# Benthic survey of the Waiau Arm to determine the distributional extent of *Didymosphenia geminata*

**NIWA Client Report: CHC2005-118**
**September 2005**

**NIWA Project: MEL06505**

# Benthic survey of the Waiau Arm to determine the distributional extent of *Didymosphenia geminata*

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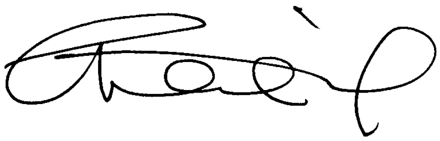
Appendix 1. Transect graphs showing distribution along and transect and relative abundance of live and dead frustules of *Didymosphenia geminate*.

Appendix 2 Estimates of volume of water in the Waiau Arm based on different water levels in Lake Manapouri.


*Reviewed by:*



Cathy Kilroy

*Approved for release by:*

Brian Sorrell

# Executive Summary


- The unwanted invasive alga *Didymosphenia geminata* was first positively identified in the Mararoa and lower Waiau Rivers, Southland, in October 2004 and is now present in the lower reaches of the Waiau Arm. Deposition of these cells into the arm is likely to be a result of water diversions from the Mararoa towards Lake Manapouri. Biosecurity New Zealand (BNZ), The Guardians of the Lakes and Meridian Energy Limited (Meridian) have raised concern over the continued translocation of *D. geminata* into the reaches of the Waiau Arm and the potential for subsequent translocation into Lake Manapouri and its likely impact on aesthetic and ecological values.

- Hydrodynamic modelling was used to determine the maximum allowable upstream flows from the Mararoa River through the Waiau Arm to Manapouri, such that sinking *D. geminata* cells would be deposited on the bed of the channel within the confines of Zone 1 (Biggs et al. 2005). This model was based on the previous operational flow regime where water from the Mararoa River was diverted, at times, up into the Waiau Arm towards Lake Manapouri. However, before the hydrodynamic model could be validated Meridian has taken the most conservative approach, on scientific advice from NIWA, by adopting a new operational flow regime (park and flush), where they have ceased to divert all Mararoa River water into the Arm and maintain a positive flow from the lake to the MLC.

- In order to assess the benthic distribution of *D. geminata* and its ability to survive and grow in the arm and to validate the model, benthic sampling surveys across and along the length of the Waiau Arm were commissioned by Meridian on advice from NIWA.

- Dead frustules (defined as either empty frustules or with constricted chloroplasts) of *D. geminata* were found on 42% of transects within zones 1 and 2. The most upstream site recorded for dead frustules was approximately 2.4 km upstream from the regular monitoring program's Zone 2 positive site. Live, or viable, frustules were found on 29% of transects. The most upstream site recorded was approximately 1.5 km upstream from the last known positive site.

- Frequency of occurrence as well as the relative abundance for both live and dead frustules increased as distance downstream (towards the MLC) increased. Within Zone 2 both live and dead frustules were typically found at least 10 m in from the bank, while in Zone 1 *D. geminata* extended across the transect from bank to bank. The maximum depth to which viable live frustules were found was 8.1m. It is unclear if these cells are actively growing or passively surviving at these depths.

- In shallow waters (1-4 m) *D. geminata* appears to be capable of growing under the low light and reduced flows of the Waiau Arm relative to those in the Mararoa River. Extensive mats of

healthy, viable material were found growing on rocks, submerged logs and smothering macrophytes. A gradual extension of *D. geminata* upstream is apparent.

- A clear demarcation in relative abundance of *D. geminata* frustules occurs at the boundary between zones 1 and 2. This decline serves to validate the hydrodynamic transport model that dead *D. geminata* frustules would settle out by about halfway along Zone 1, based on the previous flow regime of water diversion from the Mararoa River into the Waiau Arm.

- In order to ensure operational water flows do not contribute to the spread of *D. geminata* further upstream and into the lake a positive flow regime towards the MLC needs to be maintained. This flow regime has been adopted by Meridian and is currently in practice.

- Given the current extent of *D. geminata* in the arm and its ability to thrive under the low light and slow flows it is recommended that an eradication program be trialed as soon as possible. Chemical treatment of the entire length of the arm, followed by high flushing flows should be attempted in order to remove live *D. geminata* and thus prevent its eventual spread to the lake. Clearly this would need the support of all agencies and stakeholders involved.

# 1. Introduction

The unwanted invasive alga *Didymosphenia geminata* was first positively identified in the Mararoa and lower Waiau Rivers, Southland, in October 2004. Subsequent surveys have confirmed cells and fragments of *D. geminata* in the lower reaches of the Waiau Arm (Kilroy and Blair 2005). The deposition of these cells into the arm is likely to be a result of water diversions from the Mararoa towards Lake Manapouri. While overseas literature suggests that the physical and chemical environment of the Waiau Arm makes it inhospitable for the proliferation of *D. geminata*, the alga is known to colonise stable substrates within the wave washed zone of lakes (see Kilroy 2004). Biosecurity New Zealand, Guardians of the Lakes and Meridian Energy Ltd (Meridian) have raised concern over the continued translocation of *D. geminata* into the reaches of the Waiau Arm and the potential for subsequent translocation into Lake Manapouri.

Monthly surveys of the arm, consisting of benthic samples taken from the margin of the water's edge to a depth of ~1m, suggested that *D. geminata* was confined to the downstream part of the Waiau Arm (termed Zone 1) and did not appear to be actively growing in the arm itself. Based on this information, hydrodynamic modelling was used to determine the maximum allowable upstream flows from the Mararoa River through the Waiau Arm to Manapouri, such that sinking *D. geminata* cells would be deposited on the bed of the channel within the confines of Zone 1 (Biggs et al. 2005). The preliminary cap flow of $42m^3/s$ was determined based on laboratory experiments. This model was based on the previous operational flow regime where water from the Mararoa River was diverted, at times, up into the Waiau Arm towards Lake Manapouri. However, before the hydrodynamic model could be validated Meridian has taken the most conservative approach, on scientific advice from NIWA, by adopting a new operational flow regime (park and flush), where they have ceased to divert all Mararoa River water into the Arm and maintain a positive flow from the lake to the MLC.

