A	30% > 2 cm long
Maximum AFDM (g/m^2)	35	35
Maximum chlorophyll *a* (mg/m^2)	200	120

Sampling design and techniques

Your objectives

The efficacy of any monitoring programme will depend upon the design and resolution of your sampling. Well-defined objectives are essential in designing an appropriate sampling regime. Biggs & Kilroy (2000) list the main areas to be considered (see below); however, study design is often an iterative process whereby these various factors must be balanced against each other and different study designs compared to give the desired outcomes.

- Where to sample
- How often to sample
- Variables to measure
- Sampling methods and replication
- Study budget
- Approaches to data analysis
- Reporting milestones and formats

Completion of a ‘Standard inventory and monitoring project plan’ (docdm-146272) will guide DOC staff through this design process. General information about principals of sample design is provided in ‘A guideline to monitoring populations’ (docdm-870579). In general, a periphyton monitoring

study design will focus on either a spatially widespread or locally intensive issue. Spatially widespread sampling covers a broad temporal/spatial scale and many different streams and rivers. Accordingly, there may be a compromise in the resolution (closely related to cost) of data collected. In contrast, a locally intensive study seeks to detect patterns in periphyton at smaller spatial or shorter temporal scales. These studies often require high-resolution quantitative data which is more labour- and resource-intensive to collect. Inventory or resource surveys tend to fall into the former category and require rapid qualitative protocols, whereas the efficacy of a restoration project or effect of concessions on the public estate, such as mining, require intensive quantitative protocols, and could possibly be designed around detecting certain forms of periphyton communities that thrive under acid mine drainage conditions. The first decision to make is the appropriate scale of your investigation and the scales at which influential factors may be operating. This will aid greatly in answering several of the questions above.

Where and when to sample?

Again the answer to this question is intimately tied to the monitoring objective. Sample site location is strongly dictated by the opposing forces of data requirements and available budget. Basic requirements are for an impacted/monitoring site and at the very least a single reference (or control) site with which to compare. A reference (or control) site is considered to be unaffected by the impact under consideration, be that a discharge or the legacy of 150 years of agriculture. A common design is to compare sites that are upstream (reference) and downstream (impact) of a discharge or other source of impact. In the upstream–downstream example, a second (or third) upstream site may be added to estimate variation between the reference sites, whilst further downstream sites may be added to measure the extent of the impact. In order to assess differences in water quality it is essential that all sites are as physically similar as possible (substrate types, shading, flow and stream dimensions) so that confounding effects on periphyton communities are minimised or eliminated. A final reference site is often selected on an adjacent, or nearby un-impacted stream, and used to assess the condition of the entire study stream relative to regional stream conditions and communities. Alternatively, in a broadscale assessment of enrichment or other impact status of streams you will want to sample as many streams as possible throughout your region. The number and location of sites sampled will be dictated by resources available.

Once site locations and number have been established it is important to consider the meso-scale habitat characteristics you want to include. Stream ecologists tend to characterise streams and rivers by the relative amount of run, riffle or pool that occur at the sampling sites (Fig. 3). This is an important consideration when comparing biotic communities between two or more sites. In hard-bottomed streams, riffle habitats are often common, easily recognisable and biologically productive habitats that can be sampled safely even in larger rivers. However, in soft-bottomed streams riffle habitats may be rare or absent. A riffle is defined as an area of fast ‘whitewater’, usually associated with a constriction in the channel and where stony or wood substrate may occur above the surface. Conversely, a pool is an area of slow-flowing or standing water, not including the ‘whitewater’, usually at the base of a riffle. This is the deepest habitat in a river. Intermediate between pools and riffles are runs. These areas are characterised by laminar flow with a mostly unbroken surface. The most important criterion is that habitat characteristics are standardised across your sampling sites.

Biggs & Kilroy (2000) suggest that periphyton samples should most commonly be collected from 'runs' which are less prone to scour.

Figure 3. From left to right: typical riffle, run, and pool (grading into riffle) habitat.

