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Assessment of benthic barrier products for submerged aquatic weed control

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ABSTRACT

The use of biodegradable products as benthic barriers to control submerged aquatic weeds and their impact on desirable native plant species was assessed in a common garden study. Five introduced invasive species (*Ceratophyllum demersum*, *Egeria densa*, *Elodea canadensis*, *Hydrilla verticillata*, *Lagarosiphon major*), a lesser weed (*Potamogeton crispus*, also introduced), and desirable native species (*Myriophyllum triphyllum*, *Potamogeton ochreatus*, an assemblage of charophytes, and oospore rich sediment) were grown in pots under common conditions before being covered by one of three matting products. Two different grades of hessian (burlap) and a coconut fiber product were placed over the plants and anchored in the pots. Plant emergence through the barrier and biomass were assessed over a 5-month period. For all species, the trend was toward reduced emergence with increasing product density, with significantly fewer plants emerging from treated pots compared with untreated control pots for all species except *C. demersum* and the charophytes. Biomass data corroborated the trends observed in the emergence data, except that the biomass of the germling charophytes was significantly lower in the densest treatments compared with controls. There was, however, a variable response among plant species; some were inhibited by all of the products while others only had reduced emergence and biomass with the densest matting product. The variable response of the weeds and the native plants to the different products provides an opportunity for selective control of some weed species, while providing a recruitment opportunity for native charophytes species from the seed bank.

Key words: burlap, jute, hessian, weed matting.

INTRODUCTION

Introduced aquatic plant species have had spectacular success invading New Zealand's lakes and waterways. Of the introduced invasive alien species, members of the Hydrocharitaceae and Ceratophyllaceae have been the most successful and have had the greatest impact on invaded lakes and waterways by reducing biodiversity values and interfering with recreational uses of waterbodies and economic utility of waterways for hydroelectric generation and water extraction (de Winton et al. 2009). Appropriate weed control options are continually sought that can successfully protect native biodiversity, amenity values, and economic function, while reducing weed biomass and/or eradicating weed species.

The approach to submerged weed control is dependent on many factors, including available options such as mechanical, biological, chemical, and physical weed control, the choice of which is often determined by weed and sites specificities and management objectives. Where submerged aquatic weed incursions are new or relatively small, a benthic barrier (or bottom lining) can provide successful weed control on its own or as part of an integrated weed management approach.

The use of benthic barriers for localized control of aquatic weeds is well established (Peterson et al. 1974, Perkins et al. 1980, Engel 1983, Nichols and Shaw 1983, Jones and Cooke 1984, Killgore 1987, Newroth 1993, Payne et al. 1993, Carter et al. 1994, Eakin and Barko 1995, Helsel et al. 1996, Madsen 2000), and many products are readily available for small-scale use, although it has received relatively little scientific attention (Born et al. 1973, Nichols 1974, Mayer 1978, Cooke and Gorman 1980, Engel and Nichols 1984, Murphy 1988, Gunnison and Barko 1992, Eichler et al. 1995, Ussery et al. 1997, Cook et al. 1993, Caffrey et al. 2010). Considerations for successful weed control with a benthic barrier include choice of product, permeability of the product, ease of placement and retrieval (if necessary), and costs. Not all products are permeable, such as plastic sheeting, which inhibits exchange of water and gases between the benthos and the water column (Eakin and Barko 1995); these may be difficult to install and secure to the bottom of the lake (Engel 1983, Lewis et al. 1983, Cook et al. 1993) and may balloon up in places due to trapped gas from decomposing plants (Gunnison and Barko 1989, 1990, 1992). Nonpermeable benthic barriers are generally nonselective, in that all plants are smothered and controlled over time, with some variation between species in their ability to withstand shading (Carter et al. 1994, Eichler et al. 1995). There are also reports of plants growing through slits in barriers made for gas release (Cooke 1980, Killgore 1987), and with permeable barriers some species may persist and grow through the apertures (Eichler et al. 1995) as well as on the barriers from newly arrived plant fragments, particularly once suspended sediments have accumulated (Mayer 1978, Cooke 1980, Cooke and Gorman 1980, Perkins et al. 1980, Lewis et al. 1983, Nichols and Shaw 1983, Jones and Cooke 1984, Perkins 1984, Murphy 1988).