In order to assess the benthic distribution of *D. geminata* in the Arm, and to validate the model, NIWA was commissioned by Meridian Energy to undertake benthic surveys across and along the length of the Waiau Arm

The objective of this survey was to better understand the deposition/dispersal of *D. geminata* frustules along the arm (particularly with depth) to determine whether:

1. flows presently being diverted from the Mararoa River into the Waiau Arm for hydro-power generation have the potential to transport *D. geminata* to Lake Manapouri,

2. the preliminary 'cap' of flows from the Mararoa ($42m^3/s$ as determined from lab experiments on rates of *D. geminata* settling and hydraulic modelling) are adequate to prevent significant transport of *D. geminata* toward the lake; and

3. whether *D. geminata* will actually survive/grow in the environment of the Waiau Arm once deposited there, and thus present a secondary source of material which could be transported to Lake Manapouri.

# 2. Methods

## 2.1. Benthic surveys

Benthic surveys of the Waiau Arm and Lake Manapouri were conducted on 22 – 26 August 2005. Twenty-seven transects were spaced down the length of the arm at approximately 300m intervals in zones 2 and 3 and approximately 600 m intervals in zone 1 (Figure 1). Four transects were surveyed in Lake Manapouri along a depth profile of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7 m. The sites selected, off Fraser's beach and west of Richters Rock, were sites where periphytic and epiphytic algae presently grow (Figure 1). GPS co-ordinates were recorded from the true left bank of each transect surveyed in the Waiau Arm and from the shore for lake transects.

At each transect divers, on SCUBA, collected 10 benthic samples from a range of substrata (sediment, rock, log and macrophyte) spaced at even distances along the profile at right angles to the shoreline. At each sampling point descriptions of the substrate type, macrophyte community, distance from shore and water depth were recorded. In addition, periphytic and epiphytic algal communities were described from a 2 m wide band along the transect profile.

Thirty-two additional sites were selected for the collection of a single sample at approximately 0.5 to 1 m water depth. These sites were selected as areas where water was likely to pool or where floating mats were likely to be caught on submerged logs and debris in Zones 2 and 3 (Figure 2).


**Figure 1:** **Transect locations in Lake Manapouri (1-4) and the Waiau Arm.(5-32)**

**Figure 2: Spot sampling locations in the Waiau Arm. Red = samples positive for *D. geminata*, blue = negative samples**

### 2.2. Microscopic analysis

In order to determine cell viability microscopic analysis was undertaken on site. Three representative sub-samples were examined, from each sample, on a Leitz fluorovert FS inverted microscope at 100x magnification. Presence or absence, cell viability (as determined by condition of chloroplast), and relative abundance were recorded for *D. geminata* cells. Relative abundance was expressed as the percent of pooled sub-samples occupied by *D. geminata*.

## 3. Results

*Didymosphenia geminata* was not found in any of the samples collected from all four transects in Lake Manapouri. For all depths at all four sites the diatoms *Cymbella* sp. and *Tabellaria* sp. dominated the community.

Dead frustules (defined as either empty frustules or with constricted chloroplasts) of *D. geminata* were found on a total of 13 transects (42%) within zones 1 and 2. The most upstream site (transect 18 see Appendix 1) recorded for dead frustules was approximately 2.4 km upstream from the regular monitoring program's Zone 2 positive site. Live, or viable, frustules were found on 9 transects (29%). The most upstream site recorded was approximately 1.5 km upstream from the regular monitoring program's Zone 2 positive site. These new upstream records are still contained within Zone 2.

Frequency of occurrence as well as the relative abundance for both live and dead frustules increased as distance downstream (towards the MLC) increased (Figures 3 and 4). Within Zone 2 both live and dead frustules were typically found at least 10 m in from the bank, while in Zone 1 *D. geminata* extended across the transect from bank to bank (Appendix 1). The maximum depth to which live frustules were found to have colonised was 8.1m (on the day of sampling).

The highest concentration of deposited dead *D. geminata* frustules occurred in Zone 1 reaching a relative abundance of up to 95% at the start and middle of this zone and declining to 40% by the end of Zone 1. Relative abundance continued to decline in Zone 2 with as little as 5% abundance 1 km upstream from the boundary between zones 1 and 2 (Figures 3 and 4; Appendix 1).

In Zone 1 *D. geminata* was found epiphytically and metaphytically associated with macrophytes (predominately *Elodea canadensis*) forming a thick layer smothering the

