Didymo in Otago: A Summary

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Executive Summary

Didymosphenia geminata (Didymo) was initially discovered in New Zealand in October 2004, with the first recorded Didymo incursion into Otago occurring in the Hawea River in September 2005. Didymo is now present in nine unregulated rivers, six regulated rivers and three lakes within the Otago region.

Didymo infestations have a negative impact on the aesthetic values of Otago's rivers for recreational users, and may lead to an increase in pressure on non-affected rivers. Didymo has also caused significant problems in irrigation schemes by clogging pump screens, sprinkler nozzles and filters.

This report has been written to provide a summary of the biology, ecology, and impacts of Didymo in the Otago context. Despite the large body or work being undertaken on the impacts of Didymo, very little information is available on its basic ecology. Much of the current understanding of Didymo growth cycles is based on observations from the northern hemisphere and may not be applicable in the New Zealand context.

A large body of work has been undertaken by NIWA and other research institutions to investigate the effect of Didymo on the ecology of New Zealand's rivers. Results from these studies indicate that Didymo may cause a change in proportions of various invertebrates in infected rivers but cause an increase in the overall abundance of all invertebrate groups. These changes in invertebrate assemblages are likely to have impacts on higher trophic levels such as native and introduced fish. Didymo blooms also have the potential to reduce the available foraging, refuge and spawning habitat of fish.

The results of a six month intensive monitoring program on the Fraser River, as well as photographic monitoring studies from the Clutha River/Mata-Au, Hawea and Fraser Rivers, are presented with the aim of informing stake holders of the timing and duration of Didymo blooms in Otago. These results have indicated strong links between stable river flows and high Didymo growth. The most important factors controlling the extent to which variable flow affects Didymo growth and biomass appear to be channel morphology and substrate composition. There are also indications that some species of native algae may be able to out-compete Didymo under variable flow regimes or high degrees of shading.

The reduction of Didymo biomass under variable flow regimes, as seen in the Fraser River monitoring study and the Fraser and Hawea River reference photos, has important implications for Didymo management in regulated rivers and irrigation systems in Otago. This information, when combined with other methods of control such as the drying of race systems and chemical treatment provides potential for possible integrated management options for the users of Otago's Didymo affected waters.

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1. Introduction

During a routine periphyton survey in late October 2004 undertaken by the National Institute of Water and Atmospheric Research (NIWA), an unusual thick brown algal growth was observed in the lower Waiau River in Southland. A sample was taken and later identified as *Didymosphenia geminata* (Didymo). Didymo is a diatom (a type of algae) native to alpine and boreal regions of the northern hemisphere; including Europe, China and Northern America (Krammer & Lange-Bertalot, 1997).

One of the earliest diatoms recognised, Didymo was first described in 1819, though it had been known to exist for at least 30 years before then (Kilroy 2004). Since the 1980s Didymo has gradually expanded its range and has caused nuisance blooms throughout Europe and North America. Its discovery in the Waiau River was the first recorded occurrence of Didymo outside of the Northern Hemisphere, and on 17 November 2004 Didymo was declared an unwanted organism under the Biosecurity Act 1993. By this time Didymo had also been discovered in the Lower Mararoa River, a tributary of Lake Manapouri.

Didymo was formally identified in the Hawea, Clutha and Von Rivers (Table 1.1) of Otago in the spring of 2005.

Table 1.1 Incursion chronology of Didymo in Otago

Year	Month	River	Region
2005	Sept	Hawea River	Otago
2005	Sept	Clutha River	Otago
2005	Oct	Von River	Otago
2005	Nov	Lake Dunstan	Otago
2006	Jan	Waitaki River	Canterbury
2006	Mar	Lake Wakatipu	Otago
2006	May	Fraser River	Otago
2006	Jul	Lower Clutha River	Otago
2006	Aug	Matukituki River	Otago
2006	Nov	Makarora River	Otago
2006	Nov	Wilkin River	Otago
2006	Nov	Motatapu River	Otago
2006	Dec	Diamond Creek	Otago
2007	Jan	Lindis River	Otago
2007	May	Young River	Otago
2007	May	Dart River	Otago
2007	May	Kakanui River	Otago
2007	May	Cardrona River	Otago

It was soon realised that, although several studies were being undertaken on the ecological effects of Didymo, there was as yet no information available on the basic ecology of Didymo in the New Zealand context. As a result of this, the Otago Regional Council began a monitoring study on the Hawea River in November 2005 to track changes in Didymo growth through a series of reference photos, with similar monitoring programs initiated on the Clutha River/Mata-Au and Fraser River.

