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Identifying the environmental effects of sphagnum moss harvesting on wetlands

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Contents

Summary

Project and client

- West Coast Regional Council sought an updated review of the effects of moss harvesting following submissions received on a proposed plan change to remove sphagnum moss harvesting from the definition of vegetation disturbance in the Regional Land and Water Plan 2016.

Objectives

- To review the techniques for harvesting sphagnum moss from wetlands on the West Coast.
- To identify any environmental effects on wetlands (positive and negative) of harvesting.
- To assess whether any identified negative effects could be managed through standard conditions.

Methods

- Previous research was reviewed.
- Interviews were held with key stakeholders.
- Field inspections were made to assess current techniques and impacts.

Results

- Most submitters opposed to Plan Change 1 were concerned that there was no scientific evidence presented to show that sphagnum harvesting impacts were minor, or that such harvesting could be achieved sustainably. The international literature suggests that sphagnum harvesting can be sustainably managed.
- Traditional management has resulted in increased woody vegetation and decreased sphagnum yields in previously harvested conservation areas, whereas current practices on private land have increased sphagnum yields, with temporary minor impacts on vegetation and wildlife.
- The negative impacts of harvesting are generally short term and minor.

Conclusions

- Both managers and harvesters wish to protect the wetlands that nurture the sphagnum moss resource.
- Few of the currently identified Schedule 2 wetlands occur on private land, and only two of those are known to have been harvested.

- Without a rule, condition or consent process there is no guarantee that current practices will be employed by all harvesters. The concern expressed by many of those opposed to the rule change is that, as proposed, the plan change would allow cutting and crushing of vegetation in any Scheduled wetland.
- Whether to allow harvesting in a Scheduled wetland will depend on the ecological values that are to be protected or promoted. Harvesting may provide useful management in anthropogenic wetlands.

Recommendations

The options available to the Council for managing sphagnum harvesting on Scheduled wetlands include:

- Excluding sphagnum harvesting from the definition of vegetation disturbance may present the Council with a risk under its obligations to protect biodiversity in Scheduled wetlands.
- It is probably not feasible to allow harvesting only in geographically identified wetlands within the relevant timeframes.
- Allow sphagnum harvesting on Scheduled wetlands as a permitted activity rule with conditions. The conditions would need to be able to control the effects of the activity.
- Allow sphagnum harvesting on Scheduled wetlands as a controlled or limited discretionary activity. Sites and harvesting operations should be considered on a case-by-case basis.
- Impose conditions through a permitted activity rule, or on any resource consent, to enable the Council to monitor the effectiveness of the rule.
- Conditions could also set guidelines for harvesting methods on Scheduled wetlands.
- It is also recommended that a programme for monitoring be considered and implemented, regardless of which option is pursued.

1 Introduction

Sphagnum moss has been harvested from West Coast wetlands since the early 1980s from both private and Crown land, the latter under licence. More recently most harvesting has been from private land.

The main species harvested, *Sphagnum cristatum*, forms hummocks and carpets, which often dominate large areas of wetland. This is particularly so in open areas where the water table is high and the moss is not shaded by competing vascular plants. Excess water promotes the dominance of mire plants and impedes the decomposition of their dead remains, which, consequently accumulate as peat (Minayeva et al. 2017). Peatland plants like sphagnum create conditions suitable for their own self-maintenance.

Worldwide, large areas of peatlands have been drained to facilitate agriculture, forestry and peat extraction. These activities destroy the biodiversity, carbon storage capacity and hydrological regulation function of fens and bogs (Temmink et al. 2017). While sphagnum harvesting impacts are seldom this severe, careless management activities can have negative ecological effects.

There was therefore some opposition to West Coast Regional Council's Proposed Plan Change 1, which sought to remove sphagnum moss harvesting from the definition of vegetation disturbance in the Regional Land and Water Plan 2016.

2 Background

As a result of an Environment Court case in 2012 a number of minor changes were made to the West Coast Regional Land and Water Plan (May 2014), which resulted in resource consent being required to harvest sphagnum moss from Scheduled wetlands. This was understood by the West Coast Regional Council to be an unintended consequence of the Court decision, and the Council also understood that at the time the parties agreed that a permitted activity rule would probably be sufficient to manage any adverse effects from the activity.

In the lead up to Plan Change 1 on the Land and Water Plan (2016), the Council reviewed existing available research on the harvesting of sphagnum moss. From this research it appeared that the effects of the activity were negligible, and so the Council agreed to amend the definition of vegetation disturbance to exclude the harvesting of sphagnum moss to make it an activity that did not require consent rather than a permitted activity.

In response to notification of Plan Change 1, a number of submissions were received from environmental groups opposed to the harvesting of sphagnum moss in Scheduled wetlands. They disputed the Council's understanding of the original Environment Court case and felt that the commercial harvesting of sphagnum moss could have negative impacts on wetlands. Local harvesters expressed a contrary view and argued that harvesting moss is an activity that contributes to the long-term sustainability of the wetlands.

Landcare Research was contracted to provide an independent review of the effects of moss harvesting and to assess the Council's options for managing Schedule 1 and 2 wetlands.

Schedule 1 wetlands have been verified by ground assessments and include some of the significant wetlands in the region. Schedule 2 wetlands are likely to be significant, based on aerial mapping, soils and size, but have not been assessed for ecological significance. Ultimately, ecological assessments of Schedule 2 wetlands will be made using criteria in Schedule 3 (Appendix 1) to determine significance, and they will either be included in Schedule 1 or removed from Schedule 2. Specified activities on Schedule 1 and 2 wetlands require resource consent, which under the current Plan includes sphagnum moss harvesting.

Sphagnum wetlands are variously referred to as bogs, fens, swamps or pākihi, and collectively these are called mires or peatlands. These types are separated by differences in substrate and water regime, but they often co-occur (Johnson & Gerbeaux 2004).

In Westland, sphagnum peatland communities have been favoured by activities associated with past logging of native forests. Tramways have impeded drainage and forest removal has raised the water table. Here sphagnum occupies a transitional phase to closed shrubland and forest that would ultimately reduce its abundance. Although forest clearance has led to sphagnum abundance in the first instance, it is the disturbance associated with continued harvesting of sphagnum moss (particularly cutting and crushing of vegetation) that appears to be maintaining sphagnum dominance. These cut-over forests are now some of the major sites of commercial sphagnum harvesting in the South Island (Whinam et al. 2003; Díaz et al. 2007).

3 Objectives

- To review the techniques for harvesting sphagnum moss from wetlands on the West Coast.
- To identify any environmental effects on wetlands (positive and negative) of harvesting.
- To assess whether any identified negative effects could be managed through standard conditions.

4 Methods

Previous research was reviewed and interviews were held with key stakeholders (environmental groups and commercial harvesters). Field inspections were made to assess current techniques and the impacts of harvesting.

5 Concerns expressed by submitters

These concerns fell into four main categories:

- widespread loss of wetlands
- protection of natural character, indigenous biodiversity and other values of wetlands in the region
- the need to ensure the natural character of wetlands and associated ecosystems (including ecosystem functions and habitats) is sustained
- the need to manage all wetlands sustainably.

