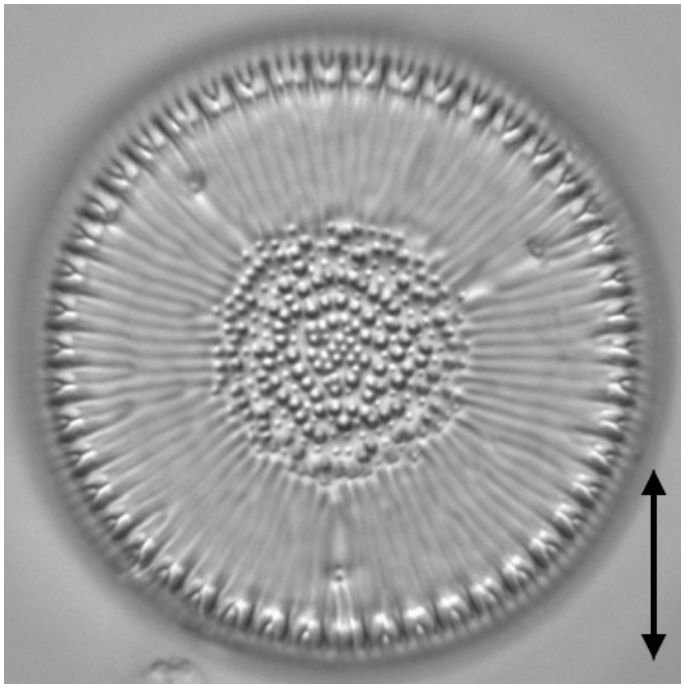
Lake Snow Technical Workshop, 20 December 2016

Report on workshop discussions and outcomes



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Prepared for the Otago Regional Council

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Cover photo: Cross section of *Lindavia intermedia*

CONTENTS

1. Workshop background 4
2. Getting up to speed 5
   2.1 Update on the science of *Lindavia intermedia* and lake snow 5
      2.1.1 Presentation by Marc Schallenberg 5
      2.1.2 Known distribution of *Lindavia intermedia* 5
      2.1.3 Presentation by Phil Novis 6
   2.2 Local authority perspectives/updates 7
      2.2.1 Otago Regional Council 7
      2.2.2 Environment Canterbury 7
      2.2.3 Environment Southland 7
      2.2.4 Queenstown Lakes District Council 8
   2.3 Ministry for Primary Industries 8
   2.4 National Institute of Water and Atmospheric Research 9
3. Does an immediate solution exist to contain or control *Lindavia intermedia* or the production of lake snow? 9
4. Priorities for further investigation and research 11
   4.1 Is *Lindavia intermedia* a native or non-native species? How long has it been here for? 11
   4.2 What are the drivers of *L. intermedia* dominance in lakes and polysaccharide overproduction by *L. intermedia*? 12
   4.3 Can we develop technologies for effective sampling and monitoring of *L. intermedia* and lake snow? 13
   4.4 How might the spread of *L. intermedia* between lakes be stopped or slowed? 13
   4.5 Other priority research/work areas discussed during the lake snow Technical Workshop 14
5. Breakdown of indicative costs for research priorities 15

Appendix A: Workshop Participants 16

Appendix B: Recommended Research and Investigation 17

1. Workshop background

Late last year, Otago Regional Council (ORC) staff organised and hosted a technical workshop to discuss aspects associated with the lake snow phenomena that has developed in some of Otago's largest alpine lakes in recent years. The invited participants represented a mix of New Zealand based algae and lake experts, regional council freshwater scientists and biosecurity staff along with ORC management. A full list of workshop attendees is presented in Appendix One at the back of this report.

Ryder Consulting was contracted to facilitate the workshop and record the proceedings. This report describes the workshop and its proceedings.

A workshop agenda and set of objectives were pre-circulated along with other background information on lake snow with the purpose of ensuring that the day remained focused on producing useful outcomes for decision makers based on the two key objectives for the day, which were:

1. To develop and prioritise research questions relevant to the identification of potentially feasible methods of managing the effects of lake snow.