As the Fraser River is augmented by water taken from Lake Dunstan, Otago Regional Council staff considered an incursion was inevitable. Monitoring for Didymo in the Fraser River began in April 2006, and by early May 2006 Didymo cells were identified in the water column. By mid-May 2006, visible Didymo colonies were present in the lower Fraser River at Marshall Rd. The size and flow regime of the Fraser River provided an excellent opportunity to study temporal and spatial variations of Didymo blooms, and fill some of the gaps in the knowledge of the basic ecology of Didymo in New Zealand.

This report provides a broad summary of Didymo in the Otago context. Scientific information has been gathered from both New Zealand and international sources on the biology, ecology and potential effects of Didymo are also discussed.

2. Biology of Didymo

Didymo is an algae belonging to the group Bacillariophyta (diatoms) which are characterised by hard silica cell walls which are often intricately patterned (Kilroy, 2004). Didymo differs from most other freshwater diatoms in several ways. When viewed from above, Didymo cells resemble the shape of a jelly-baby and are distinctive in their large cell size, commonly reaching sizes of up to 135x35 µm (Figure 2.1). This is substantially larger than most of New Zealand's native diatoms which typically reach lengths of approximately 35 µm.

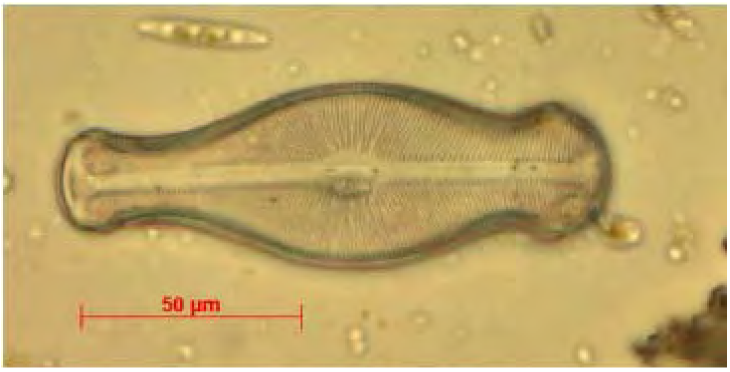

Figure 2.1 Microscopic view of a single Didymo cell (Kilroy, 2004)

Didymo uses long polysaccharide stalks which grow from the base of live cells to attach to substrate, which is considered an unusual method of attachment for diatoms (Figure 2.2). Although several closely related native diatoms such as *Gomphonema* and *Gomphoneis* grow on stalks, Didymo is unique in the length and thickness of its stalks as well as its strength of attachment to the substrate. Also unusual is Didymo's ability to attach to a wide variety of substrates including rocks, concrete, metal, and macrophytes.

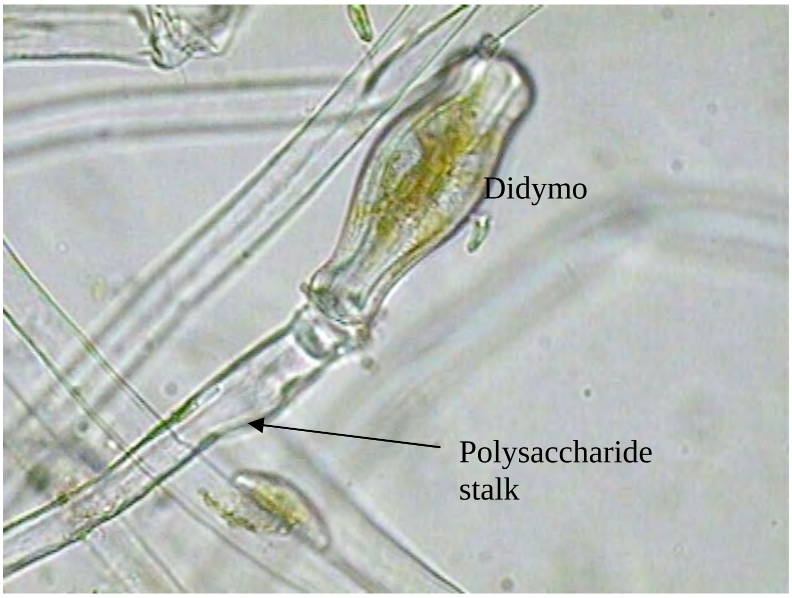

Figure 2.2 Live Didymo cell with attached stalk (Kilroy, 2004)

The size of Didymo cells and stalk material is illustrated in a scanning electron micrograph of Didymo cells with attached stalks (Figure 2.3). The size of the stalks is such that they provide a substrate for other diatoms to attach to.