As we have seen, one of the primary determinants of periphyton cover and biomass is antecedent flow. Floods, in particular those which mobilise bed material, scour periphyton away from the substrate and several weeks of stable flows may be required for periphyton communities to regain the biomass and taxa diversity observed prior to the flood (Sagar 1986; Biggs 2000b). Accordingly, sampling should only occur after at least 4 weeks of stable flows have elapsed since the last bed-mobilising flood, at or beyond five times the average flow for the week prior to that flood. This information can ideally be sourced from regional council databases or (though less desirable) anecdotal observations and rainfall records. However, this may not be possible in very flood-prone rivers or during particularly wet years, in which case careful examination of the hydrograph, when available, and weather predictions will be required to ensure sampling occurs following a relatively stable period. At the very least, discharge patterns over the preceding month should be noted or described alongside your periphyton monitoring data.

How often to sample?

Sampling frequency may also be a consideration depending upon the monitoring objectives. Periphyton communities are highly dependent on flow regime, nutrients, light and invertebrate gazing pressure. If the study focus is on nuisance proliferations, sampling occasions should coincide with the conditions that promote high biomass; often the low flow period in high summer. However, if the potential issue being assessed is the impact of year-round flow regulation (e.g. associated with a hydro-electric dam), then year-round sampling will be required. The interaction between periphyton and an endangered species such as blue duck (whio) might require sampling at a time of year associated with an important life cycle stage, such as the breeding season. Detection of linkages between biomass shifts and environmental variables requires multiple samples of periphyton over the developmental trajectory of the bloom. Conversely, broadscale relationships between flow, nutrients and periphyton growths may be described using single occasion sampling from multiple sites.

Which variables to measure?

The method of measuring your response variable, the periphyton, is dictated by your study objectives and available resources and is discussed in detail below. Alongside periphyton data it is important to collect environmental and habitat information in order to prove that your sampling locations are comparable and investigate the causes behind any patterns you may identify. Habitat assessment alongside periphyton collection is an integral part of any monitoring programme. The alteration of the physical structure of habitats is one of the major factors from human activities that degrade aquatic resources; instream and surrounding topographical features are a major determinant of aquatic communities. Both the quality and quantity of available habitat affect the structure and composition of periphyton communities. Effects of such features on biological assessment results can be minimised by sampling similar habitats at all sites being compared. However, when all sites are not physically comparable, habitat characterisation is particularly important for proper interpretation of survey results. Harding et al. (2009) provide a comprehensive guide and protocols for habitat assessment in wadeable New Zealand stream and rivers.[1] A minimum requirement habitat assessment field sheet is provided with these protocols (see 'Stream habitat assessment field sheet'—docdm-761873).

The primary determinants of periphyton biomass growth are accrual period and nutrients (Fig. 2); this information is of particular importance to any study. Additionally, an assessment of periphyton taxonomic diversity would also benefit from measures of water chemistry other than nutrients, such as silica or calcium concentrations. Design your sampling regime according to your objectives and always consult an experienced freshwater ecologist during the design stage.

Sampling methods and replication

Choice of monitoring method will be dictated by your study objectives and available resources. Refer to the 'Decision tree' for a guide to the most appropriate method for your objectives. The protocols provided here are based on those of Biggs & Kilroy (2000) and describe methods for rapid, qualitative assessment of communities and more intensive, quantitative sampling. 'Freshwater ecology: periphyton rapid assessment monitoring in streams—method 1 (RAM-1)' (docdm-769146) is appropriate to assess compliance with periphyton guidelines for aesthetic, recreational and fishing values (Table 2) and involves a replicated visual assessment of the percentage of long filamentous algae. 'Freshwater ecology: periphyton rapid assessment monitoring in streams—method 2 (RAM-2)' (docdm-769150) includes more detail about the periphyton community by visually estimating the proportional cover of 12 periphyton types on replicate rocks and can be used to assess degrees of general nutrient enrichment and water quality.