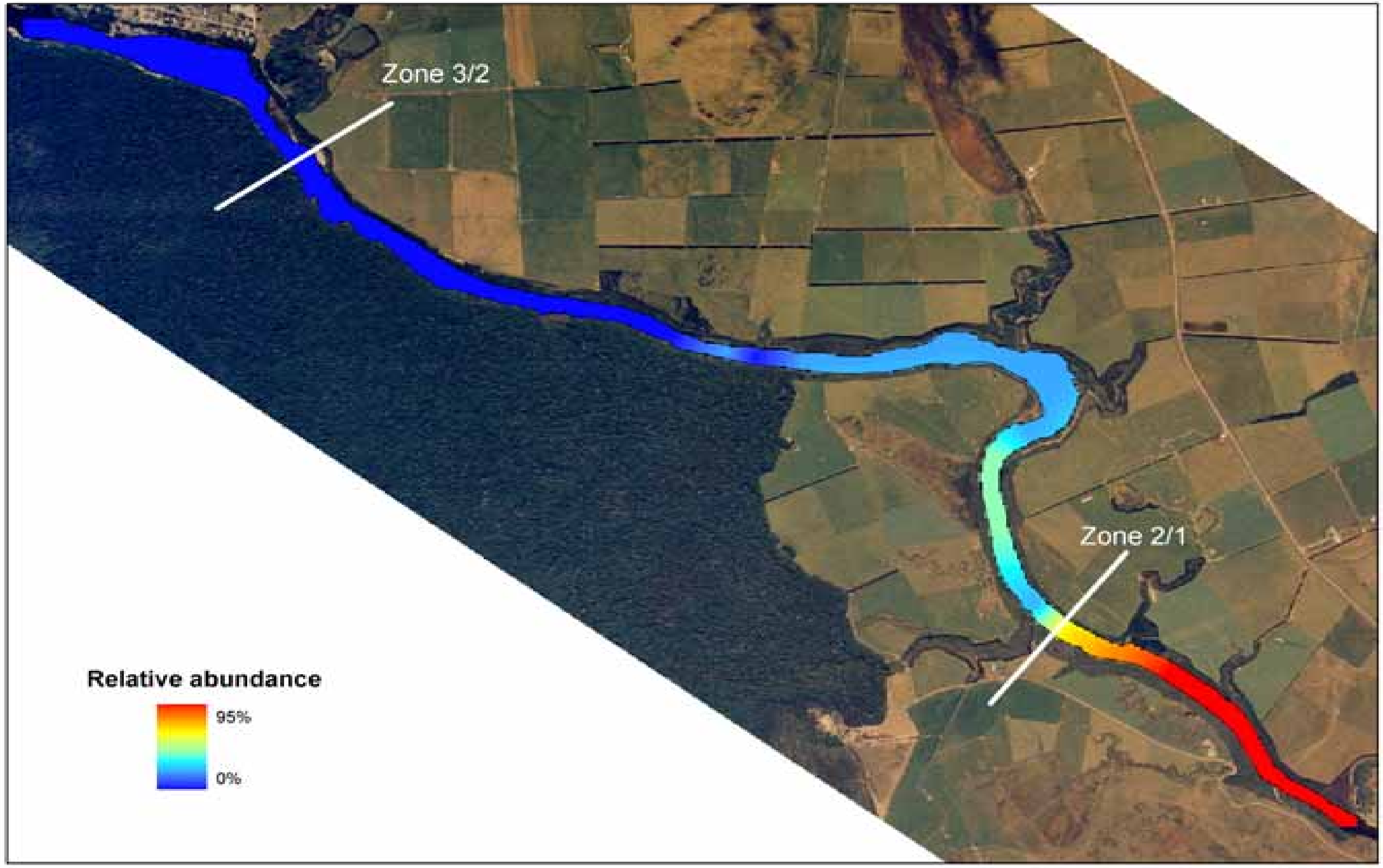



**Figure 3: Relative abundance of dead frustules of *Didymosphenia geminata* along the length of the Waiau Arm**

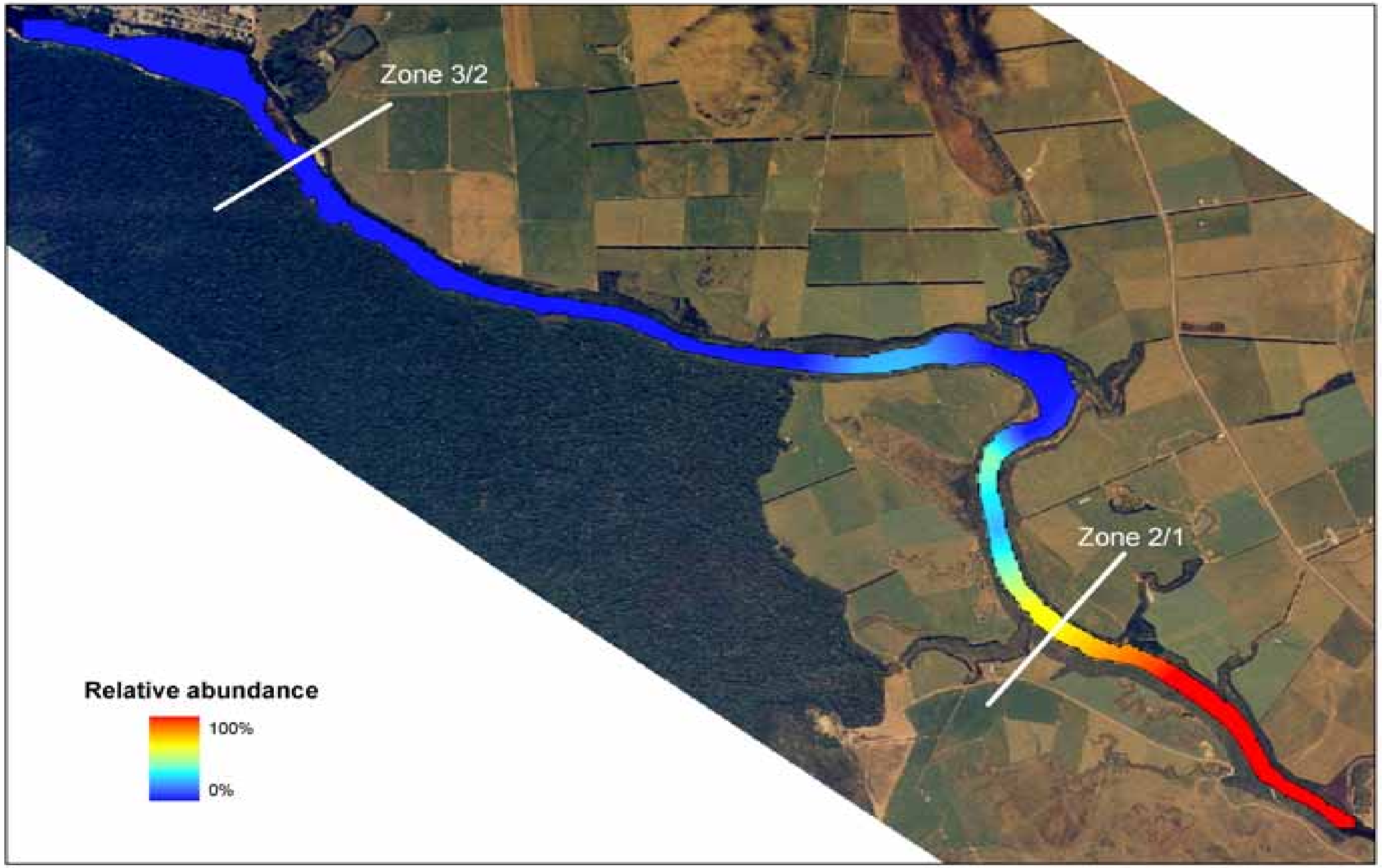



**Figure 4:** **Relative abundance of live frustules of *Didymosphenia geminata* along the length of the Waiau Arm.**

macrophytes. This thick layer spanned an area from approximately mid-way between transect 30 and 29 to approximately transect 31 covering macrophytes over a depth range of 1–4m. These macroscopic growths were visually distinguishable from other algal communities and took on the appearance of those colonies found growing attached to the rocks in the shallow reaches near the MCL. The relative abundance of *D. geminata* associated with the macrophytes decreased as distance upstream increased while the epiphyte assemblages became increasingly mixed and the visual appearance of the community became increasingly similar to that typical of a *Cymbella / Tabellaria* dominated community.

*D. geminata* was found in only two of the thirty-two spot samples taken. The positive samples were located in the lower section of Zone 1, near the MLC.

