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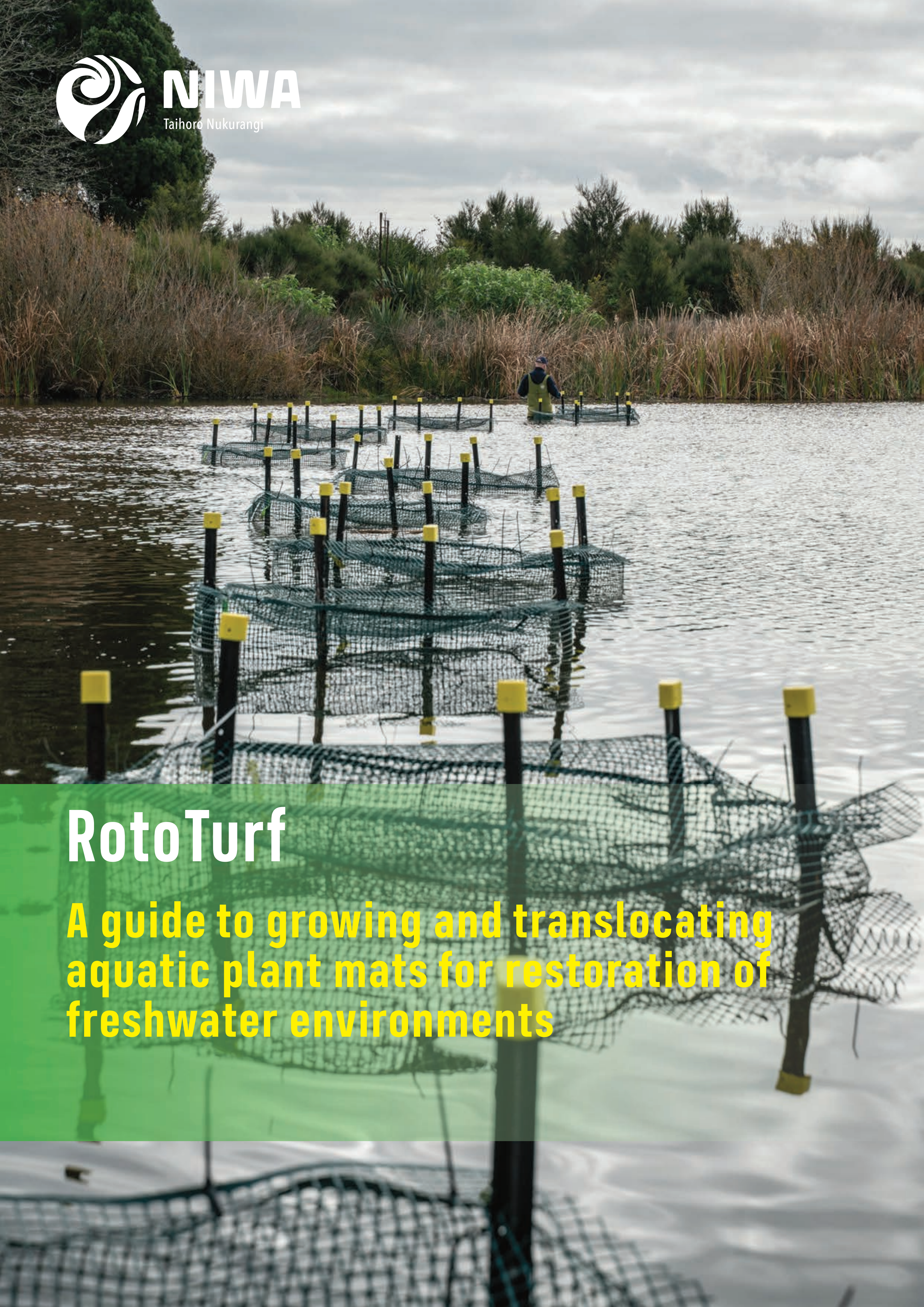
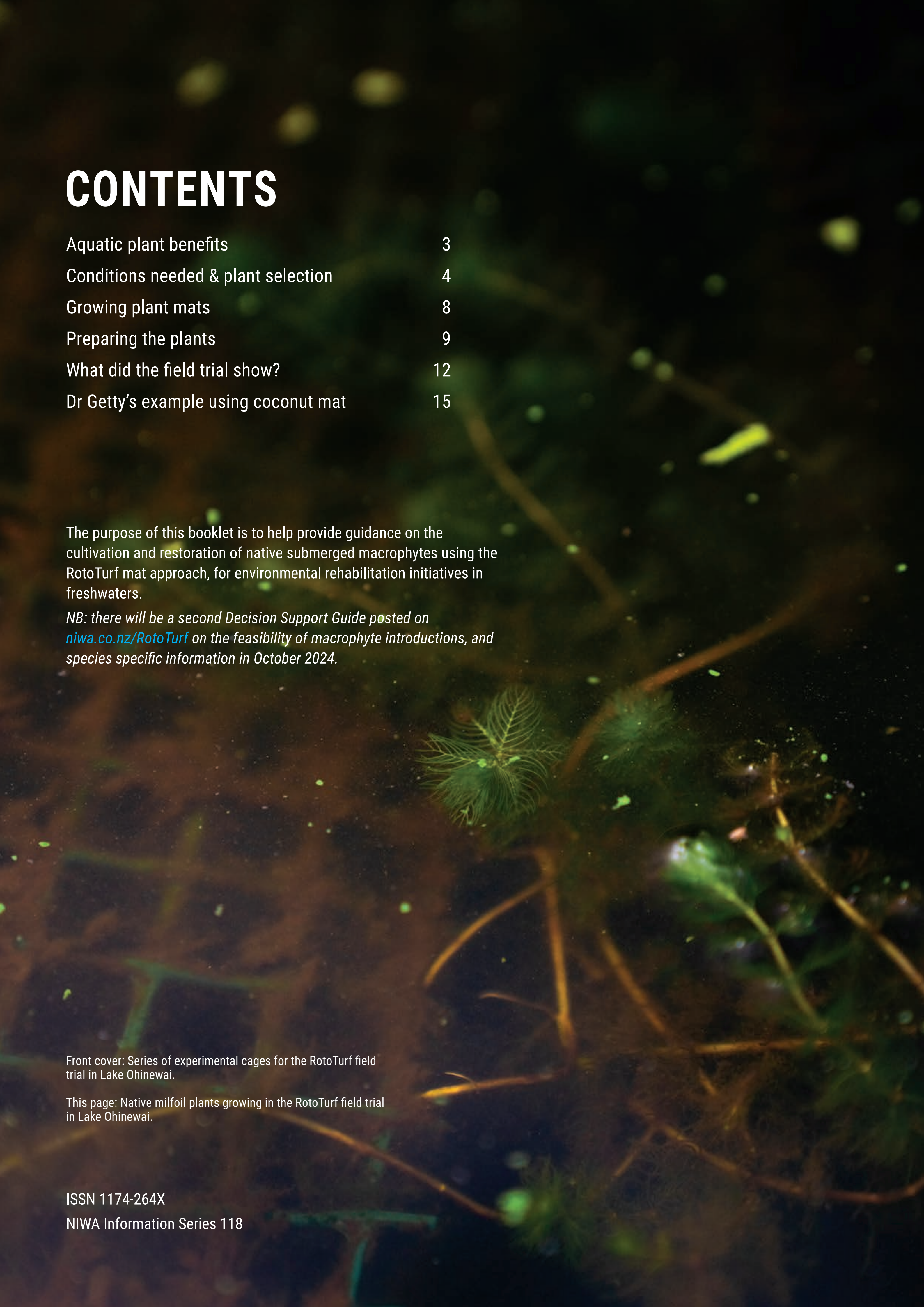