However, Caffrey et al. (2010) recently demonstrated effective control of the weed *Lagarosiphon major* and the recolonisation of a number of Ireland's desirable native plants through a jute benthic barrier. In that example, the use of jute had several advantages, aside from controlling *L. major* (and allowing native plant reestablishment); it was relatively easy to place and anchor because it sank readily once wet,

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its permeability facilitated gas exchange, and after 10 to 17 months decomposition of the jute was evident, eliminating any need to retrieve the jute (Caffrey et al. 2010).

The successful application of jute as a benthic barrier (Caffrey et al. 2010) led to further consideration of its potential wider use for weed control and littoral zone restoration, Some of the factors to test were its level of control compared with other biodegradable products and other submerged weed species, and its potential to negatively affect charophyte recruitment or that of other desirable native species, given that burial depth makes a difference to successful oospore germination and germling survival (Dugdale et al. 2001).

To address these questions, a common garden study was designed to evaluate the use of readily available natural fibre products for submerged aquatic weed control and to assess potential effects on desirable native plants species and charophyte germination.

MATERIALS AND METHODS

Experimental design

A pot study was established in containment to assess the ability of five invasive weed species (*Lagarosiphon major*, *Egeria densa*, *Hydrilla verticillata*, *Elodea canadensis*, and *Ceratophyllum demersum*), a lesser weed (*Potamogeton crispus*, also introduced), and desirable native species (pondweed [*Potamogeton ochreatus*], native milfoil [*Myriophyllum triphyllum*], and an assemblage of charophytes) to grow through three different natural products used as benthic barriers or weed matting.

Plants were sourced (only one source for each species) from local lakes and the National Institute of Water and Atmospheric Research (NIWA) culture collection at Ruakura (Hamilton, New Zealand). Each sample was prepared by taking a 25 cm apical shoot from each species and placing in a 300 mL plastic pot (8 cm high) filled with topsoil to just below the surface of the pot and overlain (about 0.5 cm) with washed river sand. The charophytes (predominately *Chara australis*) were planted as a clump with rhizoids attached (rather than individual shoots) measuring 1 cm in diameter. All plant pots were placed outdoors (NIWA Ruakura campus) in a concrete trough (13.3 m in length, 1 m deep, and 1.3 m wide) filled with water (carbon filtered, municipal supply) to a depth of about 0.5 m, and covered with 90% shade cloth to inhibit the growth of periphytic algae. The plants remained in the troughs for 6 weeks during spring (Sep to Oct 2009), by which time new shoot growth was evident for all species. Immediately prior to covering with the weed matting, all plants were cut to about 1 cm above sediment level to simulate a mechanical harvest and reduce the amount of plant biomass that would be trapped under the weed matting. For some species, in particular the introduced weed species, shoot length extended up to 1 m prior to harvest.

Additional pots were also prepared that contained lake sediment rich in charophyte oospores. In spring 2009, lake sediment was sourced from lakes Tarawera, Tikitapu, and Rotoroa and stored in the chiller (2 to 4 C) until used. Subsamples (10 mL, 4 replicates) of the sediment from each lake were removed and sieved, and oospores species were identified (using a stereo microscope Leica MZ9) and numbers recorded. Based on the oospores species numbers obtained and prior knowledge of likely germination percentage (about 5%; M de Winton, NIWA, pers. comm.), a mixing ratio for the sediment from the three lakes was determined that would provide about 82 oospores across seven species of charophyte (although two species were dominant, *Chara globularis* and *Nitella pseudoflabellata*) per 100 mL of sediment. Pots were filled with the mixed sediment (about 300 mL) immediately prior to applying the weed matting.

Three weed matting products were selected from a local supplier (Taylor Built Ltd), which differed in gap size within their weave. One was made from coconut fiber (cocomat 450; i.e., 450 g m^{-2} coconut fiber reinforced with biodegradable netting), and two were hessian products (described as 18 and 14 oz). The coconut fiber was densest in appearance, although the gaps in the weave were inconsistent. The 18 oz hessian had a gap size of about 1 mm between the weave, whereas gaps in the 14 oz hessian were up to 2 to 3 mm or less. The least dense hessian product was similar in weave to that used by Caffrey et al. (2010), based on a visual comparison with a sample supplied by Caffrey.