# 4. Discussion

The results from the benthic survey indicate that *Didymosphenia geminata* is capable of growing in the Waiau Arm. This result was somewhat surprising as international literature indicated that the conditions along the entire length of the Waiau Arm were unfavourable for *D. geminata* colonization and growth, given what we currently know about *D. geminata*'s environmental preferences (see Kilroy 2004 for details). According to that literature blooms of *D. geminata* tend to favour conditions of moderate flow and high light (favoured depth range 0.1 – 2 m), while very slow moving waters were considered unsuitable (see Kilroy 2004 for summary). Flow in the Waiau Arm at most times is imperceptible, and the margins appear to be sheltered from any wave action.  The channel is steep-sided with sandy or soft-mud sediment and has extensive macrophyte beds. These characteristics, coupled with a poor light climate, were considered unfavourable enough to prevent *D. geminata* establishing itself to any great degree. The finding that *D. geminata* is able to grow very well in the near-lentic conditions of the Waiau Arm is very significant internationally, as it greatly extends our knowledge of the possible locations where *D. geminata* could proliferate and cause ecosystem degradation.

At the time of the present study *D. geminata* was found growing attached to rocks and submerged logs and loosely associated with bottom sediment and macrophytes. Blooms of *D. geminata* were observed in the lower reaches of the Waiau Arm (Zone 1) where there has been enough time from initial colonisation to allow for proliferation. From transect 29 down to the MLC end of zone 1 *D. geminata* was found not to be restricted exclusively to the shallow depth zone (< 2 m), with a number of live samples in Zone 1 in the depth range of 4-8 m. In this depth range the light climate is low and light completely cuts out at 9.5 m (personal observation). The characean community (macroscopic algae) grows to the deepest extent to which plants (excluding bryophytes) will grow (typically 1% of surface irradiance), with the maximum depth limit determined by the availability of light (Schwarz and Hawes 1997). For this reason they can be used as an integrator of water clarity. In the Waiau Arm the maximum depth to which characeans grew was 6.4 m.

On transect 29, prolific 'cloud-like' colonies of *D. geminata* were observed on the bottom soft substrate at 7.2 m. These colonies were found to contain live, stalked cells with complete chloroplasts and a relative abundance of 95%. While these colonies appeared viable it is unlikely that light conditions would favour photosynthetic growth. It is plausible to suggest that these colonies were a recent deposition and the cells are living off their excess photosynthetic products stored in the mucilage surrounding the cell. This coupled with a reduction in metabolism; due to the cold-water temperatures, would allow cells to survive for a period of time in unfavourable light conditions.

It should be noted that on transects where *D. geminata* cells (both live and dead) were found to be present below 6 m fragments of the macrophyte *Elodea canadensis* were found to have accumulated. The accumulation of these dead fragments coupled with the deep silt layer suggests water movement is less turbulent in the deeper parts of the arm and therefore *D. geminata* cells found in this zone are less likely to be re-suspended into the water column than those in the shallow regions.

From this survey not only do we see that *D. geminata* is more than capable of growing in the shallow depths (1-4 m) in the Waiau Arm but there has been a gradual upstream extension of colonisation. This upstream extension is probably indicative of historical events in the Arm, including previous flow conditions. The 'park and flush' operational flow regime adopted by Meridian will reduce the chance of flow-assisted movement of *D. geminata* to the lake, but the fact that mats are now found growing in the Arm means that transport by other vectors, such as wind, fish and birds, is possible. At the time of the sampling floating mats, sloughed off from the shallow region near the MLC, were being driven upstream by strong southerly winds. This movement will assist *D. geminata* to migrate upstream and possibly enter into Lake Manapouri. Conditions for growth of *D. geminata* in the Waiau Arm are less favourable than the lake itself. Presently, prolific growths of *D. geminata* are smothering some of the macrophyte beds within the arm. With a more favourable light climate and more suitable substrate (cobbles) in the lake it is likely that this will occur to a greater extent in the lake. *D. geminata's* apparent ability to grow below 2m depth in the arm indicates that it is likely to be capable of growing and proliferating below the wave-wash zone in the lake.

There appears to be a clear demarcation in relative abundance of *D. geminata* frustules at the boundary between zones 1 and 2, as indicated in Figures 3 and 4. This decline serves to validate the hydrodynamic transport model proposed by Biggs et al. (2005), to ensure that dead *D. geminata* frustules would settle out of the water column before reaching the boundary between zones 1 and 2. The model, based on the previous flow regime, proposed that all diversion of Mararoa water into the Waiau Arm of Lake Manapouri should cease once flows in the Mararoa River (measured at the Cliffs water level recorder station) reach 42 $m^3$/s. At flows less than this when diversions are permitted, most suspended *D. geminata* should settle out by about half-way along Zone 1. The decline in relative abundance along Zone 1, from 95% to 40%, and the rapid further decline into Zone 2 suggests that this was already the case under the previous operating regimes where daily average flows into the Waiau Arm from the Mararoa had not exceeded the proposed maximum flow rate from January 1999 to June 2005 (Meridian's own data). The critical difference in what was observed verses what was predicted is probably a by-product of the extensive growth of *D. geminata* in Zone 1, which was not expected based on known distributions overseas. Dead cells deposited further up the arm are more likely to have been derived from the deposition of floating mat fragments, from high flows of short duration (several hours) not seen from the mean daily flow data, from sloughing off of colonies currently growing in the arm or from translocation by vectors such as wildlife, boating and fishing activities. There are a number of compounding factors that make these deposition events difficult to predict and therefore were not accounted for in the hydrodynamic model.

The spot samples were gathered at wading depths where *D. geminata* was expected to grow. The fact that all spot samples, with the exception of two samples collected near the MLC, gave a negative result raises the question of the value of such survey methods (collecting from shore at wading depths) for monitoring *D. geminata* in the arm itself, in particular in zones 2 and 1.

## 5. Recommendations

In order to ensure operational water flows do not contribute to the spread of *D. geminata* further upstream and into the lake a positive flow regime towards the MLC needs to be maintained. Meridian currently has this in place with their operational 'park and flush' regime.

Given the current extent of *D. geminata* in the arm and its ability to thrive under low light and low or no water movement it is recommended that an eradication program be trialed as soon as possible. Chemical treatment of the entire length of the arm, followed by high flushing flows should be attempted in order to eradicate *D. geminata* and thus prevent its eventual spread to Lake Manapouri.