2. To scope the methodology, timeframe and resource requirements for answering each research question.

The workshop was structured around four broad themes aimed to bring all the participants up to speed on our current knowledge of the lake snow phenomena and our level of understanding in the New Zealand context, and then to focus on addressing the two workshop objectives. The four themes were:

(i) Getting up to speed.

- Update on the science of *Lindavia intermedia* and lake snow;
- find out where local & government authorities are at with the issue;
- understand the level of community & stakeholder concern.

(ii) Canvas the experts on whether an immediate solution exists to contain or control *Lindavia intermedia* or the production of lake snow.

(iii) Formulate research priorities based on information required to identify potentially feasible methods for managing the effects of lake snow.

(iv) Determine a strategy for delivery of information.

The outcomes of discussion of these themes are presented below under appropriate headings. These are followed by some commentary on priorities for research and investigation priorities recommended by the experts to address the workshop priorities.

2. Getting up to speed

2.1 Update on the science of *Lindavia intermedia* and lake snow

2.1.1 Presentation by Marc Schallenberg

Technical information was presented by Dr Marc Schallenberg (Research Fellow at University of Otago) and Dr Phil Novis (Phycologist Researcher at Landcare Research). These two scientists have undertaken the bulk of research to date on lake snow and *Lindavia intermedia* in New Zealand.

Dr Schallenberg described how lake snow can be regarded as a biofilm, slime or flocculent that binds together biological and physical particles. This aggregation process has the effect of concentrating nutrients and aquatic life (e.g., bacteria, phytoplankton and zooplankton) with potential flow-on effects to the lake ecosystem through:

- shortening of the lake food chain (more efficient energy transfer);
- potentially changing the sinking rate of biological materials to the lake bed;
- potentially changing how nutrients are cycled within the lake.

There has been a noticeable change in the planktonic algae community in Lake Wanaka from 2008 to 2016. The diatom *Lindavia intermedia* (formally known as *Cyclotella bodanica*) is now a dominant species, indicating a shift in species composition in the phytoplankton from picocyanobacteria-dominance to diatom-dominance. Sediment core samples collected from the lake bed show that the dominant diatom species in the lake changed to *Lindavia intermedia* around early to mid-2000s. The core samples indicate that *Lindavia intermedia* was not present earlier than this time, indicating that it may not be a naturally occurring diatom in the lake. The origin of *Lindavia intermedia* in New Zealand lakes is currently unknown. It may or may not be a new species. Globally, there are reports of it being found in North America and Western Europe.

Dr Schallenberg explained that lake snow is caused by the excretion of a type of polysaccharide mucilage by *Lindavia intermedia* that form aggregates known as transparent exopolymer particles (or TEPs). It is the excessive production of this mucilage which is causing concern. Algal abundance is related to TEP production such that, more algae results in more TEP production. All centric-type diatoms, such as *Lindavia intermedia*, produce TEP, but *Lindavia intermedia* produces more than others.

2.1.2 Known distribution of *Lindavia intermedia*

At the time of the workshop, *Lindavia intermedia* was confirmed as being present in the following New Zealand lakes:

- Coleridge
- Hawea

- Moke
- Wakatipu
- Wanaka

It has been found previously in Lake Dunstan (2015), Lake Benmore (2003), Lake Aviemore, Lake Hayes (prior to 2003) and Lake Waikaremoana in the North Island (2008), however it does not appear to be present in these lakes today. Since the December workshop, *Lindavia intermedia* has been confirmed as being currently present in Lake Waikaremoana, although excessive production of TEP's and lake snow has not been documented from this lake in recent years. Professor Burns noted that in the past, the algae *Cyclotella* that has been previously identified in New Zealand lakes, may have been mislabelled (i.e., it may have been *Lindavia intermedia*, not *Cyclotella*). However, there has been no detailed taxonomic or genetic analysis to confirm those historic samples contained *Lindavia intermedia*.