Jen Miller (Royal Forest and Bird) was concerned that removing sphagnum harvesting from the definition of vegetation disturbance would allow harvesting and associated activities to occur on any wetland, with resulting loss of biodiversity. While current harvesters may agree to operate in a way that is mutually beneficial for themselves and the wetlands, there is some apprehension that without some form of control or guidelines there is no guarantee that this would continue if, for example, the industry expanded in the future. She would like to see a list of parameters that would exclude particular wetland types from sphagnum harvesting.

There are certainly a number of fragile systems (generally where sphagnum growth is very slow) that should be excluded from harvesting. These include wetland forms such as string-bogs, domed mires, blanket bogs and tarn margins, which typically occupy upland sites above 600 m. Very wet sites such as floating systems and some inter-dune swales should also be excluded.

Most submitters opposed to Plan Change 1 were concerned that there was no scientific evidence presented to show that sphagnum harvesting impacts are minor, or that such harvesting could be achieved sustainably. The Department of Conservation (DOC) also noted a lack of information on the impacts and scale of harvesting.

Some submitters raised concerns over the sustainability of sphagnum harvesting based on observations that the quantity of moss removed decreased with successive harvests. Harvesters agreed that sphagnum yields have decreased on many of the DOC concession areas, but this contrasts with improved yields that have been achieved on some private land. The difference between these outcomes is related to post-harvest management. Harvesters operating on private land have had the freedom to experiment and develop management techniques that would not be approved under current guidelines on public conservation land, because they involve heavy machinery and the cutting of shrubs. However, rather than being detrimental to sphagnum production, it appears that these techniques have increased the biomass of sphagnum obtained per hectare while the sphagnum yield on equivalent DOC concession blocks has decreased.

My cursory observations suggest that while shrub density and biodiversity have increased on the DOC concession blocks relative to those on private land, sphagnum dominance has declined markedly. DOC's position throughout the appeals process was that until the scale of harvesting is known it is not possible to determine the effects of harvesting. It is therefore useful to look at some of the numbers.

Scheduled wetlands in the West Coast Region occupy 57,832 ha, which is 2% of the total area. Most of this (50,404 ha) occurs in Westland District, where only 1,042 ha (2%) is privately owned. Overall, 3,687 ha (6%) of Scheduled wetlands in the region are privately owned. Private ownership of Scheduled wetlands in Buller and Grey Districts is 23% and 56%, respectively. These values do not include the vast majority of wetlands that are harvested for sphagnum. Only two of the Scheduled wetlands are known to have been harvested in the past, and they occur on private land. The Council is unable to differentiate between Crown-owned and privately owned land when determining rules that apply to Scheduled wetlands.

Total sphagnum exports from New Zealand in 2006 came to 500 tonnes. To sustain this on a 6-year cycle requires roughly 500 to 1,300 ha depending on productivity, of which 80 to 200 ha is harvested annually.

There has been a decrease in harvesting concessions on public conservation land, partly due to the decreasing yields outlined above, but also because of greater costs and uncertainty compared with harvesting on private land. While some conservation areas exclude sphagnum harvesting completely, harvesters can still apply for a concession. This requires an initial payment of $1,500, plus costs for an ecological assessment of harvesting impacts on conservation values. If the concession is granted, harvesters tend to pay higher royalties on DOC land than on private land.

Paul Elwell-Sutton (from Haast) suggested in his submission that ‘It may be advantageous and necessary to create a schedule of wetlands available for moss harvesting, plus conditions governing the scale, time and mode of harvesting.’ Identifying which wetlands could be subjected to harvesting may have some merit, as it would provide some certainty and alleviate the fears of all parties.

However, both landowners and harvesters were worried about losing control of activities on private land. There was concern that application of the Schedule 3 process to wetlands where sphagnum moss is currently harvested on private land, even if not listed in Schedule 2, may have an impact on their livelihoods. They were worried that conditions might be imposed on harvesting operations that would decrease yield, stifle innovation, or result in sphagnum-producing wetlands being lost altogether. The latter concern has some validity, as several wetlands have been subjected to wilful damage to lower conservation values or converted to land uses incompatible with wetland recovery, and this has been a loss to both conservation and the moss harvesting industry.

Site visits

Three sites on or adjacent to Schedule 2 wetlands and two sites of current moss harvesting were visited to observe current harvesting techniques, wetland management and recovery. Site examinations were cursory and did not include the compilation of species lists, but they were sufficient to obtain an indication of mire health and sphagnum recovery.

Within each of the harvested sites were areas that had been harvested 6 years previously, as well as areas where current harvesting operations were underway. These sites had been managed by ‘crushing’ vegetation following harvest of the sphagnum.

Some previously harvested sites were also inspected. Two of these had been harvested approximately 6 years before. The first site, on private land, had been regularly harvested approximately every 5–6 years. Bales had been extracted using a modified tractor to reduce weight per unit area, with no long-term negative impacts to the wetland. Sphagnum recovery was good, and it would currently be able to sustain another harvest. Diversity of other native species was relatively low, and woody vegetation was concentrated on the margins.

The second site was on the DOC estate, where presumably shrubs were not cut and bales were removed by helicopter. Sphagnum abundance here had declined, but other native species were doing well and woody species were becoming dominant.

A third site (HOKP119 Lake Mudgie) had been open wetland in 1987 and was where some of the first sphagnum growth trials were established. This is now returning to dense woody vegetation with little sphagnum evident (Figure 1.).

Figure 1. Regenerating shrubland in Lake Mudgie wetland, previously dominated by sphagnum.

Other sites designated Schedule 2 that were not visited as part of this investigation, but with which I am familiar, include REEP009 Rahu Saddle bogs, Ianthe Forest wetland near HARP010, WAIP003 Ōkārito Forks, and portions of HAAP006 and HAAP008 near Haast.

Vegetation history and sphagnum mire formation

Deforestation and fire, particularly since European settlement, has altered the hydrology of many wetland systems, favouring sphagnum dominance, and it is clear that most were drier and woody earlier in their history (McGlone 2009).

Many wetlands where sphagnum harvesting is currently focused would not have existed around 1840 as they would have been forested. While most harvesting occurs in wetlands that most closely resemble pākihi, these sites are generally anthropogenic wetlands, having been induced by a past history of logging, fire or other human disturbance. Forest clearance on poorly drained soils decreases transpiration and generates waterlogged conditions that impair the recolonisation of forest and stimulate sphagnum establishment and dominance (Whinam & Buxton 1997; Díaz et al. 2007). Some of these deforested sites of secondary wetlands have become major sites for the commercial harvest of sphagnum in both New Zealand and Chile (Diaz & Silva 2012).

If there is a desire to maintain the natural values of these anthropogenic wetlands, then active management will be required to prevent them from slowly returning to a forested state. In the Netherlands sphagnum harvesting was allowed in nature reserves (Denne 1983) as harvesting helped to maintain the open character of mires by simultaneously removing some seed plants. Equally, at higher shrub densities, these wetlands may provide important fernbird habitat.

6 Harvesting methods

Twenty-five years ago most harvesting was done by hand, and bale extraction was by a variety of methods, including helicopter, aerial ropeways, wooden tramways, four-wheeled motorbikes, and in one case using a wide-tracked bulldozer and sled (Buxton et al. 1995). At that time it appeared that sphagnum harvesting could be managed sustainably at some sites, but some uncertainty remained over whether the resource could cope with continued demand. Guidelines were suggested (Buxton et al. 1995; Whinam & Buxton 1997; Whinam et al. 2003), but the results of these are unknown.