While the ecological consequences of chemical treatment to the arm itself are significant, the impacts of *D. geminata* on the lake and other potential water bodies are predicted to be greater. Chemical treatment of the arm is likely to also impact on the macrophyte community and therefore runs the risk of turning the arm to a phytoplankton dominated system, although flushing from the lake will mitigate against that to some extent. However, the 'leave-alone' option is considered to be more adverse to the health of the arm, the lake and any future infested water bodies.

The success of the chemical treatment will be dependent on a number of factors including correct calculations for chemical concentrations to such a large body of water, ideal contact time and sufficient flushing velocities following treatment. Calculations of the volume of water in the Waiau Arm for different lake levels are given in Appendix 2. Small-scale trials should be undertaken in the lower end of Zone 1 where a small area is treated and monitored for effectiveness. Once the trials are deemed effective treatment of the entire arm can be undertaken and overall success monitored throughout the growth season.

Some chemical treatments that would be suitable for trialling include salt solution at a minimum 5%, chlorination with bleach and copper-based algicides. Each treatment has its own inherent advantages and disadvantages. The presence of organic matter compromises the impact of bleach and it is readily broken down in the presence of sunlight (UV), so that its impact may be very limited. Copper based algicides have been used for more than 50 years as a standard chemical control of algal problems in reservoirs in the USA. However, copper is not biodegradable and can accumulate in sediments. The efficacy of Copper – Triethanolamine complex on the green alga *Hydrodictyon reticulatum* (water net) was trialled in Lake Aniwhenua, North Island (Wells, 1994). Copper – Triethanolamine (at a loading rate to give 0.3mg copper / litre) was found to be effective at controlling surface mats of water net and water net growing on macrophytes, but did not affect water net growing on the floor of the lake. Environmental impacts were minimal with invertebrates and fish showing no signs of toxicity. The macrophytes, however, were as susceptible to the copper as the water net. At the loading concentrations used in the trial, copper did not accumulate in the sediment (Wells, 1994).

More information on the application of algicides and the associated public health risk can be found in the Public Health Risk Management Plan Guide, Pre-treatment processes – Algicide Application guide (2002), available on the Ministry of Health's website (http://www.moh.govt.nz).

## 6. Acknowledgements

We are grateful to the Manapouri Volunteer Fire Service for providing us with clean water supply and high pressure hoses for decontaminating boat, trailer, vehicle and associated gear. Colin Sinclair arranged decontamination supplies at the MLC depot.

## 7. References

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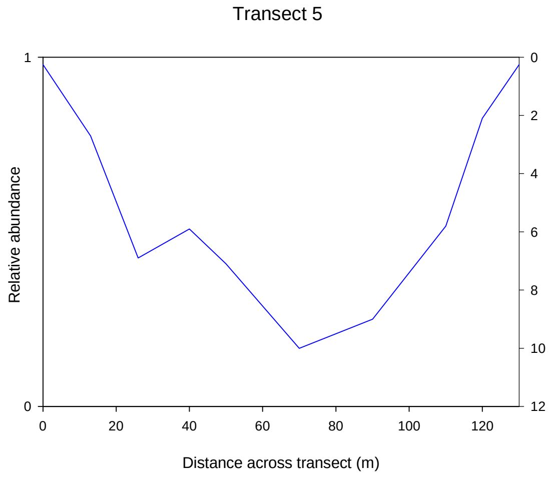
# Appendix 1