Discs of each product were cut to the size of the pots, and one disc was placed over each of the appropriate pots and secured on the sediment using three evenly spaced shade pins. Each plant species was planted in 25 pots covered with each of the weed matting products and an additional 25 pots that had no weed matting. Once covered with weed matting, the pots were labeled (species, treatment, replicate) and placed into the concrete trough in a randomly assigned spacing. Four additional pots, one with each matting product and one control, were used to evaluate the level of light reduction at the sediment surface. A logger (Hobo pendant) was placed under the matting in each pot where light level and temperature were logged for a week at 15-minute intervals. An additional logger was placed in the tank for the duration of the study, recording both ambient light and temperature. Median values calculated as the percent reduction in light compared with the untreated control (from daylight hours only) showed 89, 83, and 73% light reduction for the cocomat fiber, the dense hessian, and the light hessian products, respectively. Little temperature variation was recorded between day and night (22 to 20.5 C) and no difference between the loggers over the experimental period.

Data collection and analysis

Every month for 5 consecutive months, the emergence of shoots through the weed mat was recorded, and five pots of each type (i.e., species and matting combination) were randomly selected from the trough and destructively harvested. Plants were placed in a drying oven (80 C) until constant dry weight was achieved, and dry weights were recorded.

The emergence data were analyzed separately for each species, but with all five harvest dates included (as date by treatment interactions were not significant) using logistic regression. An ANOVA (Genstat) was performed on plant biomass data (rank transformed) for each species and harvest date separately and then combined (date by treatment interaction for biomass was not significant). Differences between treatments were separated using the Tukey HSD test (all statements of significance refer to $P \leq 0.05$).

RESULTS AND DISCUSSION

For most species the use of a weed matting product affected plant emergence (Figure 1), with a trend of reduced emergence as product density increased. This trend was significant for all of the weed species except *C. demersum*, and for all native plants except charophyte oospores. The remaining serious weed species are all members of the Hydrocharitaceae, and among these there were differences between the species with respect to their regrowth in both the untreated control pots, and the degree to which the matting impacted plant emergence. For example *L. major*, *E. densa*, and *H. verticillata* generally grew well in all control pots with more than 75% emergence, compared with *E. canadensis* which had less than 50% emergence, which is not uncommon for *E. canadensis* under cultivation in static water (Hofstra et al. 1999). However, while overall emergence was lower for *E. canadensis* than the other serious weed species, the trend of reduced emergence with increasing product density was consistent, although species varied in the degree to which emergence was affected. For example *L. major* emergence was significantly lower for all products compared with *E. densa*, where emergence was only reduced for the two densest products, and *H. verticillata* and *E. canadensis*, which were only affected by the very dense coconut fiber (Figure 1).

These variable results are likely attributed to morphological differences between the plants and their corresponding ability to produce shoots that will pass through the apertures in the different products. For example, *L. major* and *E. densa* generally have wider shoots (and stem diameters) than *E. canadensis* (Riis et al. 2010) and *H. verticillata*. A similar emergence pattern was evident among the native milfoil (*M. triphyllum*) and pondweed (*P. ochreatus*), and the lesser weed (*P. crispus*). Among these species *M. triphyllum* has slightly heavier (round stems) compared with the flattened stems of *P. crispus* and thinner stem of *P. ochreatus*, and *M. triphyllum* had a greater degree of separation among treatment types with only 10% of plants growing through the most dense product, compared with 20 and 40% for *P. ochreatus* and *P. crispus*, respectively. The charophytes are the most slender of all the plants evaluated, and although a significant reduction in emergence was detected only