It was therefore useful to observe harvest sites where several repeat harvests had been made with good sphagnum regrowth and what had been done to achieve this. Conversely, it was interesting to see areas where sphagnum recovery was poor or diminished and explore the reasons for that.

Although harvesting is still done by hand, many of the more damaging methods are no longer used as harvesters and landowners realise the economic value of maintaining healthy mires. The wide-tracked bulldozer and sled method for extracting bales has been developed further. Most commercial harvesters now use heavy machinery that has been adapted to spread the weight of the machines, either through widening the tracks on track-driven vehicles, or by creating wooden platforms so that they can be driven on the wetlands without altering the hydrology (Figure 2).

Figure 2. Heavy machinery supported by a wooden platform has less ground pressure than a person. The stump is a relic of historic forestry.

This is largely to allow the post-harvest vegetation to be crushed and left as a level surface in close contact with the water table (Figure 3), which was the key to the success of the original method. It also relies on operators avoiding repeat passes over the same site, which causes rutting and drainage. The increased yields (Figure 4) that can be obtained through this method have led several landowners to now insist that harvesters crush vegetation in this way after harvest. Others are demanding that bales be extracted by helicopter to maintain wetland water regimes. These methods are similar to recent developments on ‘bog grassland’ in Germany (Wichmann et al. 2017).

Figure 3. Sphagnum wetland after harvest and crushing of vegetation.

Figure 4. Sphagnum harvest 6 years after crushing of vegetation. Yields are four to six times greater than on sites without crushing.

7 Impacts of harvesting

Globally there is a negative perception of sphagnum moss harvesting, particularly because it is sometimes confused with peat extraction, which is often viewed as a non-renewable resource. Sphagnum harvesting involves removing part of the upper, living portion (acrotelm) of a peat bog, whereas peat harvesting removes the lower decomposed layers (catotelm) and so has greater impacts.

Over-harvesting and drainage for agriculture or urban development have contributed to this perception and the loss of many wetlands, especially in Europe. However, researchers have shown that vegetation components of degraded peatlands can be restored relatively quickly (Andersen et al. 2006). The Peatland Ecology Research Group, based at Laval University in Quebec and working in partnership with the Canadian peat industry, have developed a moss transfer technique that can re-establish sphagnum-dominated plant cover within 3–5 years following restoration, with biodiversity and hydrology approaching pre-harvest conditions. Clarkson et al. (2017) report similar recovery times in Australia and New Zealand.

This has led to investigations of sphagnum farming (paludiculture) using previously cut-over bogs as the starting points (Glatzel & Rochefort 2017). Sphagnum farming is defined as the sustainable production of non-decomposed sphagnum biomass on a cyclic and renewable basis. Trials of sphagnum farming in Germany have produced biomass of 19.5 t ha^{-1} after 9 years (Gaudig et al. 2017) and up to 6.7 t·DW·ha^{-1} yr^{-1} (Temmink et al. 2017). Methods involved the installation of underground irrigation pipes and perimeter ditches to regulate the water table, and mechanised harvesting. However, the principle of creating an even surface for moss regrowth is similar to that developed by Westland harvesters.

There is potential for paludiculture to be successful in Westland, particularly on former wetland soils where other agricultural land use may be less desirable. West Coast temperatures are warmer and the growing season longer than at the European sites. While there are obvious costs in establishing paludiculture systems, the advantages over natural wetlands include the design of harvesting areas with access ways to achieve mechanical harvest, greater control over associated vascular vegetation and water regimes, and potentially better growth. Stokes et al. (1999) suggested sphagnum yields could reach 13 t·ha^{-1} yr^{-1} in Westland with appropriate management. In their trials Temmink et al. (2017) found sphagnum was able to sequester nitrogen, which meant it could act to reduce nitrogen inputs into adjacent waterways. Within limits this could make paludiculture a useful tool on wet soils adjacent to dairy or other land uses in Westland. The N:P ratio has proven to be a particularly useful predictor of which nutrient is limiting in oligotrophic sites (Clarkson et al. 2004).

While growth rates in Westland are much faster, results from Finland at $62^{o}47'$N (Silvan et al. 2017) suggest harvesting of sphagnum biomass to a depth of no more than 30 cm has a relatively short-term (<5 years) effect on sphagnum carpet coverage and carbon sequestration, allowing a harvesting cycle of c. 30 years. They proposed that environmental effects would be negligible compared with the conventional extraction of white horticultural peat, and suggested sphagnum harvesting is more comparable with sustainable forestry.

When comparing sphagnum harvesting to forestry or agriculture conversion, Denne (1983) concluded that sphagnum harvesting was unlikely to change the basic ecosystem structure and function of mires. However, he suggested that some sensitive elements could be lost or reduced, particularly South Island fernbirds, through the loss of suitable habitat, and therefore proposed leaving some undeveloped land surrounding harvested mires. Beyond the shelter of shrubs, sphagnum can suffer from wind exposure, therefore retaining corridors of shrub cover is not only good for the ecological outcomes of the wetlands but may help to improve sphagnum growth for harvesters.

Potential negative impacts

The potential ecological impacts of sphagnum harvesting in New Zealand were first investigated in the 1980s (Denne 1983; Johnson 1988). Wetland health can decline through changes in hydrology, water pollution, nutrient enrichment, and invasion by weeds and pests, which lead to biodiversity loss and impaired wetland functioning (Clarkson et al. 2004). Sphagnum mires are very sensitive to human impact; for example, trampling may induce small pools, while removal of sphagnum in other sites may cause the substrate to dry out and slow regrowth (Denne 1983). Díaz and Silva (2012) note that indiscriminate exploitation in Chilean wetlands could cause disruption of sphagnum ecosystems, changes in water storage capacity and reduction of biodiversity.

These effects may be short or long term depending on their severity. Harvesting exposes sites to the risk of weed invasion, particularly on drier margins. Gorse and Spanish heath can be problematic, and *Sphagnum subnitens* can increase in areas where *S. cristatum* is preferentially harvested. There is the potential risk of pollution (oil or fuel) from machinery, and possible degradation of mudfish habitat. Dragging of bales by hand or use of quad bikes can result in localised drainage.

Succession to taller, woody vegetation is delayed by harvesting. This can be either positive or negative depending on the ecological values of the site (Figure 5).