**Transect graphs showing distribution along the Waiau Arm and relative abundance of live and dead frustules of *Didymosphenia geminata*. Transect locations are indicated in Figure 1. Red bars equal live and dead frustules; green bars equal dead frustules only. Depth of profile is indicated by blue line. Relative abundance scale; 0 = none found, 1 = 1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-95%, 6 = > 96%**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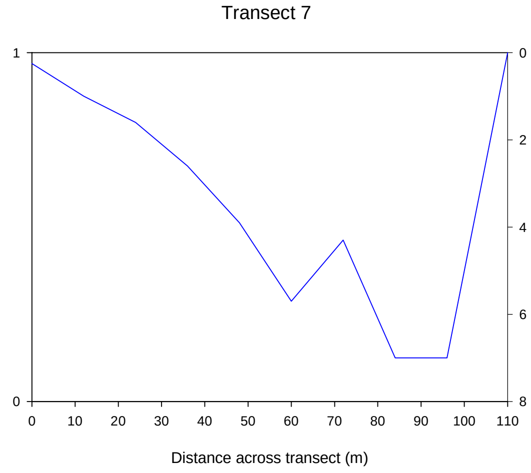
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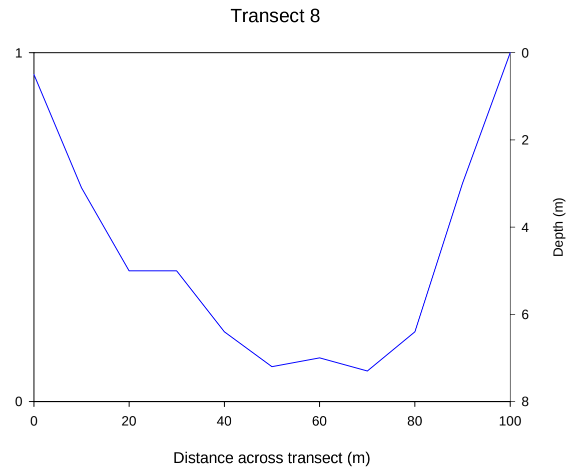
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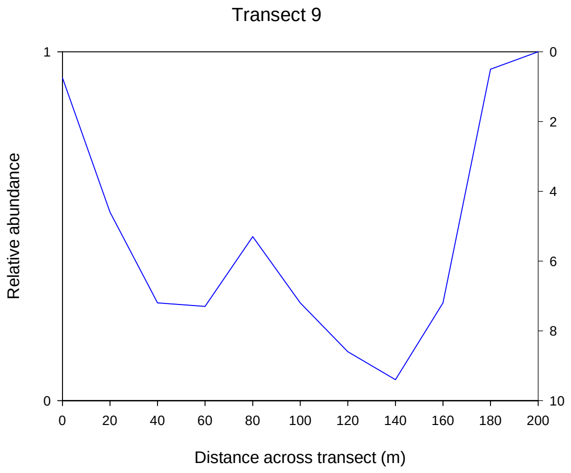
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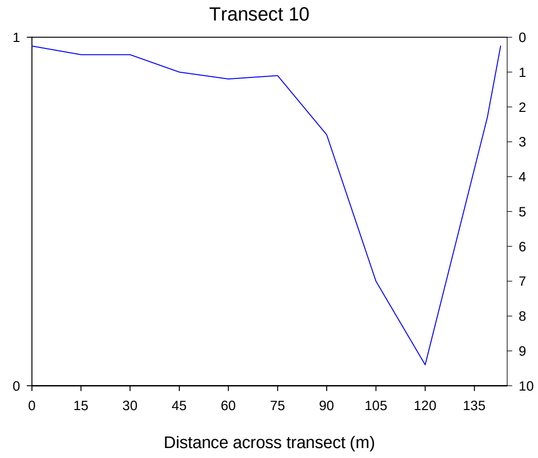
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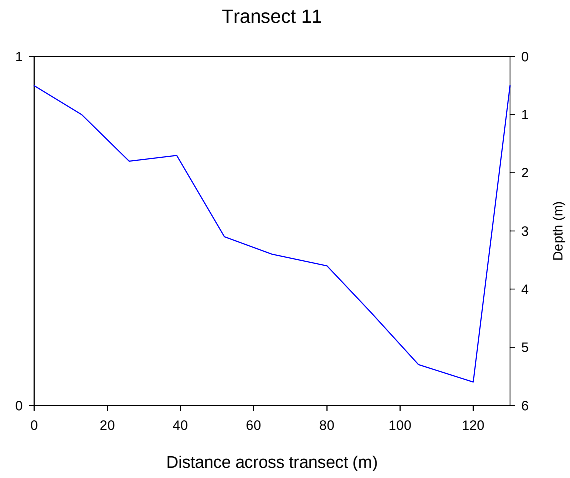
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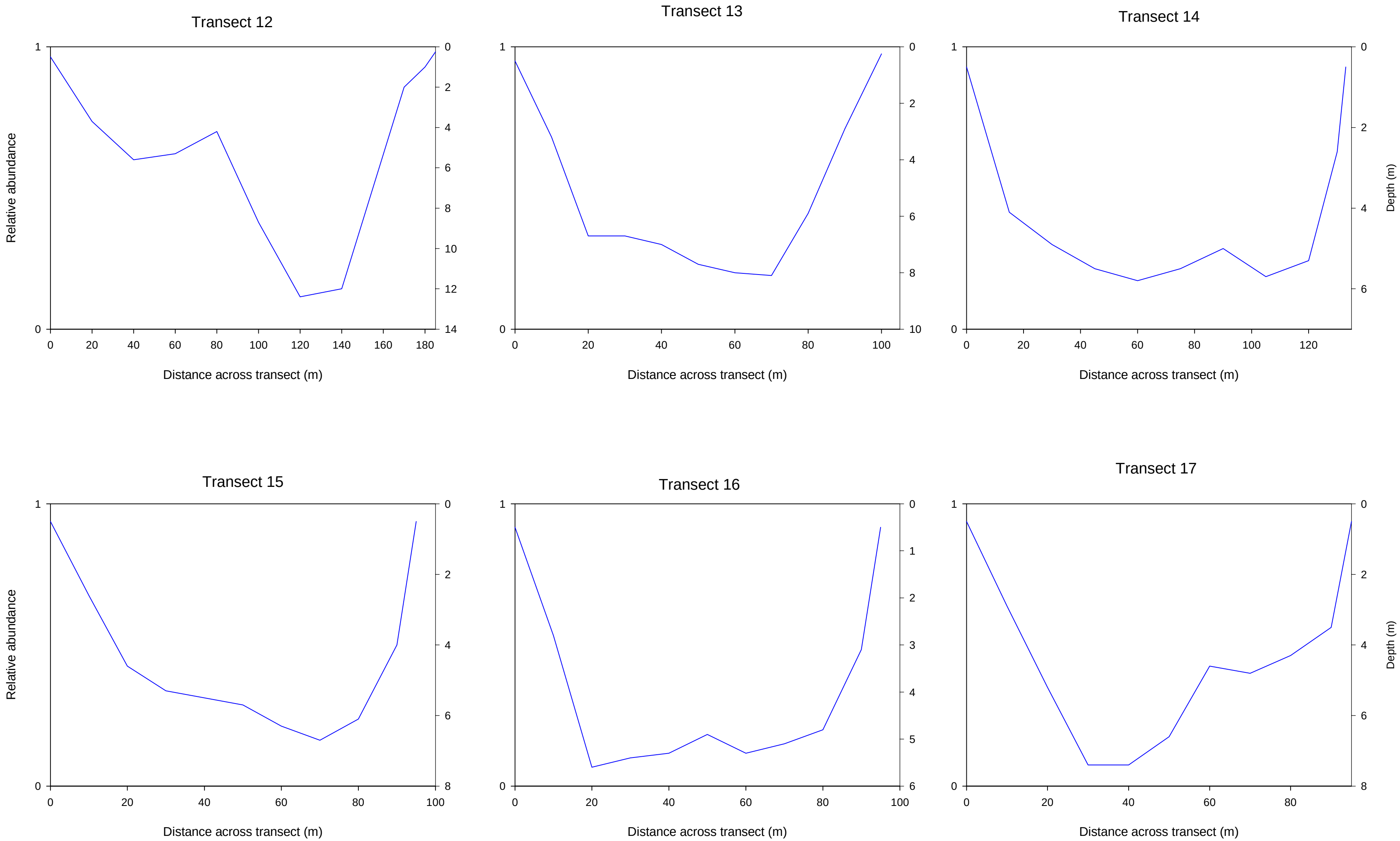
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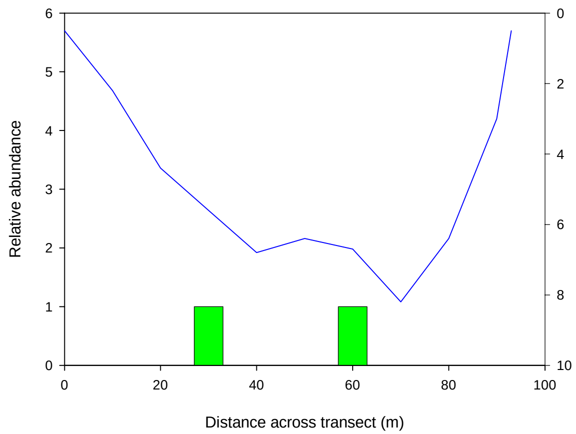
Relative abundance
Depth (m)
Distance across transect (m)