RotoTurf

A guide to growing and translocating aquatic plant mats for restoration of freshwater environments



CONTENTS

The purpose of this booklet is to help provide guidance on the cultivation and restoration of native submerged macrophytes using the RotoTurf mat approach, for environmental rehabilitation initiatives in freshwaters.

NB: there will be a second Decision Support Guide posted on niwa.co.nz/RotoTurf on the feasibility of macrophyte introductions, and species specific information in October 2024.

Front cover: Series of experimental cages for the RotoTurf field trial in Lake Ohinewai.

This page: Native milfoil plants growing in the RotoTurf field trial in Lake Ohinewai.

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AQUATIC PLANT BENEFITS

Why should we restore native aquatic plants to freshwaters?

Many of New Zealand's shallow lakes are degraded to the point where they are permanently turbid and submerged aquatic plants no longer have sufficient light to grow. Macrophytes consolidate lake sediments, take up nutrients and provide biodiversity benefits such as increasing structurally complex habitat for macroinvertebrates, supporting native fish and waterfowl. Once re-established, macrophytes provide a positive feedback loop that also supports their continued survival. But without aquatic plants, wave action resuspends lake-bed sediments, and a feedback loop is set up, trapping the lake in the degraded state.

Multiple restoration actions are required to reverse the degradation of freshwaters, including catchment management to reduce sediment and nutrient inputs, and the removal of bottom-feeding pest fish. These actions improve conditions for macrophytes to reestablish. But when plants have been lost from a lake for a long time, the native seedbank may not be healthy enough for plants to easily re-establish.

Our research took inspiration from terrestrial habitats and reseeding approaches, to develop the use of native plants in mats (whaariki), to accelerate the re-establishment of desirable native vegetation and support the restoration of degraded freshwaters.

What are aquatic plants and where are they found?