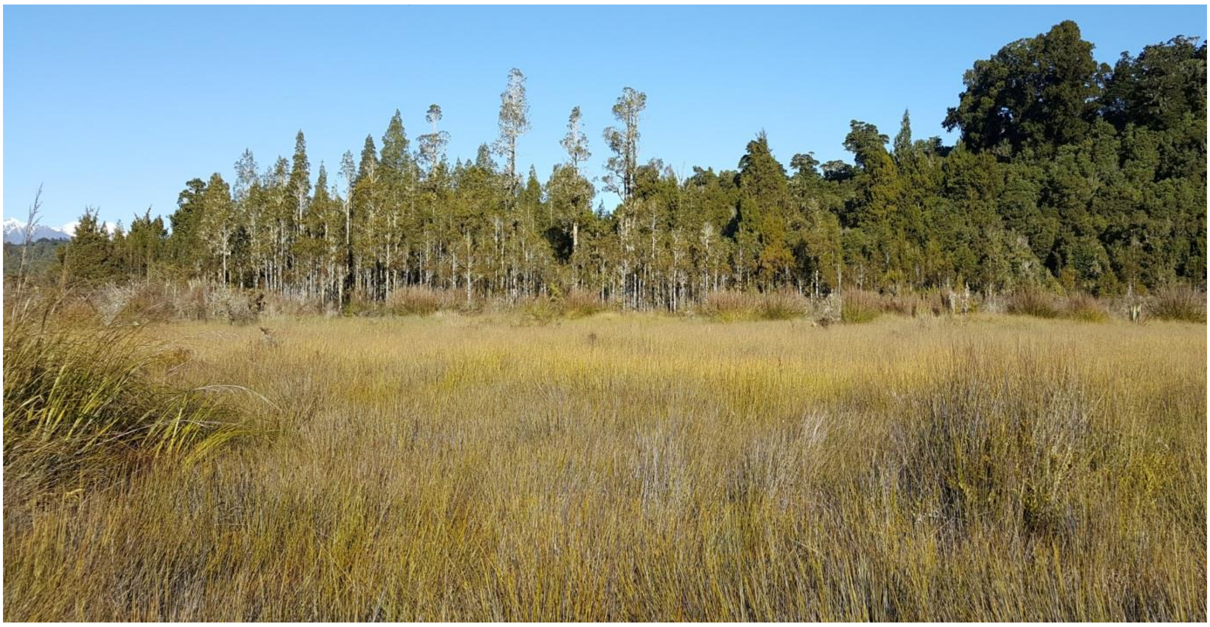

Figure 5. Sphagnum wetland 6 years after harvest with regenerating forest on the margin.

Previous guidelines (Buxton et al. 1995) suggested that sphagnum harvesting requires careful site selection, avoiding excessively wet or very dry areas, ensuring the post-harvest surface is near but above the mean water table level, and reseeding of the site (i.e. leaving about a third of the acrotelm behind to speed recovery). Avoiding machinery or practices that cause rutting or drainage of the bog was also emphasised. Failure to follow these guidelines had resulted in some moss-producing areas being severely degraded.

The use of heavy machinery would not have been encouraged previously, but local innovation has shown that by spreading the weight of these vehicles over a wide area they can be less damaging than human or animal tracking. The average human male exerts about 16 psi ground pressure when walking, whereas the ground pressure of an 8 tonne Snow Cat can be as little as 0.8 psi.

Positive impacts of sphagnum harvesting

Key wetland functions such as hydrological status are largely unchanged by sphagnum harvesting. This is particularly important if wetlands are to recover. Hydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes (Clarkson et al. 2004).

Harvesting delays succession to forest in anthropogenic wetlands by maintaining low-statured vegetation, including open rush and sphagnum moss communities. Sphagnum harvesting may be a useful management tool where there is a wish to retain the ecological values of these communities provided there is a sufficient buffer remaining as a seed source.

Management associated with harvesting can reduce invasive weeds and feral animals that are also incompatible with commercial harvesting.

Native fauna

Brown mudfish are found in pākihi and other West Coast wetlands from Karamea to Ōkārito, mostly at low altitudes (Department of Conservation 2003; Figure 6). Mudfish occur in wetlands with natural variations in water levels, but are seldom found in water more than 0.3–0.5 m depth (O'Brien & Dunn 2007). Reduction or modification of habitat is one of the major threats to mudfish, particularly drain clearance or activities that restrict the natural variations in water levels. Drain clearance, especially machine clearance where spoil and weeds are dumped on the margins, destroys the habitat for mudfish living in these drains. Fish can also be killed as they get caught up among the spoil and weeds and stranded on the banks.

There don't appear to be any data on brown mudfish numbers in harvested versus non-harvested sites. However, only one of the Schedule 2 wetlands directly mentions mudfish (HARP024 Ianthe Mudfish Habitat). This is immediately north of a wetland where sphagnum was previously harvested (Buxton et al. 1995). Denne (1983) suggested brown mudfish were likely to be displaced by harvesting, but that it was unknown what importance sphagnum mires played in their life cycle.

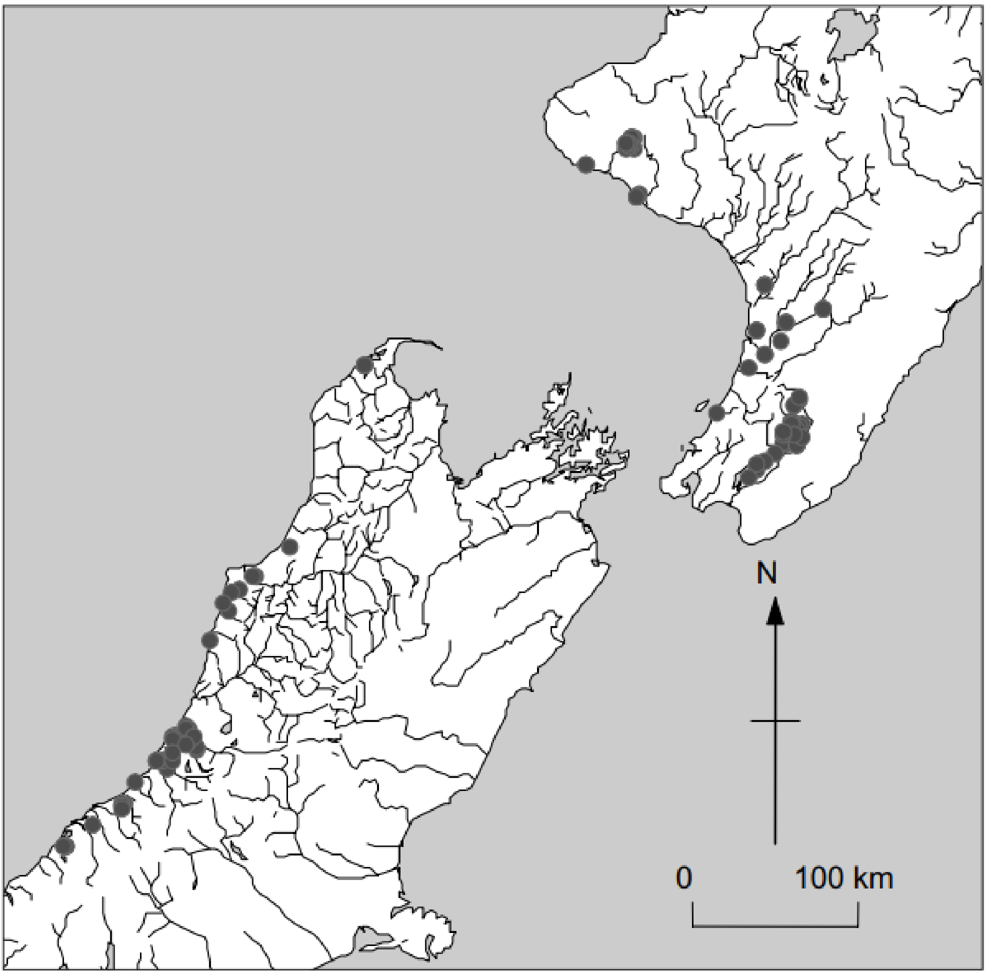

Figure 6. Brown mudfish distribution (from Department of Conservation 2003).

DOC has a very good online factsheet outlining practices to protect mudfish habitat (http://www.doc.govt.nz/nature/native-animals/freshwater-fish/mudfish/). Following are some of the key points relevant to harvesters.