NIWA
Taihoro Nukurangi

Transect 18

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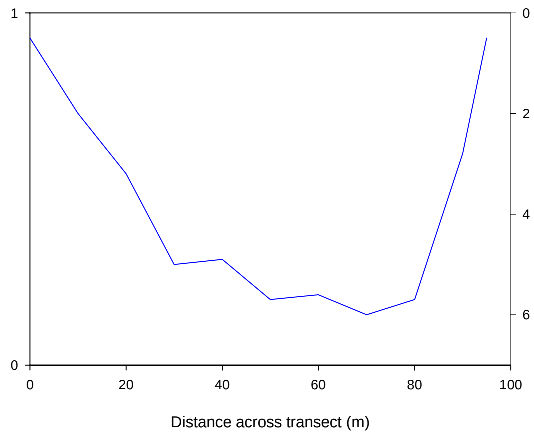


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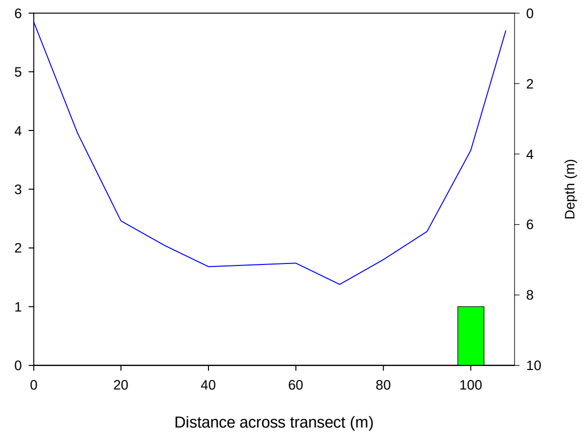


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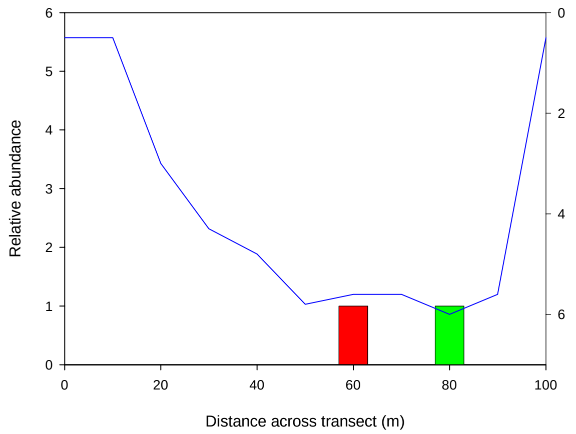


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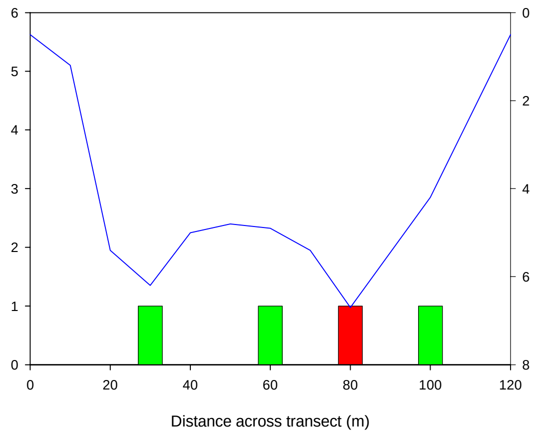


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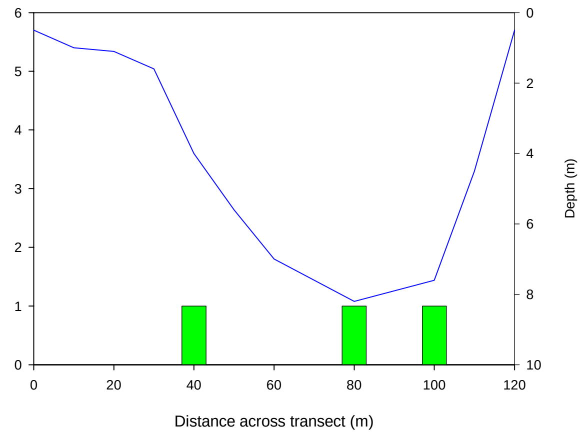
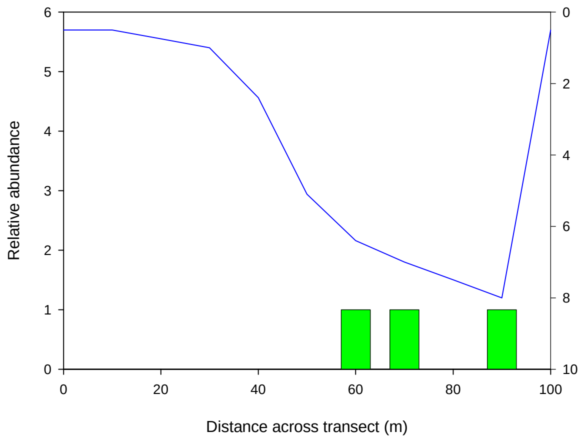
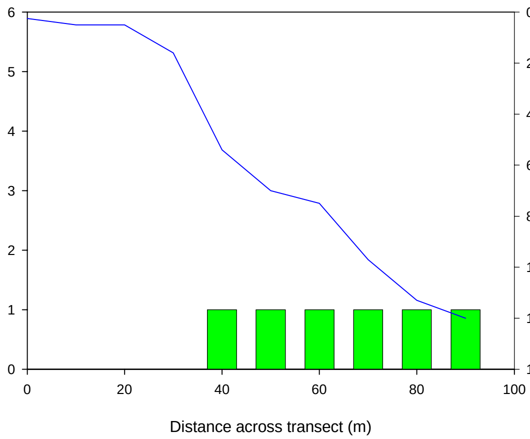