When greater sensitivity to detect change or differences in periphyton biomass is required, e.g. the effects of specific discharge or change to a flow regime, a quantitative protocol should be used. Two methods based on those recommended by Biggs & Kilroy (2000) are described in 'Freshwater

[1] http://www.cawthron.org.nz/coastal-freshwater-resources/downloads/stream-habitat-assessment-protocols.pdf

ecology: quantitative periphyton biomass sampling methods' (docdm-766000). Both involve collecting periphyton from replicate rocks, but differ in the manner of collection. Method 1a involves sampling whole stones which provides data on the whole community, on the upper and lower surface of the stone. Generally speaking, there will be little difference among sampled communities in fine gravel substrates, but heterogeneity will increase with substrate size. Biggs & Kilroy suggest this method is most appropriate for broad surveys of enrichment or periphyton biomass. Data are expressed in terms of surface area of exposed sediments. Method 1b involves collecting periphyton only from the upper surface of stones which reduces any effects of spatial variations in water velocity, light availability or invertebrate grazing associated with the undersides of stone. This method is commonly used to assess the effects of pollution, and data is expressed in terms of plane surface area (actual flat area, as opposed to area of substrate surfaces) of the stream bed.

Taxonomic surveys are also possible in New Zealand, but require considerable resources, such as laboratory equipment for analysis and trained personnel (see 'Freshwater ecology: periphyton taxonomic sampling and identification'—docdm-784937). A complete review of available methods suitable for New Zealand streams can be found in Biggs (2000b).

Within-site sample replication is an important consideration, but may have to be adjusted in the field. During RAM sampling it is standard practice to collect data at 10 points along each of 10 transects; however, the number of points within each transect may be reduced to 5 if periphyton cover proves to be highly homogenous. During quantitative sampling it is standard practice to collect 10 samples along a single transect due to the increased cost of sample processing (Biggs & Kilroy 2000). At all times be aware of the level of apparent variability within and between your sites. When variation is high, increase your replication, but note that it is best to replicate equally at every site.

Study budgets

Financial and resource issues are one of the major constraints to any sampling programme. As well as the fixed costs of planning, study design, interpretation and results write-up, the basic unit of cost is the approximate price of each sample or site. This cost should include the staff time required to collect each additional sample in the field, extra travel time needed to visit more sites, and the costs of laboratory analysis and any disposable equipment required. Once the cost of samples and an approximate budget is known, it is possible to calculate how many samples can be collected and explore options for increasing either replication (collecting more samples or visiting more sites) or resolution (collecting a finer level of detail within each sample or site).

Approaches to data analysis

Consult a biometrician or experienced ecologist about data analysis during the design and analysis stages of your study. Necessary statistical skills should be identified during project planning and appropriate advice or training sought on their use. Training in data handling and analysis is available through the DOC Training Booking System. Sometimes it may be necessary to contract people with the necessary skills to do more complex analyses. However, basic analyses can be

readily performed using Excel and R. Useful references for statistical analysis include Quinn & Keough (2002) and Zar (1999).

The first step is to carefully inspect your data. Calculate simple metrics that distil the community into understandable components, e.g. biomass per unit area, morphotype or taxonomic richness or a stream health indicator score (Biggs, Kilroy et al. 1998), and plot the results in graphical form. The analytical method used will be dictated by the objectives of the study. Are you comparing between groups of treatments or looking for trends in communities arranged along a spatio-temporal gradient? Analysis of variance (ANOVA) is used to look for differences among 'treatments'. Treatments might be samples collected before or after an alteration to the flow regime, or up and downstream of a discharge or some experimental manipulation. ANOVA makes a variety of assumptions about the nature of the data which must be met for the results to be valid. Correlation and linear regression analyses are used to test for statistical significance of incremental responses along an environmental gradient; for instance, comparing the biomass of periphyton from 20 streams with varying degrees of nutrient enrichment. More information about analysis considerations is provided in the section 'Design and implementation framework' in 'A guideline to monitoring populations' (docdm-870579).

Reporting

The final stage of any study is the report; an un-reported study may as well not have occurred. Scientific writing tends to have a very standard format although this may be altered for a specific audience. Depending on the monitoring objective, it may be necessary to create both a formal written report and a less formal presentation to communicate findings to a wider audience of stakeholders and community members. A fundamental reporting requirement is to state the monitoring objectives, describe how you addressed these objectives and present your findings in the context of those objectives. Reports may also include re-evaluation of the monitoring programme (objectives, design, field methods, etc.) and recommendations for improvements. More information about reporting tools is provided in 'A guideline to monitoring populations' (docdm-870579).