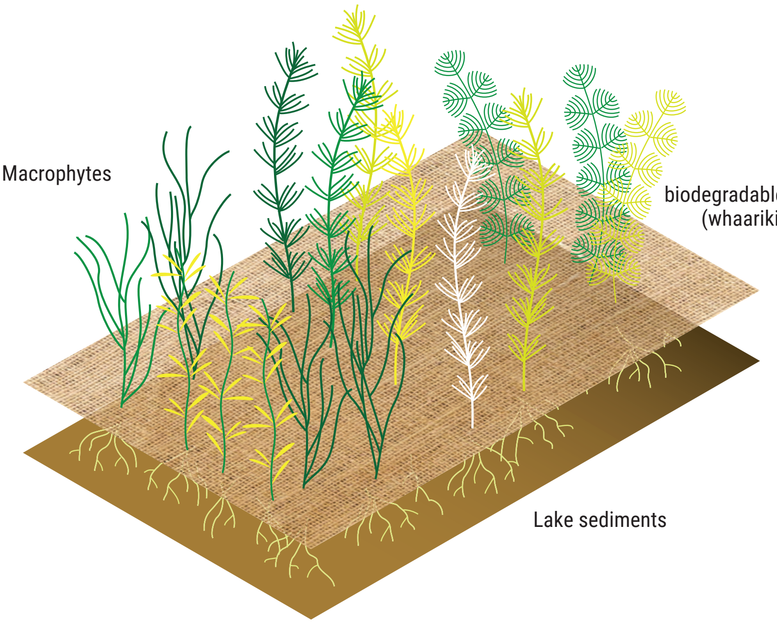
Aquatic plants (macrophytes) are large enough to see with the naked eye, growing in freshwater and brackish waterbodies.

Why are aquatic plants important?

Aquatic plants are important because they support ecosystem processes such as primary productivity (photosynthesis), nutrient sequestration, sediment aeration and stability and the provision of habitat for aquatic animals. This publication focuses on submerged aquatic plants, i.e., those that grow mostly beneath the water surface.

How much benefit do submerged plants provide and how many plants are needed?

There are positive environmental feedback loops that occur when plants are growing together as opposed to being spread further apart, such as the ability to buffer wave action, bind substrates in place and maintain an oxygenated root zone[1, 2].



Stylised diagram of the RotoTurf concept (Combining propagule selection and germination, with tackifiers or a means to integrate plant propagules into a biodegradable mat (whaariki), that will remain intact for sufficient time to allow plants to establish)

[1] Woodward and Hofstra (2022). Rhizosphere metabolism and its effect on phosphorus pools in the root zone of a submerged macrophyte, *Isoetes kirkii*. Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2021.1

[2] Woodward and Hofstra (2024). Submerged macrophyte root oxygen release reduces sediment oxygen demand: a positive feedback loop. Aquatic Botany, https://doi.org/10.1016/j.aquabot.2024.1

CONDITIONS NEEDED & PLANT SELECTION

Submerged aquatic plants require immersion in water for long-term survival, in addition to three key factors needed to support their growth:

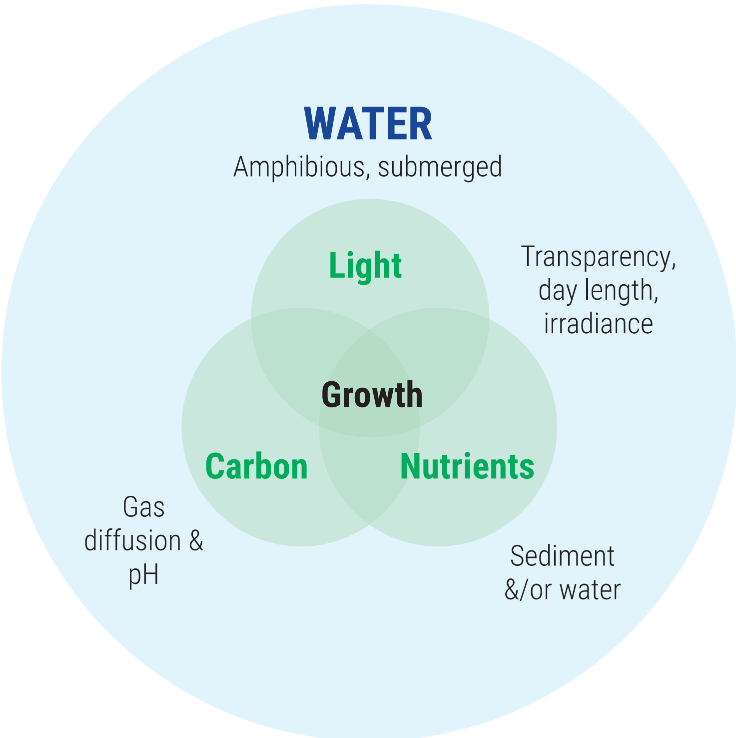
Light is essential and is strongly influenced by water transparency, but also by the availability of light that may be restricted through fouling of plant surfaces and shading by other plants and algae. Light needs to reach plant leaves for photosynthesis and growth to occur.

Carbon must be available as dissolved carbon dioxide or bicarbonate depending on water pH. Carbon is needed for growth and can sometimes be limiting, especially in still waterbodies (ponds and lakes), or where high pH may mean the carbon is unavailable to species that use carbon dioxide rather than bicarbonate.

Nutrients and trace elements are required and are accessed by submerged plants primarily from the sediment by plants with roots, as sediments are usually the richest most accessible source, although uptake from the water is also possible.

Favoured sediments are usually fine, soft and stable, enabling penetration by plant roots.