- Allow natural water-level fluctuations. Avoid using drains and weirs to manipulate water levels.
- Maintain drains using mudfish-friendly methods. Planting or retaining native plants on drain margins will suppress the growth of freshwater weeds. If physical removal of weeds is essential, then clear only short sections, or one side of the drain at a time, to retain habitat.
- Prevent invasive fish establishing by finding out what invasive fish species are present in the catchment around the wetland and being careful not to accidentally move them between waterways.

Other freshwater species that may be found associated with sphagnum mires include short-finned eels (*Anguilla* australis), galaxids *(Galaxias* spp.) and freshwater crayfish *(Paranephrons planifrons)* (Denne 1983).

Denne (1983) reports that the New Zealand Wildlife Service did not consider West Coast pākihi to have very high wildlife values, although those with reasonably dense vegetation were of considerable importance to the South Island fernbird (*Bowdleria punctata punctata*). Preferred habitat includes dense stands of reeds with shrubs and some trees. However, areas with low vegetation and sphagnum as a dominant carpet, or even-height shrubbery (e.g. mānuka or gorse), are not well inhabited.

However, fernbirds do not seem to compete well with insectivorous birds in closed forest, and Miskelly (2013) suggests that vegetation succession probably led to North Island fernbirds dying out on Great King and Aldermen Islands. Sanders and Winterbourn (1993) found that insects in sphagnum mires recovered quickly after harvesting. Therefore harvesting probably has little or only a temporary impact on fernbird diet. Harvesting may promote predator access and post-harvest control should be considered.

Experimental studies are needed to determine the effects of vegetation density, human presence, and sphagnum harvesting on fernbird populations. However, harvesters report that fernbirds commonly call and move around them while they are harvesting. Fernbirds were also heard calling at Taminelli Creek and Ward Road during site visits for this project.

Other threats to wetlands include grazing by domestic stock, and feral animals. Rooting by pigs has been observed on some wetland margins and landowners have initiated control operations.

Significant wetlands and size

Feldmeyer-Christe and Küchler (2017) found that the quality of bog vegetation (the proportion of specialist species) increased with distance from bog margins and associated draining structures. This means wetland shape may be as important as total area. Deane et al. (2017) found that the complete removal of small wetlands resulted in the highest risk to regional species diversity for a given decrease in the total area of the regional wetland estate. Therefore it may not be useful to restrict significant areas of pākihi to those over 40 ha in size as indicated in Schedule 3. Equally, it may be possible for sphagnum harvesting to be compatible with species diversity goals when this involves only a portion of larger wetlands.

Can management for sphagnum harvesting and conservation be compatible?

Just as the best sites can be selected for protection, Johnson (1988) argued it should also be feasible to seek harvesting sites where there is little conflict with biological conservation, where downstream hydrological effects are likely to be minimal, where the impacts of sphagnum harvesting can be monitored from the outset, and where experimental trials can be aimed at maximising sphagnum regrowth.

Studies in New Zealand (Buxton et al. 1995) have shown that sphagnum height growth is improved when growing under partial shade of other species compared to open sites. Vascular plants reduce irradiance and water losses, and consequently maintain high relative humidity, which provides optimal growth conditions for sphagnum. Pouliot et al. (2011) demonstrated that the microclimate provided by vascular plants at moderate densities can enhance sphagnum growth. They also showed that rushes can provide physical structure to support moss growth. This has also been observed by harvesters in Westland.

Working with local harvesters to develop site-specific guidelines for moss harvesting allows harvesters to contribute their knowledge and ensure that guidelines are workable, sustainable and cost-effective (Peck & Studlar 2008).

8 Monitoring

Ideally, monitoring involves the comparison of treatments and controls established in close proximity to one another and followed through time. While this was not possible for the sites visited in this project, it was possible to compare some areas known from past experience with their current state and gain information from their management history. Harvested sites could also be compared with similar areas that have never been harvested to gauge the impacts of harvesting activity. The difficulty with this is when harvesting practices have changed or other conditions vary between sites.

Recovery can be gauged to some extent by comparing recently harvested areas with areas where the number of years since the last harvest is known. It is possible to estimate this age from annual changes in shoot elongation of the moss, which is most commonly associated with red-brown bands caused by low winter temperatures (Figure 7).

Figure 7. Annual red-brown bands associated with slower sphagnum growth alternate with paler sections formed during more rapid shoot elongation.

Clarkson et al. (2004) list five semi-independent indicators of wetland condition based on major threats and stress factors known to damage wetlands. The indicators are scored for the wetland as a whole. They are:

- change in hydrological integrity
- change in physicochemical parameters
- change in ecosystem intactness
- change in browsing, predation and harvesting regimes
- change in dominance of native plants.

Guidelines for scoring wetlands based on these indicators are attached in Appendix 2. Each indicator component is scored on a scale from 0 to 5, with 5 representing the unmodified or best condition and 0 representing the most degraded condition. The average values for each indicator are totalled to give a score out of 25 (Table 1).

Most actively harvested wetlands should score relatively highly (20+) using these indicators, meaning they have a low degree of modification. Suggested minimum values for each indicator component would be 4 on any inspection, except for harvesting level, which could drop to 3 (25–49% actively harvested or 50–75% recovering from earlier harvesting).

Monitoring using these indicators would be valuable for ensuring that conservation values are retained, and would also help harvesters and landowners to maintain their wetlands to maximise sphagnum production. Permanent plots based on Clarkson et al. (2004) would help to monitor vegetation composition, cover, and structure. These indicators also help to demonstrate that all components need to be considered together when assessing impacts on wetlands. Although harvesting is only one factor, it can have direct as well as indirect effects on wetland health.

Table 1. Hypothetical example of the indicator index to determine wetland condition

Indicator	**Indicator components**	**Specify and comment**	**Score 0–5**	**Mean score**
Change in hydrological integrity	Impact of man-made structures	Old drain near one boundary, none in wetland	4	4
	Water table depth	Remains high in most areas	4	
	Dryland plant invasion	Low. Confined to margins	4	
Change in physio-chemical parameters	Fire damage	No recent evidence	5	4.5
	Degree of sedimentation/erosion	No sediment, some minor spot erosion	4	
	Nutrient levels	Remaining low at present	5	
	Von Post index (peat bogs only)	Plant structure distinct, yields yellowish water	4	
Change in ecosystem intactness	Loss in area of original wetland	15% of original area converted to agriculture	4	4
	Connectivity barriers	Some pasture conversion downstream	4	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	Stock excluded by fences, some browsing by possums	4	3.7
	Introduced predator impacts on wildlife	Low predator access, fernbirds frequent	4	
	Harvesting levels	40% of wetland recently harvested	3	
Change in dominance of native plants	Introduced plant canopy cover	Gorse on margins, less than 25% cover	4	4
	Introduced plant understorey cover	Very little, mostly on margins	4	
Total wetland condition index / 25				20.2

Notes: Degree of modification is assigned as follows: 5 = very low/none; 4 = low; 3 = medium; 2 = high; 1 = very high; 0 = extreme. Source: Clarkson et al. 2004.

9 Conclusions

Both managers and harvesters wish to protect the wetlands that nurture the sphagnum moss resource. There has been a trend towards more harvesting on private land and less on public conservation land. Few of the currently identified Schedule 2 wetlands occur on private land and only two of those are known to have been harvested. Correspondingly, the majority of Scheduled wetlands have an additional level of protection by virtue of the processes required for any activity on the DOC estate.