2.1.3 Presentation by Phil Novis

Dr Novis is an algae researcher at Landcare Research, with particular expertise in genetics and taxonomy. He described how *Lindavia intermedia* is a diatom; a group of algae distinguished from other groups by having a silica wall. Dr Novis noted that centric diatoms (diatoms with radial symmetry or symmetry around a central axis), such as *Lindavia intermedia*, have extremely complicated systematics[1]. Typically algae cells are identified with morphological features using microscope techniques. Development of genetic approaches (using molecular markers) can help differentiate between different species where morphological characteristics are similar. Dr Novis recently developed such markers for *Lindavia intermedia*.

Preliminary genetic work by Dr Novis indicates that there is some detectable genetic variation between NZ and US populations of *Lindavia intermedia*, but how meaningful this is remains unclear. Sediment core samples taken from the bed of Lake Wanaka, found *Lindavia intermedia* in the top part of the core, indicating it is probably a recent introduction to New Zealand.

Dr Novis is undertaking further research, funded by the Otago Regional Council, to determine whether the species is a recent introduction from overseas, and if so, to attempt to locate the source of that introduction. Genetic profiles of samples from three NZ lakes (Coleridge, Wanaka and Wakatipu) will be examined and compared with samples coming from overseas. Getting samples from overseas has proved difficult up to now, in part due to the northern hemisphere just coming out of winter (meaning many lakes have been frozen and unable to be sampled). Dr Novis commented that the last attempt to sequence and assemble a diatom chloroplast genome was very successful, and they have succeeded previously in developing markers from chloroplast and nuclear genomes for addressing similar questions, including from diatoms.

[1] Systematics is the field that deals with how organisms are separated and classified into distinct species or taxonomic groups.

2.2 Local authority perspectives/updates

Presentations were then made by staff from Otago Regional Council, Environment Canterbury, Environment Southland and Queenstown Lakes District Council.

2.2.1 Otago Regional Council

Dr Adam Uytendaal and Dr Dean Olsen described how ORC's past SOE lake sampling programme had limited ability to detect *Lindavia intermedia* and lake snow, and consequently a more targeted monitoring program had to be introduced. As part of the SOE lake monitoring program, a three-year intensive boat-based monthly monitoring programme commenced in September 2016, on lakes Wanaka, Hawea, Wakatipu and Hayes. Extra parameters have been included to better inform on lake snow dynamics. Zooplankton and phytoplankton community composition is sampled routinely. ORC also undertake 'snow tows' to detect the presence of lake snow. A snow tow is a downrigger towed through the water column at a set depth, speed and distance, allowing a quantitative assessment of lake snow (i.e., biomass of lake snow per unit of sampling effort) to be determined. This method is repeatable over sites and lakes. ORC staff are also interested in assessing other parameters to measure to investigate the presence and abundance of lake snow, such as *Lindavia intermedia* cell counts. Currently, ORC staff are working with laboratories and service providers to develop techniques to provide this information on a routine basis.

Dr Uytendaal and Dr Olsen explained to the workshop that ORC's focus is on providing answers for the public and on preserving Otago's lakes. They noted that the public are seeking concrete action, however, unfortunately, there is a worldwide lack of precedent and no template to follow with lake snow, hence the need for this workshop with collective expertise. Public meetings in Wanaka and Queenstown had revealed great concerns, including whether the 'Check, Clean, Dry' method is suitable for lake snow, and calls for introducing cleaning procedures for multisport events (e.g., Challenge Wanaka) to prevent further spread.

2.2.2 Environment Canterbury

Environment Canterbury's interest in lake snow was conveyed by Dr Adrian Meredith and Ms Sian Barbour. They noted that *Lindavia intermedia* has been confirmed in Lake Coleridge, which is a major reservoir for Canterbury's water infrastructure. Water from the lake is released down the Rakaia River for irrigation, therefore there are potential issues with clogging water filters and other irrigation infrastructure.