Key factors for submerged macrophyte growth



Selecting the right plants?

The right plants will depend on what is known to be present at the lake or site of interest (see Permissions page 6), or what was known from the site in the past, and what the current habitat is. Mana whenua, landowners, Department of Conservation, Regional Council, Manaaki Whenua – Landcare and NIWA are all potential information sources or may have relevant records.

Where water clarity is poor, as is the case for nutrient-enriched degraded lakes in general, it is likely that the 'right plants' will be species that can grow in low light conditions[3]. Plants growing in similar conditions locally, will provide an indication of which plants are suitable. For example, *Nitella* sp. aff. *cristata* and *Potamogeton ochreatus* were found in the low light of a naturally stained lake (Lake Koraha)[4]. In addition, some species (e.g., *Myriophyllum triphyllum*, *Potamogeton cheesemanii*) are relatively tall, or have surface leaves (*P. cheesemanii*), which means they can 'escape' to higher light conditions near the water surface.

Photos: *Nitella* sp. aff. *cristata* (top left), *Potamogeton ochreatus* (top right), *Potamogeton cheesemanii* (lower left), *Myriophyllum triphyllum* (lower right).

[3] de Winton and Champion 1993. The vegetation of the lower Waikato lakes. Volume 1. Factors affecting the vegetation of lakes in the Lower Waikato. NIWA Ecosystems Publication, No. 7

[4] https://niwa.co.nz/lakes/freshwater-update/freshwater-update-66-july-2015/lake-koraha-hidden-gem-waikato

Where can aquatic plants be sourced?

Sourcing and collecting macrophytes should consider:

- plant availability and potential importance of eco-source principles,
- the ability of the source environment to sustain collection,
- biosecurity considerations (MPI), and
- regulatory requirements or permissions.

Some native freshwater submerged species are used in the aquarium and pond plant trade; these could be sources for culture.

For sustainable collection ideally no more than 10% of the plants present in the targeted harvest area should be removed unless appropriate controls are in place (e.g. careful monitoring of donor population recovery). Harvesting should not be from a locality that might be critical for population recovery. If there are concerns about the sustainability of wild harvesting of whole plants, then seed or limited propagules could be sourced and further propagated under culture.

Permission

Permissions and/or approvals* need to be sought for both the collection and the translocation of submerged macrophytes. While no regulations apply to their maintenance in culture, plant hygiene is very important (see Preparing the plants page 9) to minimise contaminant risk.

Of prime importance is that there is support for the intended restoration and appropriate involvement of iwi, hapū and whānau and other parties with authority and interests in the collection and recipient sites, for example councils. Status of these sites (i.e., ownership, designations, status) will guide this approval and consultation process.

*For example: Collection of aquatic life for research purposes requires a Fisheries special permit (https://www.mpi.govt.nz/fishing-aquaculture/fisheries-management/how-to-apply-fisheries-special-permit/). Permits for collection of aquatic plant samples from public conservation land (e.g., National Parks, reserves) are required from DOC (https://www.doc.govt.nz/get-involved/apply-for-permits/research-and-collection/). The Aquatic Life Transfers Standard Operating Procedure (SOP) provided by Department of Conservation sets out the process for applications to transfer and release live aquatic life to freshwater under several pieces of legislation. Special considerations apply to national parks, plants with protected status, and possibly other Acts according to s26ZM(3)(a) Conservation Act 1987 (Conservation Act 1987 No 65 (as at 07 August 2020), Public Act – New Zealand Legislation).

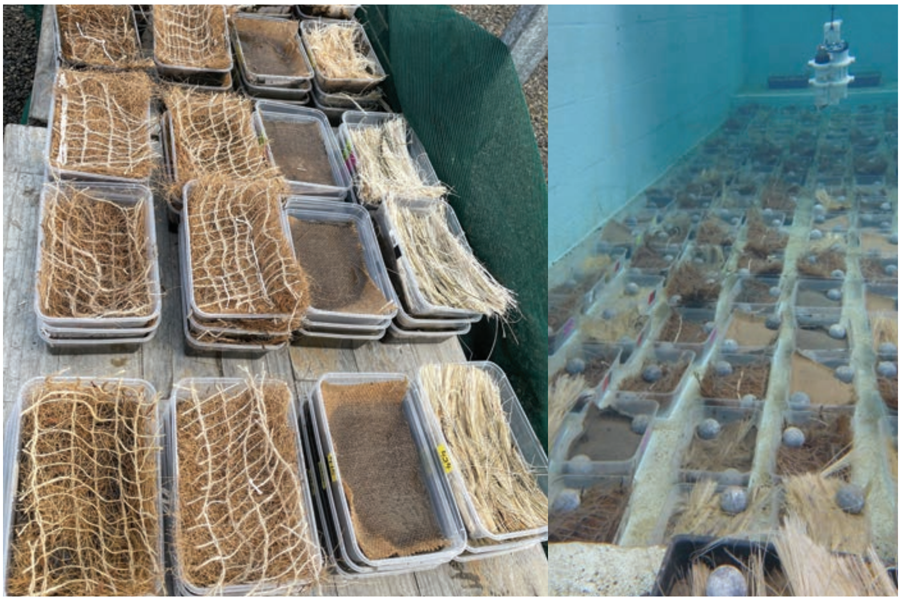
What types of biodegradable matting can be used?