Didymosphenia geminata (didymo)

The non-native and highly invasive alga didymo was first detected in the Waiau River, Southland, New Zealand in October 2004. Subsequently, it has been detected in numerous other rivers in the South Island but has yet to be detected in North Island waterways (as at June 2013; see the Ministry for Primary Industries (MPI) didymo webpage[2] for more background information about didymo). In suitable conditions didymo forms thick mats that may clothe significant portions of stream bed (Kilroy et al. 2005). Long-term effects of didymo on the stream ecosystems of New Zealand are still unknown; however, the aesthetic and recreational impacts can be considerable. Didymo is capable of rapidly overwhelming the existing periphyton community. Didymo cell division rates may be nutrient-limited in some streams suggesting that cells can be incorporated with other periphyton types in assessment of enrichment. Nevertheless, caution should be applied as didymo blooms (that are the result of stalk

[2] http://www.biosecurity.govt.nz/pests/didymo

elongation—cells are attached at the tip of these stalks) appear to be dependent on cold, clear, well-oxygenated and extremely low-in-phosphorus water (Kilroy & Bothwell 2011; Bothwell & Kilroy 2011, 2012).

As such, didymo biomass increase may indicate either an improvement or decline in water quality depending on the starting conditions. Didymo appears to proliferate in lake-fed or regulated rivers; this should be borne in mind when considering the potential impacts of flow regulation on rivers where didymo is currently present, but not at nuisance levels because of naturally high flood disturbance.

When undertaking water sampling for didymo, specific sampling protocols should be applied.[3]

Figure 3. Left: mature growths of didymo adhere to benthic substrates. Right: Didymo covers the bed of the upper Buller River, Westland. Photos: Jens Zollhoeffer.

Decision tree

This introduction should enable you to navigate the decision tree and decide upon the appropriate sampling and laboratory regime for your objectives. DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272) which outlines the objectives of your study and the protocols you have chosen to address those objectives. This plan should be peer-reviewed by a TSO or science officer to confirm your choices. Essentially, the choice is between methods which estimate coverage versus those that measure biomass or taxonomic composition. Cover data is adequate for the consideration of aesthetic or recreational effects, particularly if resources are limited and periphyton is only one aspect of the study. However, quantitative biomass or taxonomic-based methods should be used in situations where you wish to quantify the impacts of a particular activity on periphyton communities—be it the impact of acid-mine drainage from coal mining, or the

[3] See http://www.biosecurity.govt.nz/pests/didymo/protocols
The didymo samples analysis protocol is available at:
http://www.biosecurity.govt.nz/files/pests/didymo/didymo-protocol-sampling-micro-analysis-sep-07.pdf
There are also a number of other protocols as well in regards to analysing a sample. In the South Island, microscopic analysis is carried out, while in the North Island, microscopic and DNA analysis is done.