Environment Canterbury's SOE monitoring programme covers 30 lakes, but currently the programme is not geared towards detecting *Lindavia intermedia* or lake snow. Consequently, ECan's interest at this stage was one of getting up to speed on what is known about lake snow and how best to detect its presence.

2.2.3 Environment Southland

Mr James Dare and Mr Randall Milne from Environment Southland reported that Environment Southland had begun monitoring for lake snow across five sites in lakes

Manapouri and Te Anau, using similar methodology to that employed by ORC. Environment Southland's concerns were similar to ECan's, that is, avoiding the spread and distribution of lake snow. They reported that public awareness in Southland is quite low and currently there is no education programme in place and no message being conveyed to the public about lake snow. Environment Southland was keen to learn what measures the public can take to help by cleaning gear (e.g., using a 'Clean, Check, Dry' message) and how to slow the transfer of *Lindavia intermedia* to other lakes.

Mr Dare raised the potential effect of light limitation in lakes Manapouri, Te Anau, and Hauroko, due to humic input from surrounding beech forests, affecting the sensitivity of these lakes to lake snow. The potential risk of lake snow over the busy Christmas holiday period was also raised, particularly with the uncertainty and difficulty in cleaning gear to reduce potential spread of *Lindavia intermedia*.

2.2.4 Queenstown Lakes District Council

Dr Deborah Lind explained how the QLDC's focus was the direct impact on infrastructure, although there was an awareness of the potential impact on tourism. Filters and intakes associated with Lake Wanaka and Wakatipu were being clogged, resulting in low water pressure, affecting the drinking water supply. Some investigation into relocating lake intakes to deeper water and improved treatment methods had been considered, however data collected by QLDC indicated that this was not an option.

It was suggested QLDC may be able to check its records to determine whether there have been any change in the number of lake snow complaints through time, or whether there been any changes in where the complaints were coming from. Such information may help give clues as to whether lake snow is increasing in its abundance and distribution in lakes Wakatipu and Wanaka.

2.3 Ministry for Primary Industries

MPI staff (Mr Brian Quinn and Ms Rose Bird) explained that their role is focussed on the detection of new organisms and potential threats to New Zealand's environment. MPI run the 'Check, Clean, Dry' program, which has expanded to not just cover Didymo, but also other pest plants (e.g., *Lagarosiphon* and hornwort). The validity of this program to lake snow was queried by workshop participants. MPI currently have a work program with NIWA to look at the effectiveness of 'Check, Clean, Dry' on other invasive species. It has recently been confirmed that this program will also look at *L. intermedia* and lake snow.

Central government's involvement with lake snow was also queried by other workshop participants and it was explained that MPI's involvement would require a case to be lodged formally, by telephone, and that lake snow, or more specifically *Lindavia intermedia,* would need to be identified as a new organism to New Zealand. Once a new incursion has been validated, the process moves to a response team. Once involved, MPI could assist regional councils with diagnostics and logistics.

Since the December workshop, a letter from Otago Regional Council to MPI formerly advised

MPI of the likely incursion of *Lindavia intermedia* into lakes Wanaka, Wakatipu and Hawea.

2.4 National Institute of Water and Atmospheric Research

Diatom expert Dr Kilroy was heavily involved in research around the Didymo incursion and investigated methods to curb its spread. She expressed the view that the 'Check, Clean, Dry' message, similar to that used in the Didymo incursion, is a good message as a matter of principle[2]. She made the point that if lake snow is a recent incursion, then it could continue to spread to other lakes, therefore it was important to know where it occurs by undertaking delimiting surveys, such as were undertaken with Didymo. These surveys can determine where *Lindavia intermedia* is present, but not necessarily whether lake snow was being produced. Dr Novis pointed out that when *Lindavia intermedia* is present in low numbers, such as in previous years, there were no complaints from the public. So it can be present, but not necessarily abundant.