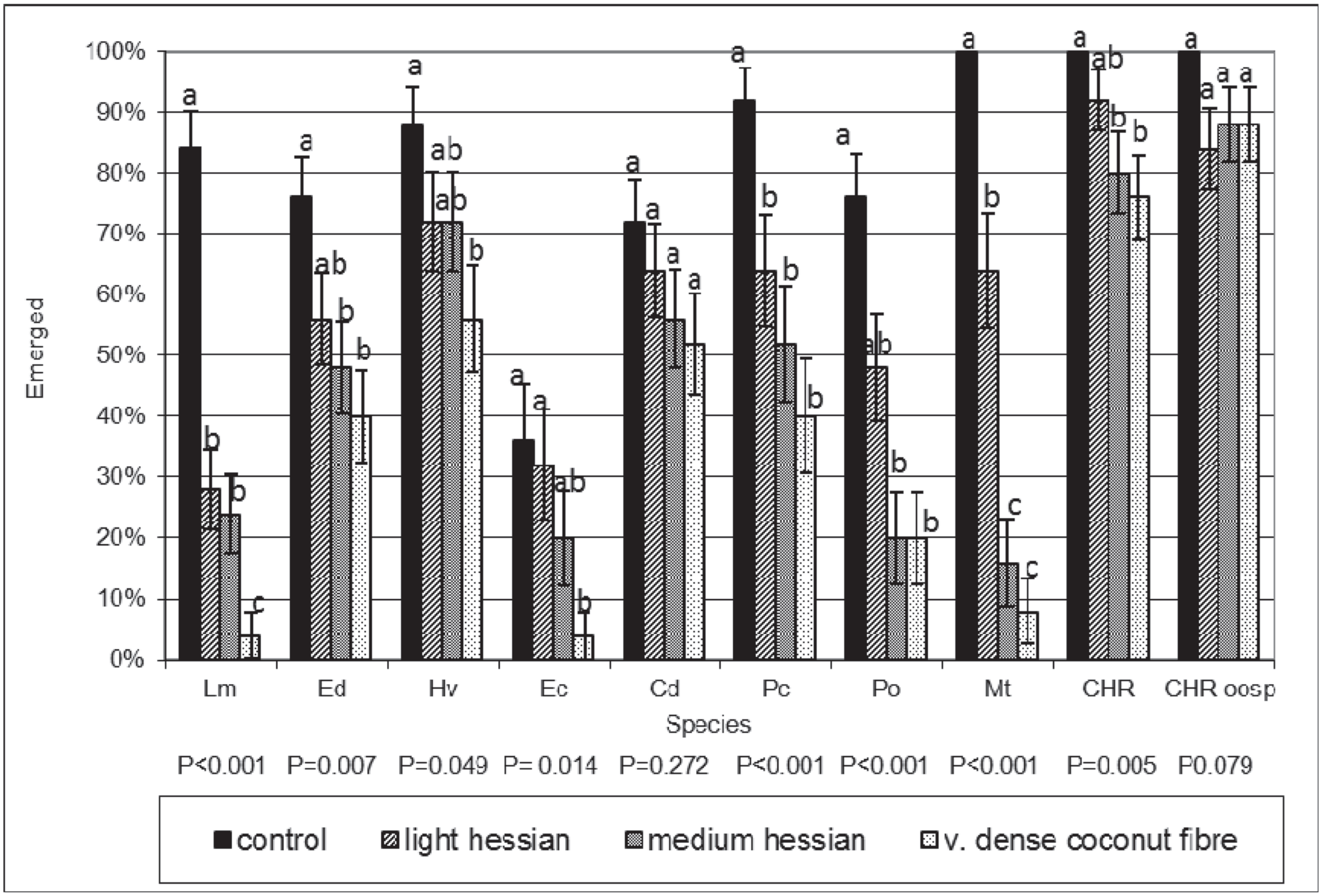

Figure 1. Emergence of each species from pots treated with different matting products. The values shown are means from the five harvest months (n = 25) with associated standard errors. For each species, significant differences (Tukey HSD, $P \leq 0.05$) in biomass between treatments are represented by different letters, with P values from initial analyses below the species abbreviations. Species abbreviations are as follows; Lm is *L. major*, Ed is *E. densa*, Hv is *H. verticillata*, Ec is *E. canadensis*, Cd is *C. demersum*, Pc is *P. crispus*, Po is *P. ochreatus*, Mt is *M. triphyllum*, CHR is charophyte and CHR oosp is oospore rich lake sediment.

for the two densest products, the percent emergence still remained above 75% for all treatments. As expected, the young charophytes (germlings) that emerged from the oospore-rich lake sediment were not affected by the presence of a weed matting barrier, with emergence in all treatments greater than 80%. Like the charophyte germlings, *C. demersum* emergence was unaffected by the matting barriers; however, this species has notably wider stems than the germlings (visual observations), yet still had a slender growth form as indicated by its relatively low biomass compared with robust *C. demersum* plants regularly observed in lake populations.