The purpose of the matting is to support plant cultivation in large numbers and ease the translocation process to the lake bed. Over time the mat itself will break down naturally (biodegrade) while the plants become anchored (root into) the lakebed themselves.

Mat considerations include:

- the ability to support plant growth
- weight – light enough so that it can be moved, but heavy enough to sink
- breakdown that is slow enough to allow for plant cultivation and translocation timeframes.

Products made from hessian/jute, coconut, muka (harakeke/flax fibre) and wool (incl. with hessian and hemp) were tested. Wool and muka lasted the longest before breaking down, but plant growth in culture tanks was best on wool mats.



Photos: Before (left) and during (right) a mat degradation study where mat products were laid in trays with different substrates and placed in a tank to age. Every month for over a year the mats were assessed and tested to determine which products broke down the fastest.

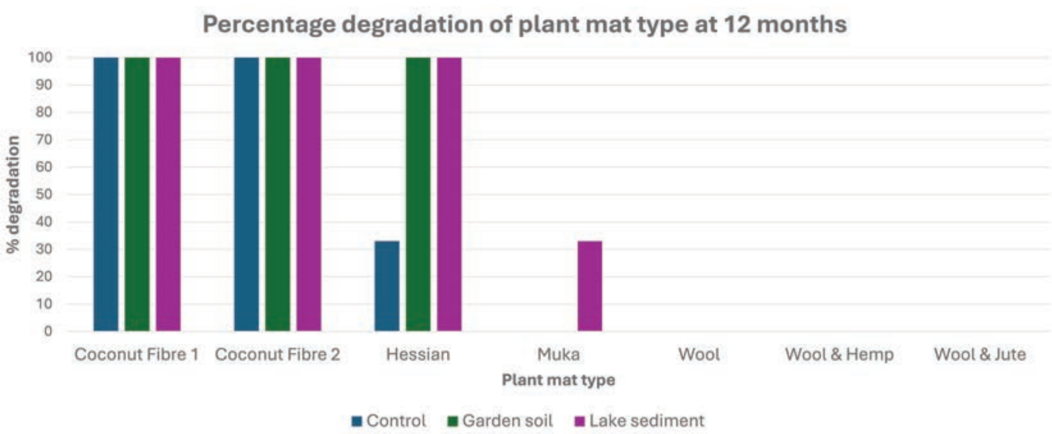


Figure: Seven types of mat were tested that varied in their density (e.g., coconut fibre 1 and 2) or their composition. The mats were placed in shallow trays either with a substrate (i.e., garden soil or lake sediment) or without a substrate (the control).

GROWING PLANT MATS

Culture conditions

Light

Although artificial light can be used, natural light is best and for large-scale mat preparation it is likely to be more cost-effective in outdoor tanks. Plants use light, described as photosynthetically active radiation (PAR) in wavelengths 400 to 700nm, and generally the higher the PAR the faster the plant growth. Natural light availability varies seasonally with day length, being less in winter, and more in summer. If algae are an issue, shading with shade cloth can be used to reduce the light to culture tanks and reduce the potential for algae growth that might otherwise compete with the plants. For submerged plants at least 10% of surface light should be maintained (as a minimum). Plant growth rates under 90% shade cloth will be slower than those under 50% shade cloth. Slower plant growth rates will influence the timeframe until the mats are ready to be moved to the lake.

Covering outdoor tanks will have the added benefit of keeping out any unwanted herbivores (see Challenges section page 14).

Nutrients

Using water that is generally low in nutrients (e.g. tap water) can help to avoid algal growth. Alternatively, low nutrient water can be used in combination with a substrate nutrient supply (see below).

Substrate

There is a balance sought with the matting type that is used, the plant species, and how well the plants grow into and through the mats. While it is beneficial for plant growth that the plant roots seek out the nutrients in the substrate, it is important to ensure the plants are attached to the mat rather than rooting only into the substrate. Hence only a thin layer (10mm max) of substrate is needed. If the plant mats are placed on deep substrate for cultivation, the plants may become anchored in the substrate, and when the mats are removed from the culture tank for translocation the plants can pull out (through the mat) breaking up the RotoTurf.

Suitable substrates include fine-textured soils or sediments with a low to moderate organic content up to 20%. Substrate sources could either be sediment from the recipient environment (substrate from the area you are going to plant e.g., for testing suitability) or commercially available products. Screened topsoil modified with washed sand in about a 50:50 mix works well. Slow-release fertiliser may be added to the substrate for prolonged culture periods (>2 months).

Temperature

Water temperature can influence the rate (speed) of plant growth but is likely to be less important than daylength and light. Optimal water temperatures are usually in the range from 15 to 25°C.