Current practices associated with sphagnum harvesting, particularly cutting and crushing of vegetation, conflict with traditional conservation management of wetlands. Traditional management has resulted in increased woody vegetation and decreased sphagnum yields in previously harvested conservation areas, whereas current practices on private land have increased sphagnum yields with only temporary minor impacts on vegetation and wildlife. Current practices may therefore also decrease the harvesting footprint.

However, without a rule, condition or consent process there is no guarantee that current practices will be employed by all harvesters, including any future harvesters. The number of Scheduled wetlands sought for harvesting will likely always be low, but it may be difficult for the Council to allow harvesting as an activity that does not require consent due to potential industry expansion or other unforeseen effects. The impact of cutting and crushing of vegetation can be more than minor, and the concern expressed by many of those opposed to the rule change is that, as proposed, the plan change would allow this in any Scheduled wetland. While this is unlikely given that most Scheduled wetlands occur on conservation land, the Council may determine that harvesting in Scheduled wetlands is more suitable as a controlled or limited discretionary activity in order to protect values on private land.

Both harvesters and those interested in wetland conservation are seeking clarity regarding areas that can be utilised for sphagnum harvesting. Setting geographical limits by identifying Scheduled wetlands that are either suitable or unsuitable for harvesting would be ideal, but this would require detailed information to enable decisions to be based on the ecological values of each site. This is essentially the Schedule 3 process. While current methods may be best practice for sphagnum harvesting, they do not replicate natural conditions and should be confined to previously modified and harvested wetlands.

Whether to allow harvesting and the methods used will depend on the ecological values that are to be protected or promoted. For example, harvesting with cutting and crushing of vegetation will promote the continued dominance of sphagnum, whereas harvesting without cutting or crushing of vegetation will lead to dominance by woody vegetation. So long as no degradation of the Scheduled wetland occurs, harvesting could occur on wetland areas that contribute to larger or significant Scheduled wetlands and may provide a useful management tool, especially in anthropogenic wetlands. However, monitoring including permanent plots is needed to determine rates and trends in vegetation composition, cover and structure, to be able to assess effects and inform rules or conditions.

10 Recommendations

The options available to the Council for managing sphagnum harvesting on Scheduled wetlands include:

1. Excluding sphagnum harvesting from the definition of vegetation disturbance. This may present the Council with a risk under its obligations to protect biodiversity in Scheduled wetlands. While the number of Scheduled wetlands involved is low, no conclusive data exists on the impact that harvesting will have on the ecological value of wetlands.

2. Geographically identify wetlands suitable for harvesting in the Regional Plan and allow harvesting in these areas only. Although ideal, because it would provide a high level of certainty for all parties, this option is likely to require more information than is currently available, or can be realistically obtained within the relevant timeframes, and so is probably not feasible.

3. Allow sphagnum harvesting on Scheduled wetlands as a permitted activity rule with conditions. Conditions would need to be able to control the effects of the activity.

4. Allow sphagnum harvesting on Scheduled wetlands as a controlled or limited discretionary activity. This would allow the suitability of sites and harvesting operations to be considered on a case-by-case basis, and would allow the Council to exercise discretion through the consent process. However, this option would result in costs associated with the consent application process.

5. Conditions should be imposed through a permitted activity rule, or on any resource consent. Conditions could restrict harvesting to previously harvested sites or restrict the area available for harvesting in Scheduled wetlands; for example, allowing a small amount of harvesting (up to XXm^2) or a percentage of the Scheduled wetland. Harvesters could be required to notify the Council in advance of commencing harvesting on Scheduled wetlands and provide specified information (e.g. yield per hectare, percentage of wetland harvested, harvest strategy) to enable the Council to record where harvesting takes place and to monitor the effectiveness of the rule.

6. Conditions could also set guidelines for harvesting methods on Scheduled wetlands. For example, if heavy machinery is used in a Scheduled wetland to optimise the post-harvest surface, the weight should be distributed so that ground pressure is no more than 3.5 psi (2,500 kg/m2).

7. Monitoring using wetland indicators and permanent plots (Clarkson et al. 2004) would be useful for both harvesters and the Council to establish baselines before harvesting and to highlight potential threats to wetland health. Monitoring after harvesting will help to determine vegetation patterns and rates of recovery, inform best practice for harvesting, and inform refinements to any rules or conditions. It is recommended that a programme for monitoring be considered and implemented, regardless of which option is pursued.

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12 References

Andersen R, Francez A, Rochefort L 2006. The physicochemical and microbiological status of a restored bog in Québec: Identification of relevant criteria to monitor success. Soil Biology and Biochemistry 38: 1375-1387.

Buxton RP, Johnson PN, Espie PR 1995. Sphagnum Research Programme: the ecological effects of commercial harvesting. Landcare Research Contract Report LC9495/124 for Department of Conservation. 46 p.

Clarkson BR, Sorrell BK, Reeves PN, Champion PD, Partridge TR, Clarkson BD 2004. Handbook for monitoring wetland condition: coordinated monitoring of New Zealand wetlands. Wellington, Ministry for the Environment. 74 p. doi: 10.7931/J2Z60KZ3.

Clarkson B, Whinam J, Good R, Watts C 2017. Restoration of *Sphagnum* and restiad peatlands in Australia and New Zealand reveals similar approaches. Restoration Ecology 25: 301–311. doi: 10.1111/rec.12466.

Deane DC, Fordham DA, He F, Bradshaw CJA 2017. Future extinction risk of wetland plants is higher from individual patch loss than total area reduction. Biological Conservation 209: 27–33. http://dx.doi.org/10.1016/j.biocon.2017.02.005.

Denne T 1983. Sphagnum on the West Coast, South Island, New Zealand: resource characteristics, the industry and land use potential. MSc thesis, Centre for Resource Management, University of Canterbury and Lincoln College.

Department of Conservation 2003. New Zealand mudfish (Neochanna spp.) recovery plan 2003–13. Threatened Species Recovery Plan 51. Wellington, Department of Conservation. 25 p.

Díaz MF, Bigelow S, Armesto SJ 2007. Alteration of the hydrologic cycle due to forest clearing and its consequences for rainforest succession. Forest Ecology and Management 244: 32–40. http://dx.doi.org/10.1016/j.foreco.2007.03.030.

Díaz MF, Silva W 2012. Improving harvesting techniques to ensure Sphagnum regeneration in Chilean peatlands. Chilean Journal of Agricultural Research 72: 296–300.

Feldmeyer-Christe E, Küchler M 2017. Quality loss of Swiss bog vegetation: the key importance of the margins. Mires and Peat 19(3): 1–15. doi: 10.19189/MaP.2016.OMB.237

Gaudig G, Krebs M, Joosten H 2017. Sphagnum farming on cut-over bog in NW Germany: long-term studies on *Sphagnum* growth. Mires and Peat 20(4): 1–19. doi: 10.19189/MaP.2016.OMB.238.

Glatzel S, Rochefort L 2017. Growing sphagnum. Mires and Peat 20(0): 1–3. doi: 10.19189/MaP.2017.OMB.276.

Johnson PN 1988. Sphagnum moss in Otago. Department of Conservation, Science & Research Internal Report 34. 18p.

Johnson PN, Gerbeaux P 2004. Wetland types in New Zealand. Wellington, Department of Conservation. http://www.doc.govt.nz/documents/science-and-technical/WetlandsBW.pdf.