3. Does an immediate solution exist to contain or control *Lindavia intermedia* or the production of lake snow?

The workshop participants then entered into a robust discussion on whether a 'silver bullet' solution existed to deal with *Lindavia intermedia* and lake snow. After some discussion, the experts agreed that they knew of no control for diatoms worldwide that would not affect other, non-target organisms. It was also highlighted that *Lindavia intermedia* would remain in sediments on the lake bed (in spore form) regardless of treatment of the water column, resulting in an extremely high potential for regeneration. The cost of an attempted eradication was also regarded as potentially huge, and one which could only be considered as viable if there was no chance of recolonisation.

A targeted genetic-based solution, such as bio-control specific to the species, was discussed, but it was not known if such an approach had been attempted elsewhere. However, experts were of the view that if a solution to remove an algal species from a large lake has been found overseas, it would be well known. Other peripheral issues and questions around targeted treatment were raised. For example, as *Lindavia intermedia* populations exist in smaller nearby lakes (e.g., Moke Lake), which lake or lakes would be targeted? Parallels were drawn with other invasive aquatic species such as Didymo and *Lagarosiphon*. *Lindavia intermedia* may be more difficult to eradicate than Didymo. It occurs throughout a large section (>30 metres) of the water column in lakes, whereas Didymo attaches to rock surfaces. The ecology of Didymo is much better understood now than it was ten years ago, yet it is still unable to be controlled. Professor Burns noted that there is a worldwide increase in centric

[2] The ORC letter to MPI also also requested that research into the effectiveness of 'Check, Clean, Dry' message for lake snow be given priority and that it be accelerated if practicable.

diatoms, such as *Lindavia intermedia*.

In general, workshop participants considered that there is potential scope for developing management options to reduce the problem of lake snow if the mechanisms underlying its production and distribution can be understood. The discussion on an immediate solution culminated in the development of the following workshop statement:

"*The workshop participants discussed whether a known and practical solution exists for ridding the planktonic organism, Lindavia intermedia, that produces the material responsible for lake snow from affected lakes. The participants unanimously agreed that no such solution exists.*

While chemicals exist that are known to effectively kill algae, including phytoplankton diatoms (such as chemicals used in swimming pools), they are non-selective and likely to kill all other plankton species within the application area. The exact ecological consequences of such non-selective destruction to the planktonic community are unknown, but are more than likely to be extremely negative for the lake ecosystem and the lake outflow river. Further, the scale of application that would be required to achieve total eradication in lakes the size of Lake Wanaka would be massive, with unproven outcomes.

While emerging technologies may lend themselves to targeting the control of a specific organism (e.g., bio-control agent), no such technology currently exists for Lindavia intermedia or other similar organisms."

4. Priorities for further investigation and research

The latter part of the workshop focused on issues and questions around developing research priorities to increase our level of understanding about lake snow and to identify potentially feasible methods for managing its effects. A draft list of research priorities prepared by Dr Novis and Dr Schallenberg was used as a basis for discussion. These are summarised in the table presented in Appendix Two and have been colour-coded to indicate a general level of priority, based on the need for information. Feedback from the experts since the workshop indicated some subtle changes in the table, however it is fair to say that most viewed the majority of research recommendations are either having high or medium-high priority. The priority ranking also attempts to recognise that some components will take longer to organise and undertake whereas others (e.g., literature reviews) are less reliant on external factors (e.g., equipment, seasonal components, etc.).

The following sub-headings present key questions that were identified and discussed further with respect to developing a research and investigations programme. A more comprehensive list is presented in Appendix Two.

4.1 Is *Lindavia intermedia* a native or non-native species? How long has it been here for?

The experts considered these questions are important for the following reasons:

(i) If *Lindavia intermedia* is a native species, then understanding what has triggered its recent increase in distribution and abundance is necessary in order to steer us in the right direction on effective management options.

(ii) If *Lindavia intermedia* is a recently introduced species that prefers low-nutrient, high clarity lakes, then it may mean we have to live with its presence, but develop management strategies to minimise its effect on lake users.