PREPARING THE PLANTS

Any risk of transmitting pest plants, unwanted invertebrates or fish must be minimised by identifying native plants carefully and minimising transfer of water or sediment between the source and the eventual recipient environments. Collected plants should be rinsed vigorously in clean running water and checked to ensure they are visibly free of any other species (e.g., snail eggs, caterpillars), described here collectively as 'hitchhikers'.

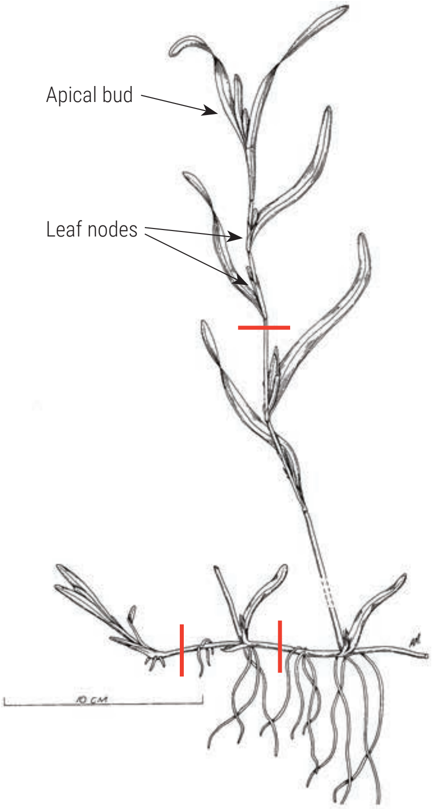
Most aquatic plant species can be stored for approximately a week in a chiller (4°C), in a sealed plastic bag or container, without excess water around the plants. Large volumes of plants should not be placed on top of each other during this storage period as this may result in compression and breakage. Only when the mats and tanks are ready for planting, should the plants be removed from the chiller. Care should be taken to ensure that the plants do not become dry once they are removed from the bag. Submersing in cool, fresh water prior to planting can help.

Cultivation tanks should be deep enough so that the plants will remain submerged under water, and shallow enough to be operationally manageable with approximately 50 to 70cm water depth. Wetting the mats prior to planting, means the mats will sink faster and minimise the time that the aquatic plants are out of the water. This is particularly important on hot sunny days, where drying times are short. Ideally plant on cool, overcast days (late winter) in the North Island of New Zealand. Weights such as rebar, rocks or sandbags can be used to hold the mats in place during cultivation (and when translocated) until plant roots anchor to the sediment below.

Different planting approaches may be required for different types of plants or species. But in general, submerged macrophytes propagate well from vegetative fragments. Vegetative propagules may be a shoot section or horizontal rhizome that includes several upright shoots, or entire small plants. Best results are obtained if the apices are intact (apical bud) and there are numerous leaf nodes (axillary buds) on the stem from which roots or additional branches can develop. Shoot sections, including nodes, should be inserted 5 to 10cm into the matting, tucking the shoot into the weave.

The production timeline for macrophyte culture, is informed by the timing of the planned restoration and the required development of macrophyte growth on the mats. For instance, a long culture period may be required where taller material is needed to 'escape' light limitation, if this is likely to occur at the translocation site (see Plant considerations page 11).

Growth rates for native submerged macrophytes will vary depending on the availability of the key factors required to support growth (see Conditions page 8). However, usually values of a minimum of two to three months should be used for planning to produce mats for translocation.



This plant could easily be divided (cut) where the red lines indicate to create four new individual plants.


Planting into muka and coconut fibre (top left) for small scale matting trials, muka and wool mats (right)

Native plants of milfoil and pondweed on a muka mat after approximately 6 weeks. Lead weights were used to hold the mat in place on plastic trays (that were buoyant) during this small-scale tank trial.

Underside of a plant mat showing roots of the milfoil (*M. triphyllum*) that have grown through the mat, these will allow the plants to attach to the lakebed.

Translocating to the recipient site

Plant considerations

The transport of submerged macrophytes to the recipient site requires ways to prevent their desiccation, for instance, by covering with lightweight coverings that are maintained wet or spraying with water. Keeping plants cool and shaded from direct sunlight will also be beneficial.

Decisions on where to introduce plants at the recipient site should identify a 'safe site' for submerged macrophytes. For submerged macrophytes a planting depth needs to be beyond short-term water level fluctuations and out of high energy wave wash zone, but within a suitable light climate based on the height of the plants.

Submerged aquatic plants need light to grow, and when light becomes limiting for extended period the plants will fail to produce enough biomass to off-set loss processes (e.g., browsing or wave damage) and the plants will die out in time. Light reaching the submerged plant should be at least 10% of the light above the water surface. In very murky/turbid water this could mean that 50cm tall plants are needed for water that is only 60cm deep, for example. As a practical consideration if the plant leaves cannot be seen from the surface once the plants are in the lake, there is unlikely to be sufficient light at that depth to support plant growth.

Timing

Planting early in the growing season is generally considered best as it gives plants an opportunity to become established while water clarity is likely to be relatively high (i.e., before summer algal blooms) and to maximise their growth prior to reduced winter light conditions. Plants should have roots throughout the mat before they are transplanted.