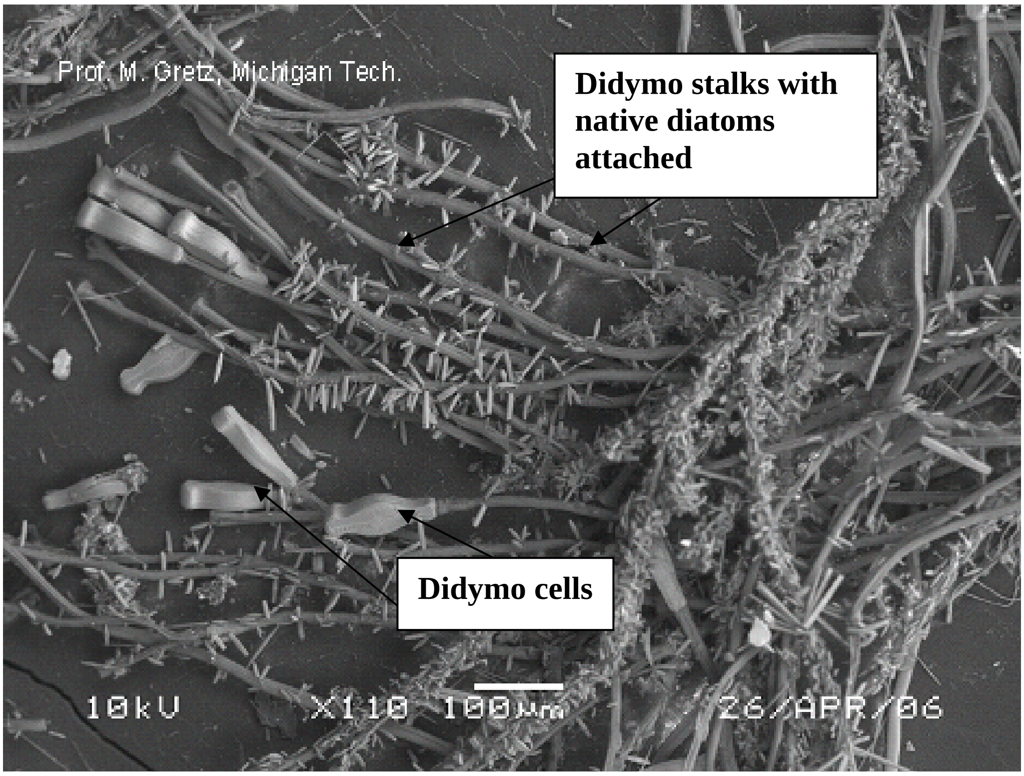

Figure 2.3 Scanning Electron Micrograph of Didymo cells and stalks

2.1 Didymo reproduction

As with other diatoms, Didymo is able to reproduce by vegetative cell division or cloning. Each cell splits into two and grows a new stalk, therefore each branch point in the stalk represents a new cell division. Most diatoms undergo sexual reproduction, and although this has been shown to occur in Didymo populations in the Northern Hemisphere, it has yet to be observed in New Zealand. It is therefore probable that all populations of Didymo within New Zealand are genetically very similar. There is as yet no information on the speed at which Didymo cells divide and grow, but the extremely rapid accumulation of biomass observed in many rivers indicate that this could take less than 30 hours.

2.2 Ecology of Didymo

It is important to note that much of the early knowledge of Didymo ecology in New Zealand was based on information from America and Europe. As it has spread in the South Island, Didymo has broken most of the rules set out by these early assumptions, requiring a complete re-think on the ecology of the organism. The following summary is based on New Zealand studies and observations, as well as some information from northern hemisphere examples.

2.3 Physiochemical preferences

Much of the earlier literature describes Didymo as being restricted largely to alpine areas (Cleve 1894-96, Hustedt 1930, Patrick & Reimer 1975, Krammer & Lange-

Bertalot, 1997). However, it is becoming clear that Didymo is not restricted to the "*cold oligotrophic waters*" (Krammer & Lange-Bertalot, 1997) as originally thought. There are several recent examples of Didymo occurring over a much wider range than initially predicted. In Poland, Kawecka & Sanecki (2003) concluded that Didymo "*occurs over a wider ecological range than previously assumed*", while in Romania it has been observed to be growing "*in lowland rivers and high up in the mountains*" and has been described as having a "*large ecological amplitude*" (Kilroy 2004, *pers comm* with Cristian Gudasz, Babes-Bolyai University, Cluj, Romania, 2004).