If *Lindavia intermedia* is found to be non-native, MPI and central government can assist. Otago Regional Council staff commented that, from a council perspective, the management of lake snow would not change if it was found to be native or non-native.

The question of native or non-native was regarded as a top priority area to focus on to help support the direction of some of the other recommended work streams. Three research approaches were recommended to address this question:

a) Investigation of cell genetics (chloroplast microsatellite analysis). This is currently underway, with funding from Otago Regional Council, but won't be completed until the middle of 2017. The work requires samples from overseas and these won't be available until after the northern hemisphere winter. High quality samples, dominated by the species, are required.

b) Comprehensive examination of NZ diatom samples, collections and reports. It is noted that some field sampling is already underway in Canterbury. Collections from Canterbury lakes started in February (funded by ECan, including checking samples for presence of *Lindavia* and preparing voucher specimens (slides) from all samples). It is also noted here that some checking of historical records has already been completed and some experts have since considered that there may be limited value in further searching for historic diatom samples, unless they have been catalogued (to avoid spending excessive time searching for material).

c) Historical dynamics of *L. intermedia* in NZ lakes from which it has been reported using paleolimnological diatom analysis of dated sediment cores. So far, core data has been obtained from lakes Wanaka, Wakatipu and Coleridge. So these lakes probably do not require further sampling.

4.2 What are the drivers of *L. intermedia* dominance in lakes and polysaccharide overproduction by *L. intermedia*?

Understanding why *L. intermedia* has become the dominant phytoplankton in several of our lakes was considered to be a key step in being able to determine whether its dominance and spread can be managed. Similarly, understanding what triggers the overproduction of TEPs is a vital knowledge component for considering potential management options. To address these questions, the following research approaches were recommended:

a) Literature review of shifts in lake phytoplankton to increased abundance of centric diatoms. A review of current knowledge about the species including distribution, biology and environmental preferences was considered to have a high priority.

b) Are historical *L. intermedia* dynamics correlated to environmental drivers in our lakes? The experts regarded addressing this question had a high to medium-high priority. This area of work is also subject to a MBIE Endeavour Fund Research Programme Proposal led by the University of Otago in collaboration with various stakeholders and other research entities. A component of this multi-discipline proposal includes lake functioning (i.e., drivers, responses, hotspots, hot moments) and key indicators of change. Lake snow investigations and other lake water quality monitoring would form a part of this component. This funding proposal is still being developed and it won't be known until later in the year whether the funding proposal is successful.

Another related question posed by the experts in relation to drivers was whether proliferations of *D. geminata* (Didymo) and *L. intermedia* in South Island waters, and the over-production of polysaccharide by these two species, were related to a common driver or drivers or a common incursion (invasion) event. Both species suddenly appeared in the early 2000s in oligotrophic (extremely low nutrient) South Island waters.

Understanding polysaccharide (TEP) overproduction is a key issue to understanding the reasons behind lake snow presence in New Zealand lakes and the experts considered this

issue to have a high priority. They recommended the following two main work streams be undertaken:

a) A comprehensive literature review on diatom polysaccharide overproduction in lakes. This is seen as a fundamental, first step requirement prior to commencing any detailed studies, and should progress as soon as possible.

b) Studies of the relationships between diatom polysaccharide overproduction in New Zealand lakes and (1) nutrient availability, (2) climate warming, (3) wave action and (4) algae grazing pressure. These are important questions and likely to require research over several years. A range of experiments and investigations were put forward by the experts, including lab-based and in-lake mesocosm [3] experiments, and gathering information about conditions associated with lake snow blooms in lakes.

4.3 Can we develop technologies for effective sampling and monitoring of *L. intermedia* and lake snow?

Monitoring programmes are considered not sufficiently robust for lake snow detection. The methods currently used to detect lake snow are basic and provide limited information on the vertical and horizontal distribution within the lake water column. A better understanding of the presence of *L. intermedia* and lake snow within a lake is required to help more accurately determine linkages with environmental drivers.