Safe sites

Planting-out should target sheltered bays to mininise losses from wave/current damage. Provision of safe sites also includes considering the relative abundance of waterfowl and potentially pest fish and any associated need for protection from herbivores using exclusion cages or similar (see Field trial page 12), at least until such time as the plants are sufficiently established and abundant to withstand grazing and disturbance. There is little information to gauge this threshold or point of balance to secure macrophyte survival in the presence of herbivores (depending on their relative abundance) in New Zealand. Testing plant establishment in-lake within protective cages for a year to better assess local conditions may be advisable before a larger investment is made[5]. For instance, trialling species in the sediment of the target location would determine if the substrate is suitable.

[5] Hilt et al 2006. Restoration of submerged vegetation in shallow eutrophic lakes — a guideline and state of the art in Germany. Limnologica 36: 155–171. https://doi.org/10.1016/j.limno.2006.06.001

WHAT DID THE FIELD TRIAL SHOW?

What we trialled

Plants were sourced for translocation from Lake Puketirini with permission (see Permissions page 6) and planted into mats that were cultivated for four to five months in outdoor culture tanks at NIWA's Ruakura Aquatic Research Facility.

The recipient site was in Lake Ohinewai which has a large population of resident geese as well as pest fish. To protect the plant mats from being grazed and uprooted, cages were installed in shallow water in the lake. Because the lake level can drop markedly over summer, rafts were also used to provide a control group of plants, where the water depth of the plant mats could be maintained.

What we found

Light levels were very low (e.g., maximum in water visibility of 20cm), so that only the taller plants, that were in the photic zone at the time of translocation continued to grow. These plants increased the surface area of the cage that they occupied over the summer (5 months). The water level did not recede over the field trial period, so light conditions did not improve for plants in the shallows. This meant that plants that were too short to reach the photic zone failed to survive and were not detected in the shallow water cages when monitored two months after installation, whereas the same species was still present in less water and higher light conditions (i.e., in the control rafts).

This demonstrates the need have a clear understanding of in-lake conditions and how they may be used to inform the selection of sites to place the RotoTurf.

RotoTurf of native pondweed (*Potamogeton ochreatus*) transported and ready for lake installation

Underside of a wool mat on translocation day showing the milfoil roots that have grown through the mat, ready for lake installation.

Milfoil mat being installed in a 1m deep exclosure (cage to keep out pest fish).

Water body constraints – plant mats or plant bombs?

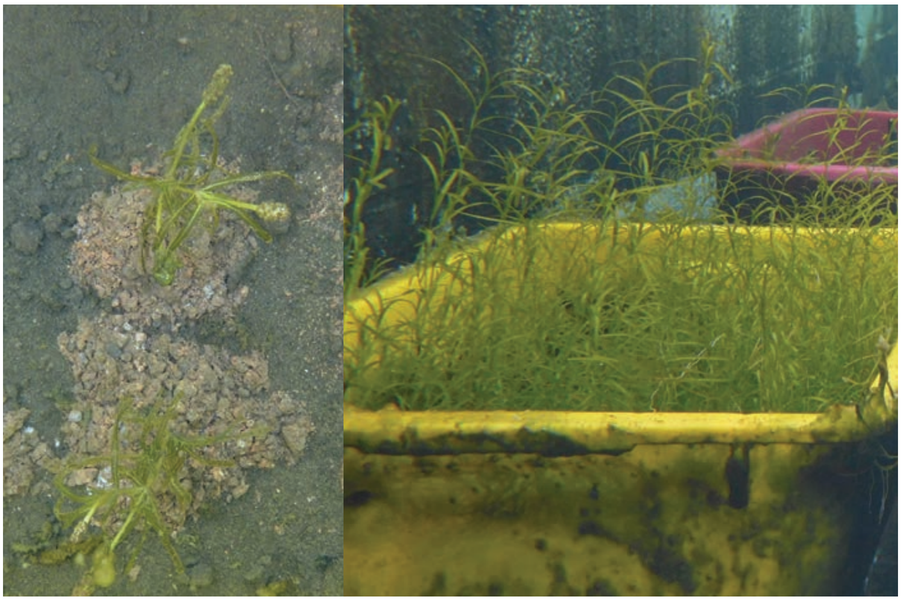
RotoTurf is most suitable where shorelines are wadeable or readily accessible. Where access is not suitable for wading, plant bombs may be a feasible alternative to RotoTurf.

What are plant bombs?

Plant bombs are balls made of a soil mixture (e.g., clay+garden soil+gravel) that native plants can be secured into, and then the bombs can be dropped into water anchoring the plants to the lake bed[5, 6]. The balls were approximately 4cm in diameter, with the aim of using as little soil mixture as possible, whilst achieving a 'stickiness' from the clay that would hold it all together, and enough weight from the gravel to aid sinking.