McGlone MS 2009. Postglacial history of New Zealand wetlands and implications for their conservation. New Zealand Journal of Ecology 33: 1–23.

Minayeva TY, Bragg OM, Sirin AA 2017. Towards ecosystem-based restoration of peatland biodiversity. Mires and Peat 19(1): 1–36. doi: 10.19189/MaP.2013.OMB.150.

Miskelly CM 2013. Fernbird. In: Miskelly CM ed. New Zealand birds online. http://www.nzbirdsonline.org.nz/species/fernbird (accessed 29 August 2017).

O'Brien LK, Dunn NR 2007. Mudfish (Neochanna Galaxiidae) literature review. Science for Conservation 277. Wellington, Department of Conservation. 88 p.

Peck JE, Studlar SM 2008. Establishing international guidelines for the sustainable harvest of forest moss. Evansia 25: 65–71.

Pouliot R, Rochefort L, Karofeld E, Mercier C 2011. Initiation of Sphagnum moss hummocks in bogs and the presence of vascular plants: is there a link? Acta Oecologica 37: 346–354.

Sanders MD, Winterbourn MJ 1993. Effect of sphagnum harvesting on invertebrate species diversity and community size. Science and Research Series No. 57. Wellington, Department of Conservation.

Silvan N, Jokinen K, Näkkilä J, Tahvonen R 2017. Swift recovery of *Sphagnum* carpet and carbon sequestration after shallow Sphagnum biomass harvesting. Mires and Peat 20: 1–11. doi: 10.19189/MaP.2015.OMB.198.

Stokes JR, Alspach PA, Stanley CJ 1999. Effect of water table on growth of three New Zealand Sphagnum species: implications for S. cristatum management. Journal of Bryology 21: 25–29. doi: 10.1179/jbr.1999.21.1.25.

Temmink RJM, Fritz C, van Dijk G, Hensgens G, Lamers LPM, Krebs M, Gaudig G, Joosten H 2017. Sphagnum farming in a eutrophic world: the importance of optimal nutrient stoichiometry. Ecological Engineering 98: 196–205. http://dx.doi.org/10.1016/j.ecoleng.2016.10.069.

Whinam J, Buxton R 1997. *Sphagnum* peatlands of Australasia: an assessment of harvesting sustainability. Biological Conservation 82: 21–29.

Whinam J, Hope G, Clarkson B, Buxton RP, Alspach PA, Adam P 2003. *Sphagnum* in peatlands of Australasia: their distribution, utilisation and management. Wetlands Ecology and Management 11: 37–49. doi: 10.1023/A:1022005504855

Wichmann S, Prager A, Gaudig G 2017. Establishing Sphagnum cultures on bog grassland, cut-over bogs, and floating mats: procedures, costs and area potential in Germany. Mires and Peat 20(3): 1–19. doi: 10.19189/MaP.2016.OMB.235.

Appendix 1 – Schedule 3: Ecological Criteria for Significant Wetlands

The criteria in this Schedule will be used to ascertain whether a wetland is ecologically significant. A wetland is ecologically significant if it meets one or more of the following criteria:

Ecological Context

1) The ecological context of the wetland has one or more of the following functions or attributes:
   a) It plays an important role in protecting adjacent ecological values, including adjacent and downstream ecological and hydrological processes, indigenous vegetation, habitats or species populations; or
   b) Is an important habitat for critical life history stages of indigenous fauna including breeding/spawning, roosting, nesting, resting, feeding, moulting, refugia, or migration staging points (as used seasonally, temporarily or permanently); or
   c) It makes an important contribution to ecological networks (such as connectivity and corridors for movement of indigenous fauna); or
   d) It makes an important contribution to the ecological functions and processes within the wetland.

Representative wetlands

2) A representative wetland is one that contains indigenous wetland vegetation types or indigenous fauna assemblages that were typical for, and has the attributes of, the relevant class of wetland as it would have existed circa 1840.
3) This criterion will be satisfied if the wetland (not including pakihi wetlands) contains either:
   a) Indigenous wetland vegetation types that have the following attributes:
      (i) The indigenous wetland vegetation types that are typical in plant species composition and structure; and
      (ii) The condition of the wetland is typical of what would have existed circa 1840 in that:
         - Indigenous species dominate; and
         - Most of the expected species and tiers of the wetland vegetation type(s) are present for the relevant class of wetland; or
   b) The wetland contains indigenous fauna assemblages that:
         - Are typical of the wetland class; and
         - Indigenous species are present in most of the guilds expected for the wetland habitat type.
4) A pakihi wetland is a representative wetland where:
   a) It is greater than 40 hectares in area; and
   b) It is dominated by a mixture of sedges, ferns, restiads, rushes, mosses and manuka (Leptospermum scoparium) of which Baumea spp, Sphagnum spp, Gleichenia dicarpa, and Empodisma minus are the main species.
5) The representative wetland criterion applies to the whole or part of the wetland irrespective of land tenure;
6) Each wetland is to be assessed at the ecological district and freshwater bio-geographic unit scale.

Rarity

7) The wetland satisfies this criterion if:
   a) Nationally threatened species[1] are present[2]; or
   b) Nationally at risk species or uncommon communities or habitats are present and either:
         - The population at this site provides an important contribution to the national population and its distribution;
         - There are a number of at risk species present; or

- The wetland provides an important contribution to the national distribution and extent of uncommon communities or habitats;

c) Regionally uncommon species are present; or Is a member of a wetland class that is now less than 30% of its original extent as assessed at the ecological district and the freshwater bio-geographic unit scales; or
d) Is a member of a wetland class that is now less than 30% of its original extent as assessed at the ecological district and the freshwater bio-geographic unit scales; or
e) Excluding pakihi, it contains lake margins, cushion bogs, ephemeral wetlands, damp sand plains, dune slacks, string mires, tarns, seepages and flushes or snow banks which are wetland classes or forms identified as historically rare by Williams et al (2007).

Distinctiveness

8) The wetland satisfies the distinctiveness criterion if it has special ecological features of importance at the international, national, freshwater bio-geographic unit or ecological district scale including:
   a) Intact ecological sequences such as estuarine wetland systems adjoining tall forest; or
   b) An unusual characteristic (for example an unusual combination of species, wetland classes, wetland structural forms, or wetland landforms); or
   c) It contains species dependent on the presence of that wetland and at their distribution limit or beyond known limits.

Explanation

9) The wetland classes may be determined in a number of ways including the classification index of Johnson and Gerbeaux (2004).
10) Wetland indigenous vegetation types are identified with reference to the dominant plant species that are present, the structural class, wetland class and hydrosystem (see for example Johnson and Gerbeaux (2004) or similar method).
11) The three freshwater bio-geographic units in the West Coast region are the Northwest Nelson-Paparoa, Grey-Buller and Westland units (Leathwick et al 2000).
12) Ecological districts are described and mapped in McEwen (1987). The maps of the ecological districts on the West Coast region have been refined by David Norton and Fred Overmars for use at the 1:50,000 scale and are available from the Department of Conservation (West Coast Conservancy).

[1] The Threatened and At Risk categories are defined in the current version of the New Zealand threat classification system (Townsend et al. 2008). Species are reassessed according to these categories approximately every three years.
[2] For mobile species such as kotuku, this requires some assessment of the importance of the site for the species i.e. the intention is not to include areas such as wet pasture where these birds are foraging.