Research approaches recommended by the experts include:

- The development of new sensor technology to monitor *in situ* polysaccharide (TEP) concentrations in lakes – ie the presence of the 'lake snow' mucus
- The development of cost-effective and efficient methods for quantitatively sampling lake snow (at different depths).
- Determining whether environmental DNA methods could be developed for the sensitive detection of *L. intermedia* in lakes.

The first two approaches were considered to have a high to medium term priority. There was considerable discussion around potential monitoring approaches and methods. University of Otago and University of Waikato staff indicated that they have lake monitoring equipment potentially available for trialling in Lake Wanaka.

4.4 How might the spread of *L. intermedia* between lakes be stopped or slowed?

This is perhaps an obvious question, but it is clear that the proliferation of *L. intermedia* is

[3] Mesocosms are typically enclosures (e.g., large polyethylene bags) that enable control over environmental conditions for experimental purposes. They are frequently used in lake investigations to control variables like zooplankton densities and nutrient concentrations.

already causing concern in Lakes Wanaka and Wakatipu, and the overproduction of polysaccharide is proving more than a nuisance to some users of these lakes. It is possible that the current situation could worsen in these lakes, and the risk of *L. intermedia* spreading to other lakes and dominating the phytoplankton community is real with uncertain outcomes.

Some experts considered extensive and accurate surveys to understand the spatial distribution of *Lindavia intermedia* throughout New Zealand is critical to support containment and treatment. At present ORC, Environment Southland and ECan staff are working with algal experts to develop screening techniques that will allow this.

Research questions posed at the workshop included:

- Are the Biosecurity New Zealand Didymo sanitation methods adequate for the disinfection of *L. intermedia*?
- Are additional scrubbing methods needed to remove *L. intermedia* from boats and recreational equipment?

It is understood that, since the workshop, MPI has asked NIWA to run trials to determine whether the 'Check, Clean, Dry' methods currently recommended for Didymo are also effective on *Lindavia intermedia*. Preliminary preparation for these trials has been undertaken and NIWA are waiting for a supply of fresh material to run tests. Tests are expected to be completed by the end of June (dependent on obtaining suitable material to work on). ORC staff are assisting NIWA and MPI with the collection of this material.

4.5 Other priority research/work areas discussed during the lake snow Technical Workshop

There was discussion at the workshop around more immediate simple methods for obtaining information on the presence of lake snow. These included a citizen science approach that provided accessible and quick feedback mechanisms for detecting and reporting lake snow (e.g., web reporting). It is noted that ORC has since implemented a lake snow online reporting form (https://form.jotform.co/63557436856873).

As already addressed, some of the above work components are already underway (genetic identification of *Lindavia intermedia*, sampling of Canterbury lakes for identification of algae, NIWA trials on the 'Check, Clean, Dry' approach, further identification of algae samples from other New Zealand lakes), and funding applications for some components are in preparation through other funding processes (e.g., Otago University's MBIE research application 'Sustaining the Southern Great Lakes'). Further, ORC staff last month undertook trials of the 'BioFish', an advanced water quality testing instrument that is capable of collecting real-time data on water depth, temperature, conductivity, dissolved oxygen, chlorophyll fluorescence, light transmittance and photosynthetic active radiation as it is towed through the water column. The trial aims to see if the BioFish can be used to measure the presence and distribution of lake snow in greater detail than has previously been capable.

5. Concluding comments

Following the workshop, the experts were forwarded a list of the research and investigation items discussed at the workshop (as described above), and were asked to comment on their appropriateness and relative priority listing. While there was some range of views within the experts around the priority for various research components, these differences were fairly subtle and a general view remained that the majority of items had a high to medium-high priority.