Plants of *M. triphyllum*, *P. ochreatus*, and *N*. sp. aff. *cristata* were all assessed in a mesocosm study to see how well they would establish and grow after being bombed. The bombs each had a single shoot (approximately 15cm long) of either *M. triphyllum*, *P. ochreatus* or a small clump (approximately 1cm diam.) of *N*. sp. aff. *cristata*. All of these species expanded vegetatively in the sediments from initial points of colonisation. This method has the benefit of not requiring a long cultivation period prior to use, but there is a greater risk that any disturbance could dislodge the plant shoots before they have time to take root.

This approach of dropping plants directly into a lake can also be achieved with pre-cultivated plants, that are grown in biodegradable pots (e.g., peat or wood fibre pots).



P. ochreatus after the bombs were dropped with the small piles from fractured bombs clearly seen and the plant shoots trapped in place (top left) and after 3 months' growth (right).

[6] Woodward et al 2017. Waikato shallow lake rehabilitation, phase one. WRA16-034

Challenges – what can go wrong?

New Zealand has a native moth with an aquatic caterpillar (*Hygraula nitens*). The caterpillar feeds on a wide range of both native and invasive aquatic plants[7]. For cultured plants where there are no predators of the grazers such as fish, the caterpillars can cause significant damage, at levels seldom seen in the wild. To avoid issues with caterpillars, or any other potential 'hitchhiking' species entering the culture tanks, all sourced plants should be washed in clean water and visually inspected to determine they are 'clean' before they are used. Covering culture tanks with shade cloth, or a fine mesh is a means to prevent moths from entering and laying eggs.

Experience indicates the time of year for collection (i.e., winter - early spring) and collection from sites where caterpillars are naturally controlled by fish predation can minimise the risk of caterpillar damage.

Similarly covering tanks will also restrict access to frogs or waterfowl. Frogs should be discouraged as tadpoles will graze on or damage the leaves of some plants, not just the algae. If tadpole numbers are high this can have a negative impact on plant growth.

Waterfowl can rapidly consume and uproot aquatic plants and their access to culture tanks should be prevented.

Consideration checklist

- [ ] Have the project goals been clearly identified?
- [ ] Have all interested parties been identified?
- [ ] Are any aquatic plants present in the waterbody, and if not - what local populations exist?
- [ ] Has the feasibility of translocation been considered?
- [ ] Are there suitable safe sites in the waterbody?
- [ ] Have all necessary permissions been obtained?

See our Decision Support Guide at **niwa.co.nz/RotoTurf** for for site-specific considerations and the feasibility of macrophyte introductions, and species-specific information.

[7] Redekop et al (2016). *Hygraula nitens*, the only native aquatic caterpillar in New Zealand. Hydrobiologia, DOI 10.1007/s10750-016-2709-7

Dr Gettys' example using a coconut fibre mat and Vallisneria

NB: This is an example only, while native to the USA, no species of Vallisneria should be used in New Zealand as Vallisneria species are non-native[8] pest plants[8].

Early trials compared two matrix materials (cotton burlap/jute, coir/coconut fibre), both of which were natural, biodegradable products that were cut into 45 x 60cm mats. Plants failed to establish in either matrix when cultured without an underlying soil bed, so all planted mats were kept underwater on soil beds during the grow-out period. 100% burlap was too thin to allow the incorporation of plant roots, so plants rooted into the soil underneath the burlap instead of into the burlap itself. Also, burlap ultimately proved to be unstable and failed to provide the structural integrity needed to transport intact mats to the field. Coir was thicker (1.2cm) than the burlap and dense enough to allow plants to form well-developed roots directly in the material, providing a good structural base for transported plant mats to the field (photos 1, 2).

Field trials also used a coir matrix but these mats were much larger[10]. Prefabricated mats were around 1m x 4.5m and composed of 3-cm-thick mattress coir encased in coir-based rope-netting. Individual plants were "tucked in" to the coir approximately 15cm apart and secured by tightening the rope netting around the crown of the plant (photos 3, 4). After 4 to 6 months of culture in greenhouse tanks, the original 150 plants per mat expanded to form a well-established population of up to 5,000 plants per mat.

Before transport to the field, the greenhouse tanks holding the planted mats are drained of water for easy access to the mats. Each mat was rolled using a post as a spool, allowed to drain for up to an hour, then wrapped in plastic bags to keep the mat moist. Rolled mats of Vallisneria could be held under these conditions for several days (protected from high temperatures and direct sunlight) before being trucked to the field.

At the transplant site, the mats were floated into position and unrolled (photo 5). Mats were then anchored to the bottom with custom-made landscape staples, fabricated from rebar with a 1m span with 30cm legs (photo 6).


1


2


3


4


5


6

[8] New Zealand Plant Conservation Network. **https://www.nzpcn.org.nz/flora/species/vallisneria-australis**

[9] **https://niwa.co.nz/sites/default/files/Freshwater%20invasive%20species%20of%20New%20Zealand%202020_1.pdf**. *Vallisneria australis* is an Unwanted Organism

[10] BioD-pillows, by RoLanka

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Further Information:

niwa.co.nz/RotoTurf

Here you can find:

Native freshwater plant cultivation booklet

Decision Support Guide: site-specific considerations and the feasibility of macrophyte introductions, and species specific information [due October 2024]

August 2024

Climate, Freshwater & Marine Science