Appendix 2 – Guidelines for scoring of indicator components (from Clarkson et al. 2004)

https://www.landcareresearch.co.nz/publications/researchpubs/handbook_wetland_condition.pdf

Each indicator component is scored on a scale from 0 to 5, with 5 representing the unmodified or best condition and 0 representing the most degraded condition. A 'Specify and Comment' column in Table 1 (above) provides information on the reason a particular score has been given so that it can be recalled at a later date. This is essential if the scoring system is to be used to monitor change in condition over time, which is its main function. The scores are based on observations made and data collected during site visits, and from knowledge/data about the site already available.

Indicator and components	**Score and degree of modification**					
	5	**4**	**3**	**2**	**1**	**0**
	None/very low	**Low**	**Moderate**	**High**	**Very high**	**Extreme**
Δ Hydrological integrity H1: Impact of manmade structures	None or not impacting on wetland.	Affect less than 25% of the wetland.	Affect 25–49% of the wetland.	Affect 50–75% of the wetland.	Dominate wetland (>75%)	Totally dominated or affected by man-made structures.
H2: Δ Water table depth	No detectable changes.	Abnormally lowered (or raised) only occasionally and temporarily	Noticeably lower for short periods during dry spells. Average water table shows small but definite decline over time.	Lowered for long periods during dry spells. Average water table in wetland has noticeably declined over time.	Very low for most of year, not recharged fully by high rainfall events. Average water table much lower than previously.	Unable to be easily measured throughout season. Now a 'dryland' Or artificially totally flooded.
H3: Dryland plant invasion	No/ virtually no dryland plants in wetland.	<25% of wetland has dryland plant species present	25–49% of wetland has dryland plant species present.	50–75% of wetland has dryland plant species present.	>75% of wetland has dryland plant species present.	All species (100%) in community are dryland species
Δ Physicochemical parameters P1: Fire damage	No evidence of fire damage.	Recent fires (<2 years) removed vegetation in <25% of wetland; Or vegetation virtually recovered from older fires.	Recent fires (<2 yr) affected 25–49% of wetland; Or veg in 50–75% wetland still recovering from older fires.	Recent fires (<2 yr) affected 50–75% of wetland; Or veg in >75% wetland still recovering from older fires.	Recent fires (<2 yr) affected >75% of wetland. Or fire sensitive species now extinct.	Above ground vegetation completely destroyed (immediately post-fire).
P2: Degree of sedimentation/ erosion	None: high water clarity (<40 NTU), no visible sediment, stable banks and soil.	Water clarity 41–80 NTU; Or visible sediment deposits affect <25% of wetland; Or some minor spot erosion visible.	Water clarity 81–120 NTU; Or visible sediment deposits affect 25–49% of wetland; Or erosion spots linked and causing minor structural damage.	Water clarity 121–160 NTU; Or visible sediment deposits affect 50–75% of wetland; Or widespread erosion or scouring over greater than 50% of area.	Water clarity >160 NTU; Or visible sediment deposits affect >75% of wetland; Or widespread erosion causes severe damage throughout.	All wetland character lost due to prolonged extreme turbidity, almost total infilling by sediment, or unchecked erosion and scouring.

Indicator and components	**Score and degree of modification**					
	5	**4**	**3**	**2**	**1**	**0**
	None/very low	**Low**	**Moderate**	**High**	**Very high**	**Extreme**
P3: Nutrient levels	No evidence of eutrophication.	Localised (<25%) or infrequent signs of algal blooms or changes in nutrient concentrations or vegetation composition.	25–49% of area shows algal blooms, increased nutrients or vegetation change to high-nutrient species.	50–75% of area shows algal blooms, increased nutrients or vegetation change to high-nutrient species.	Eutrophication has shifted >75% of system to almost continuous algal blooms or monospecific stands of high-nutrient plants.	All wetland character lost due to eutrophication: now just a pond or dryland with no higher wetland plants present.
P4: von Post index Relevant to peat bogs only	1 undecomposed; plant structure unaltered, yields clear colourless water.	2–3; plant structure distinct, yields clear, yellow or brown water.	4–5; plant structure becoming indistinct. Yields turbid brown water, some peat may escape between fingers, residue mushy.	6–7; plant structure indistinct, about half the peat escapes between fingers, residue strongly mushy.	8–9; plant structure very indistinct, two-thirds to almost all peat escapes between fingers.	10 completely decomposed; plant structure unrecognisable, all peat escapes between fingers.
Δ Ecosystem intactness E1: Loss in area of original wetland	No loss: original wetland area essentially intact.	<25% of original area lost.	25–49% of original area lost.	50–75% of original area lost.	>75% of original area lost, remnants still retain some original character.	Wetland lost, or almost lost but remnants completely modified.
E2: Connectivity barriers	None: All natural upstream and downstream connections retained.	<25% of upstream or downstream connection lost.	25–49% of upstream or downstream connection lost.	50–75% of upstream or downstream connection lost.	>75% of connection lost with some minor links remaining.	Isolated: all former connections to other water bodies lost.
Δ Browsing, predation & harvesting regimes B1: Damage by domestic or feral animals	No domestic animal or feral animal browsing or trampling damage.	<25% of wetland showing light-medium damage; Or very light or localised browsing throughout wetland.	25–49% of wetland showing medium-heavy browsing and/or trampling damage.	50–75% of wetland medium-heavily browsed and/or trampled.	>75% of wetland heavily browsed and/or trampled.	All wetland character lost due to severity of browsing and trampling activity.

Indicator and components	**Score and degree of modification**					
	5	**4**	**3**	**2**	**1**	**0**
	None/very low	**Low**	**Moderate**	**High**	**Very high**	**Extreme**
B2: Introduced predator impacts on wildlife	No/virtually no predator access or impact; Or wetland & catchment under long term effective predator control.	Low levels of predators – susceptible wildlife spp still present Or pulsed predator control. Low predator reinvasion from catchment.	Medium predator impact, decline in numbers of some wildlife species. Or control very intermittent /or of not all predators. Medium reinvasion from catchment.	High declines in populations and/or loss of 1 or 2 wildlife species. Or no or ineffective predator control. High reinvasion from catchment.	Severe declines in wildlife population and species number. Or no predator control. Very high reinvasion from catchment Predators/signs visible.	Extreme: most native wildlife species extinct in wetland. Predators/signs highly visible.
B3: Harvesting levels	No harvesting (plants, birds, fish or other components) activity in wetland.	<25% of wetland with medium-heavy harvesting damage; Or light damage throughout wetland Or virtually recovered from earlier harvesting.	25–49% of wetland affected by active harvesting; Or 50–75% of wetland recovering from earlier harvesting.	50–75% of wetland affected by active harvesting; Or >75% of wetland recovering from earlier harvesting.	Active harvesting affecting >75% of wetland.	All wetland character lost due to harvesting activity.
Δ Dominance of native plants D1: Introduced plant canopy cover	No introduced plants in canopy i.e., all plants are native.	<25% canopy cover of introduced plants.	25–49% canopy cover of introduced plants.	50–75% canopy cover of introduced plants.	>75% canopy cover of introduced plants.	All canopy plants are introduced.
D2: Introduced plant understorey cover	No/ virtually no (<1%) plants in understorey are introduced.	<25% cover of introduced plants in understorey.	25–49% cover of introduced plants in understorey.	50–75% cover of introduced plants in understorey.	>75% cover of introduced plants in understorey.	All/virtually all (>99%) plants in understorey are introduced.