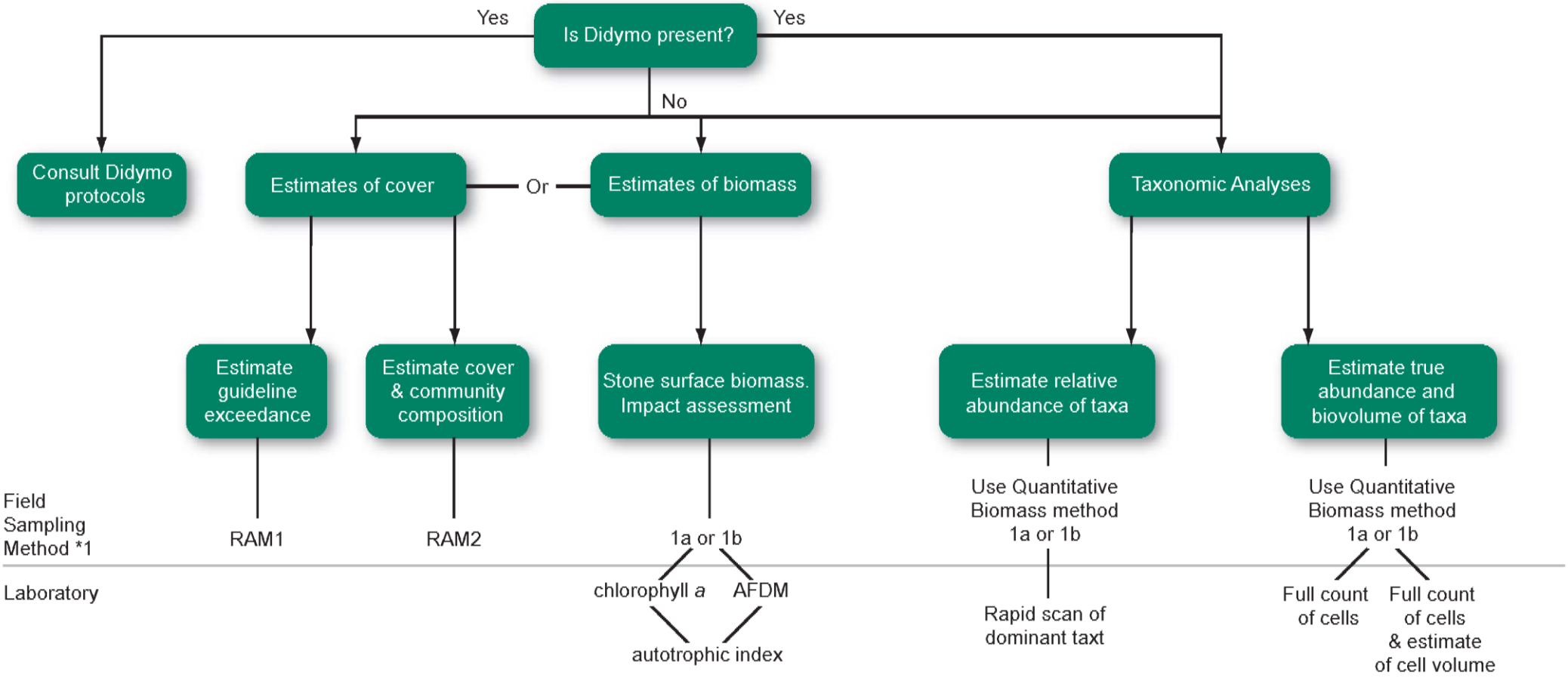
impacts of riparian planting and increased shade on stream communities. Even if quantitative biomass sampling is undertaken, you should still make notes on periphyton cover and composition, so that your laboratory results can be cross-checked and so you can determine whether the biomass/community was composed mostly of long filaments versus mats or films.

The methods for periphyton monitoring in freshwater ecosystems are:

- Freshwater ecology: periphyton rapid assessment monitoring in streams—method 1 (RAM-1) (docdm-769146)
- Freshwater ecology: periphyton rapid assessment monitoring in streams—method 2 (RAM-2) (docdm-769150)
- Freshwater ecology: quantitative periphyton biomass sampling methods (docdm-766000)
- Freshwater ecology: periphyton taxonomic sampling and identification (docdm-784937)

If in doubt it is better to collect more information in the field and not process it, than to have an initial data set that is inadequate to address your objectives.

Decision tree for periphyton monitoring in freshwater ecosystems



Resources/ resolution	High replication	Low replication	Low replication	Low replication
	Low resolution	High resolution	High resolution	Very high resolution
	Low cost per sample	High cost per sample	High cost per sample	Very high cost per sample
Data	Qualitative	Quantitative	Quantitative	Quantitative

*1 A bare minimum habitat assessment should be carried out at every site (see '[Stream habitat assessment field sheet]'—docdm-761873).

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Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-769146	Freshwater ecology: periphyton rapid assessment monitoring in streams—method 1 (RAM-1)
docdm-769150	Freshwater ecology: periphyton rapid assessment monitoring in streams—method 2 (RAM-2)
docdm-784937	Freshwater ecology: periphyton taxonomic sampling and identification
docdm-766000	Freshwater ecology: quantitative periphyton biomass sampling methods
docdm-870579	A guideline to monitoring populations
docdm-146272	Standard inventory and monitoring project plan
docdm-761873	Stream habitat assessment field sheet