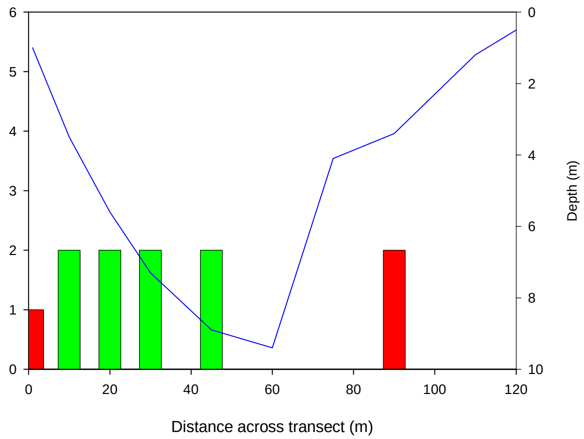
Transect 24



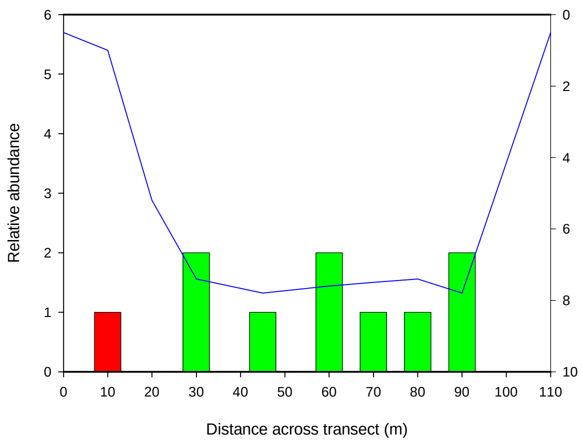

Transect 25



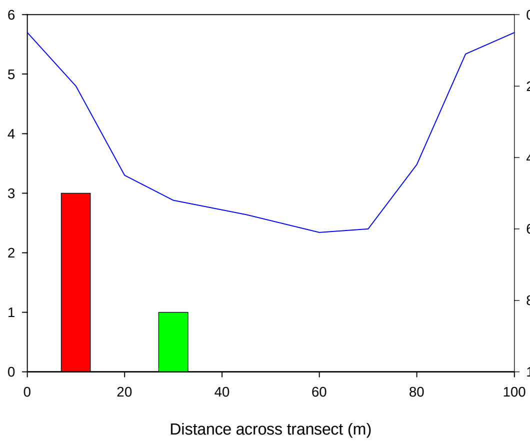

Transect 26

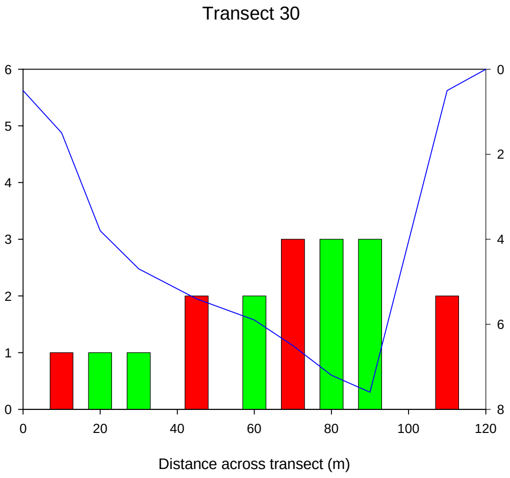


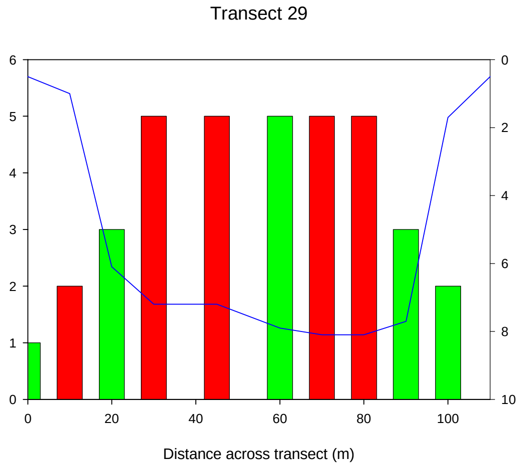

Transect 27

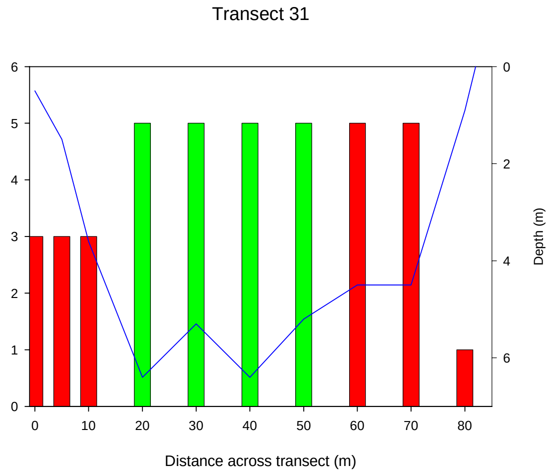


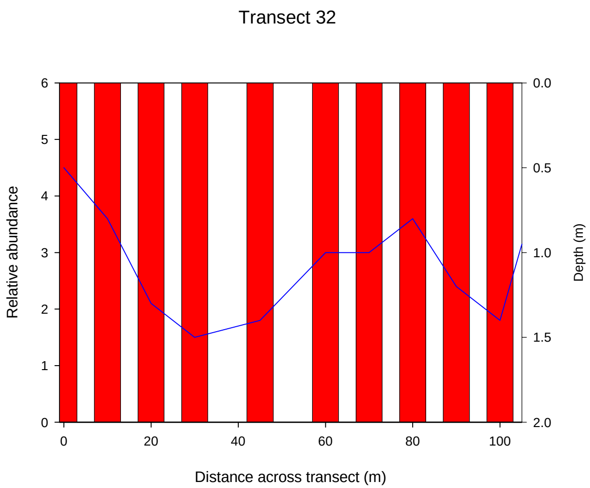

Transect 28




Transect 30
Distance across transect (m)


Transect 29
Distance across transect (m)


Transect 31
Depth (m)
Distance across transect (m)


Transect 32
Relative abundance
Depth (m)
Distance across transect (m)

# Appendix 2

**Table 1:** **Estimates of volume of water in the Waiau Arm based on different water levels in Lake Manapouri. Calculations are derived using a formula developed by Alan Hunt, Maunsell Ltd.**

| Lake Level (m above sea level) | Volume ($m^3$) |
|---|---|
| 176.0 | 2193763.2 |
| 176.2 | 2315928.6 |
| 176.4 | 2446598.3 |
| 176.6 | 2585772.2 |
| 176.8 | 2733450.4 |
| 177.0 | 2889632.8 |
| 177.2 | 3054319.5 |
| 177.4 | 3227510.4 |
| 177.6 | 3409205.6 |
| 177.8 | 3599405.1 |
| 178.0 | 3798108.8 |
| 178.2 | 4005316.8 |
| 178.4 | 4221029.0 |
| 178.6 | 4445245.5 |