In Otago, Didymo is observed colonising a wide geographic range of aquatic habitats, from mountain streams, to lakes and lowland rivers.

2.4 Hydrology and habitat stability

Observations from New Zealand and overseas have indicated that the most favourable conditions for Didymo growth are periods of low stable flow (Sherbot & Bothwell 1993), especially in lake-fed and regulated rivers (Cox,1996). This has been observed in several rivers in New Zealand, including the Mararoa, Hawea, Clutha River/Mata-Au, Fraser, Waiau, and Waitaki River. Once a colony is established, it is believed higher velocities are likely to promote Didymo growth by allowing faster transfer of nutrients to live cells (Kilroy 2004). Because Didymo is so firmly attached to the substrate, it is able to persist and resist scouring in higher velocities than any similar native species and reach a much higher biomass under similar flow conditions.

Observations in many New Zealand rivers where Didymo is present have shown a band of very thick growth in the moderate to fast flowing water, thinning towards the middle of the channel where velocities are higher (Figure 2.4) and the substrate is more unstable (G. Martin, pers. comm.) As summarised by Kilroy *et al* (2005a), *"it seems that Didymo is capable of growing almost everywhere in rivers where the substrate is not constantly unstable"*.

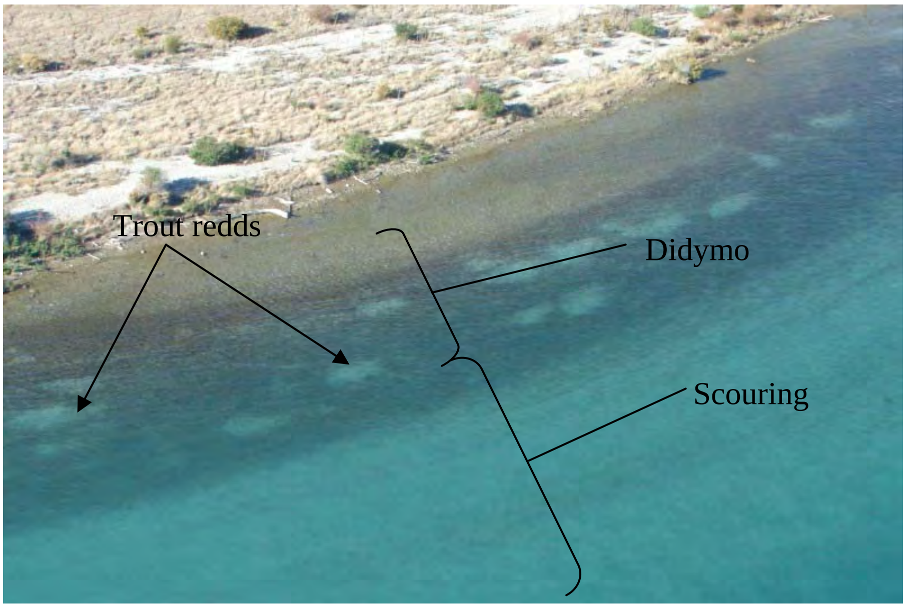

Figure 2.4 Scouring of Didymo from mid-channel in the Clutha River/Mata-Au (A Horrel, Clutha Fisheries Trust). The lighter patches amongst the Didymo are freshly dug trout redds

2.5 Didymo in lakes

There are several observations of Didymo growing along lake edges in Europe, and there is evidence in Otago and Southland that this is also the case in New Zealand. Didymo has been observed growing along the edges of Lake Wakatipu near the mouth of the Von River, opposite the mouth of the Greenstone River near Pigeon Island, Queenstown Bay (Figure 2.5) and at the Clutha arm of Lake Dunstan. Indications are that Didymo in lakes may be limited to areas of high wave action and/or some degree of flow.

Figure 2.5 Didymo growing on rocks in the wash zone in Queenstown Bay, Lake Wakatipu

2.6 Spatial and temporal variations of Didymo blooms

Early reports based on northern hemisphere observations stated that it was likely that Didymo would only bloom during low summer flows (Kilroy, 2004). It has become apparent that the timing and duration of Didymo blooms is quite unpredictable. Monitoring studies undertaken in the Clutha River/Mata-Au, Hawea, and Fraser Rivers, combined with a substantial body of anecdotal evidence, have shown that Didymo blooms are not limited to the warmer months of the year as initially predicted. Heavy blooms of Didymo have been observed throughout the winter in many rivers in New Zealand, including the Clutha River/Mata-Au Waitaki, Fraser, and Hawea rivers (Graeme Martin, Don Robson, Jeff Donaldson [ORC] and Graeme Hughes [Fish & Game] pers. comm.).