Appendix A: Workshop Participants

Dr Gavin Palmer, Otago Regional Council
Dr Dean Olsen, Otago Regional Council
Dr Adam Uytendaal, Otago Regional Council
Mrs Rachel Ozanne, Otago Regional Council
Mrs Emma van der Merwe, Otago Regional Council (minutes)

Dr Phil Novis, Landcare Research
Dr Marc Schallenberg, University of Otago
Associate Professor Gerard Closs, University of Otago
Emeritus Professor Carolyn Burns, University of Otago
Professor David Hamilton, University of Waikato
Dr Dave Kelly, Cawthron Institute
Dr Cathy Kilroy, National Institute of Water and Atmospheric Research

Dr Adrian Meredith, Environment Canterbury
Ms Sian Barbour, Environment Canterbury
Dr Deborah Lind, Queenstown Lakes District Council
Mr James Dare, Environment Southland
Mr Randall Milne, Environment Southland

Mr Brian Quinn, Ministry for Primary Industries
Ms Rose Bird, Ministry for Primary Industries

Dr Greg Ryder, Ryder Consulting (facilitator)
Mr Ben Ludgate, Ryder Consulting (note taking)

Appendix B: Recommended Research and Investigation

Priority Ranking	Code
High - Immediate	
High - Medium term	
Medium - Medium term	

RESEARCH GROUP	COMPONENT	PRIORITY RANKING	INDICATIVE TIMING
Is *Lindavia intermedia* a native or non-native species? How long has it been here for?	(i) Investigation of cell genetics (microsatellite analysis) that is underway, but won't be completed until the middle of 2017. (ii) Comprehensive examination of NZ diatom samples, collections and reports. (iii) Historical dynamics of *L. intermedia* in NZ lakes from which it has been reported using palaeolimnological diatom analysis of dated sediment cores.		mid 2017 3-6 months from starting
What are the drivers of: ***L. intermedia* dominance in lakes; and polysaccharide overproduction by *L. intermedia*?**	A. *L. intermedia* – drivers behind distribution (i) Literature review of shifts in lake phytoplankton to increased dominance by centric diatoms. (ii) Are historical *L. intermedia* dynamics correlated to environmental drivers in our lakes? [Note: This work is covered in the University of Otago MBIE bid.] (iii) Are proliferations of *D. geminata* (Didymo) and *L. intermedia* in South Island waters related to a common driver?		3-6 months from starting hard to estimate
	B. Polysaccharide overproduction (i) Comprehensive literature review on diatom polysaccharide overproduction. (i) Study of the relationships between diatom polysaccharide overproduction in NZ and; (1) nutrient availability, (2) climate warming, (3) wave action and (4) grazing pressure. [Note: This work is covered in the University of Otago MBIE bid.]		3-6 months from starting possibly 2-3 years from starting

RESEARCH GROUP	COMPONENT	PRIORITY RANKING	INDICATIVE TIMING
Can we develop technologies for effective sampling and monitoring of *L. intermedia* and lake snow? [Note: All of these points are covered by the University of Otago MBIE.]	(i) The development of new sensor technology to monitor *in situ* polysaccharide concentrations in lakes. (ii) The development of cost-effective and efficient methods for quantitatively sampling lake snow in lakes (at different depths). (iii) Can environmental DNA methods be developed for the sensitive detection of *L. intermedia* in lakes?		possibly 2-3 years from starting 1-1.5 years from starting 6 months from starting
How might the spread of *L. intermedia* between lakes be stopped or slowed? [Note: assumes implementing a containment program is worthwhile]	(i) Are the BNZ Didymo sanitation methods adequate for the disinfection of *L. intermedia*? (ii) Are additional scrubbing methods needed to remove *L. intermedia* from boats and recreational equipment? (iii) Does lake snow contain viable *L. intermedia* cells when dry?		Currently underway 6 months from starting
Other priority research/work areas discussed during the December lake snow technical workshop.	(i) Support for citizen science – web reporting of lake snow encounters. (ii) Working with the professional trout guide community to document lake snow dynamics around the lakes.		Otago Regional Council already have established an online reporting system