In general, the biomass data support the observations and trends described in the emergence data, with significantly less plant biomass obtained from treatment (compared with control pots) of the same species (Figure 2). The exception was the charophyte oospore rich sediment pots, where significantly lower germling biomass was obtained from pots with the two denser matting products than in the untreated control pots. Although emergence may not be compromised by the use of these products, selection may be for smaller germlings (potentially smaller species), which resulted in the lower biomass in some treatments.

Results in the present study are similar to other lake-based studies and observations where varied success in controlling aquatic weeds using different benthic barrier products has been documented. A number of studies describe the regrowth of plants through gaps between barrier products (Killgore 1987), including recovery after barrier removal indicating a tolerance for being smothered (Perkins 1984, Carter et al. 1994); plant recolonization via fragmentation or seed deposition along with suspended sediments on top of the benthic barrier (Perkins et al. 1980, Lewis et al. 1983, Perkins 1984, Cook et al. 1993); and growth through permeable barriers (Perkins et al. 1980, Jones and Cooke 1984, Caffrey et al. 2010). For example, Perkins et al. (1980) reported some Eurasian watermilfoil stems growing through an Aquascreen barrier, and Jones and Cook (1984) reported *Najas flexilis* growing on and through hessian barriers. Perkins (1984) made a distinction between plant species, finding that finer-leaved species can penetrate apertures in barriers, and that the use of such barriers may promote succession of other undesirable species (e.g., *Potamogeton pectinatus*). Finer-leaved species were reported to penetrate the hessian (jute) benthic barrier used to control *L. major* in Ireland (Caffrey et al. 2010). In that example, several species of charophytes (*Nitella flexilis*, *Chara globularis*, *Chara virgate*, and *Chara rudis,* a physically larger charophyte species) were recorded to have grown through the barrier. Additionally, *E. canadensis* and two