Observations from several New Zealand rivers including the Clutha, Hawea, Fraser and Waitaki have shown that blooms can occur at any time of year and can span many months in duration.

3. Potential effects of Didymo

3.1 Invertebrates

One of the most important ecological interactions occurring in infected rivers is the effect of Didymo on stream invertebrates. Invertebrates alter the biomass of algae by grazing, and are also an important food source for both native fish and introduced sports fish such as brown and rainbow trout.

Didymo has been shown to alter *proportions* of various invertebrate taxa in infected rivers causing an increase in the proportions of undesirable pollution tolerant species such as chironomids (midges) and worms which are less favoured by fish, and a decrease in the proportions of more desirable species such as stoneflies and mayflies which are important as a food source for both native fish and trout.

Despite the shift in the *proportions* of various invertebrates in the presence of Didymo, affected rivers have much higher *densities* and *biomass* of <u>all</u> classes of invertebrates, including the more desirable species.

There is also a decrease in the overall diversity of invertebrate communities in rivers affected by Didymo compared to uninfected sites, as well as a decrease in the average weight of invertebrates in infected rivers.

These results are merely preliminary and a more detailed study is currently being undertaken by NIWA to accurately describe the effect of Didymo on invertebrate communities.

3.2 Trout

Although the effects of Didymo on trout are largely unknown, it is likely that there will be both direct and indirect effects on trout in infected rivers.

The reduction in the average size of invertebrates in Didymo-affected areas may have important implications for both small and large size classes of trout. It is probable there will be much more food available to small trout due to the substantial increase in the number of small invertebrates, from which recruitment in food limited streams may actually benefit.

Studies undertaken in New Zealand (Hayes *et al*, 2000, Hayes 1996) have shown that declining prey size reduces the growth potential of brown trout as a result of the increased foraging time required.

This raises the possibility that Didymo infestation may cause a shift in size class distribution of trout populations in infected rivers. The reduction in size and increase in invertebrate densities may lead to a subsequent increase in trout densities but a reduction in the number of larger fish.

Without any specific scientific information available on the effect of Didymo on trout feeding ecology, there are several anecdotal observations that may be able to shed some light on this issue. Otago Regional Council has received several reports from anglers that both the upper and lower Clutha River/Mata-Au are fishing well with trout selectively foraging over Didymo beds and feeding on the many small mayflies and other invertebrates entering the drift (R Fitzpatrick, T Bichel, pers. comm.).

3.3 Trout spawning and recruitment

It is unlikely that Didymo will have a negative impact on spawning as trout are easily able to dig through Didymo mats to reach the gravel below (Figure 3.1). Once spawning is completed however, Didymo is able to very quickly re-colonise trout redds and accumulate mats up to 3 cm thick in a matter of weeks (Figure 3.2). It is this buildup of Didymo biomass on top of redds that may have a serious negative impact on recruitment.

Figure 3.1 Newly dug trout redd in the Fraser River

Figure 3.2 Trout redd covered with a 20 mm thick mat of Didymo after 10 days in the Fraser River

Thick Didymo mats may prevent oxygen from flowing through the gravel and may lead to the death of larvae and fry. It is also possible that these mats of Didymo may effectively armour the stream bed, preventing fry from reaching the surface (Figure 3.3).

Figure 3.3 Gravel bound together by Didymo at Laing Rd, forming a matrix which armours the substrate

3.4 Native fish

As yet there is minimal information available on the effect of Didymo infestation on native fish. However, there are many areas of concern, ranging from food source changes, to the removal of interstitial spaces and decreases in dissolved oxygen.

Specifically in Otago, the greatest potential concern to date is for the nationally threatened (DOC, 2004) lowland long-jawed galaxiid (*Galaxias cobitinis*) in the Kauru and Kakanui Rivers in North Otago. The lowland long-jawed galaxiid burrows into the gravel to prevent stranding during low flows, and thick mats of Didymo may prevent it from doing so. Didymo may also smother the gravels and cobbles used by many galaxiids and other small native fish for spawning. In response to this threat, the Department of Conservation has closed the Kauru River to fishing in an attempt to reduce the likelihood of Didymo entering this system.