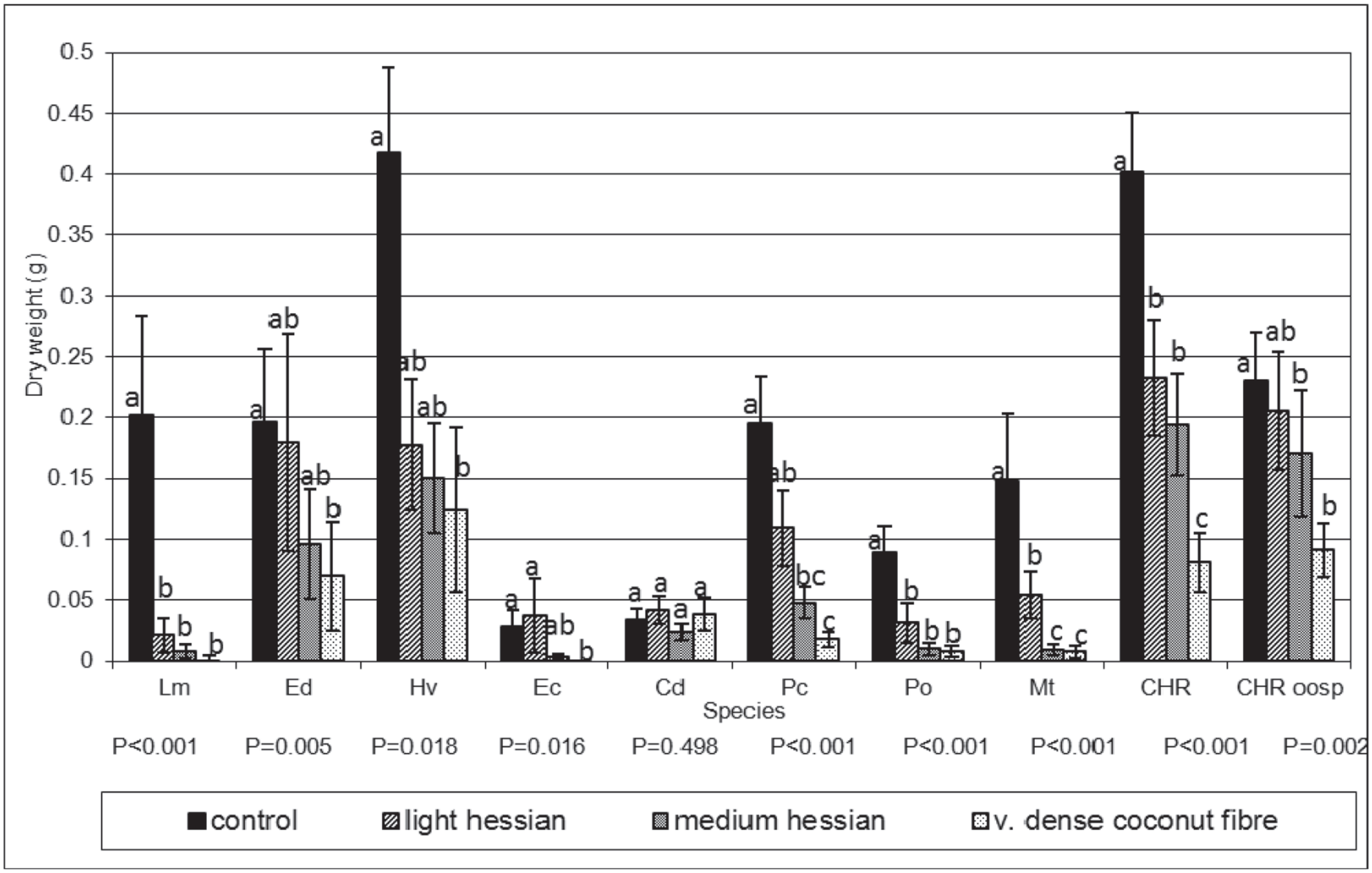

Figure 2. Biomass of plants that emerged through each matting product. The values shown are the means across each of the five harvest months (n = 25) with associated standard errors. For each species, significant differences (Tukey HSD, P ≤ 0.05) in biomass between treatments are represented by different letters, with P values from initial analyses below the species abbreviations.

species of milfoil, (*Myriophyllum alterniflorum* and *Myriophyllum spicatum*) were also recorded growing through the hessian, though none were abundant (Caffrey et al. 2010).

In general, a relationship seems to exist between plant stem diameter and aperture size in permeable barriers with respect to a plant's ability to penetrate and grow through the barrier. Denser products such as those used in the present study were ideally suited for the control of select invasive species, including *L. major* and *E. densa*, which have thicker stems compared with *H. verticillata*, *E. Canadensis*, and *C. demersum*; thus, any tall growing macrophytes (e.g., pondweeds and milfoils) that may be present among weeds would also be controlled. Note, however, that native plant species (in New Zealand) are locally displaced by *E. densa* and *L. major*. In that regard, the potential for re-establishment of native plants from seed bank material is important, and the possibility of selecting for charophyte species based on germling size may warrant investigation. However, in demonstrating the differences between species in their emergence and growth through the barrier products, this study illustrates an opportunity for selective control and native plant recruitment through the use of biodegradable products.

In addition, once the hessian decomposes, the barrier for all native submerged species is removed allowing full native plant recovery. Because none of the weed species has a seed bank, by the time hessian degrades (estimated as 10 to 17 months by Caffrey et al. 2010) the vegetative propagules would also be gone. Similar native plant recovery is observed when tall weed beds have been treated with diquat (for example). The exposure of sediments to light and removal of invasive weeds allows a full spectrum of native species to regenerate; however, weeds regrow after herbicide treatment, and native plants are once again displaced. A biodegradable benthic barrier can potentially achieve a more sustainable recovery than herbicides, albeit on a smaller scale.

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