Seeding the Way:

A Guide to Restoring Native Plants in Great Salt Lake Wetlands

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From densely vegetated marshes to sparse patches of playa vegetation, native plants of Great Salt Lake drive healthy wetlands. They provide habitat, cover, and food for the many birds, amphibians, insects, and mammals that call these wetlands home. Disturbances to these wetlands, such as treating invasive *Phragmites australis* (hereafter *Phragmites*) or building dikes, can impact native plant communities.

Reestablishing native vegetation is critical to rebuilding healthy wetlands. Though there is still much to be learned, here we have summarized our knowledge of the "what, where, and how" of native plant revegetation in these wetlands, specifically using native seed. This guide is intended to inform seeding efforts in Great Salt Lake wetlands after any disturbance, including post-treatment of *Phragmites*.

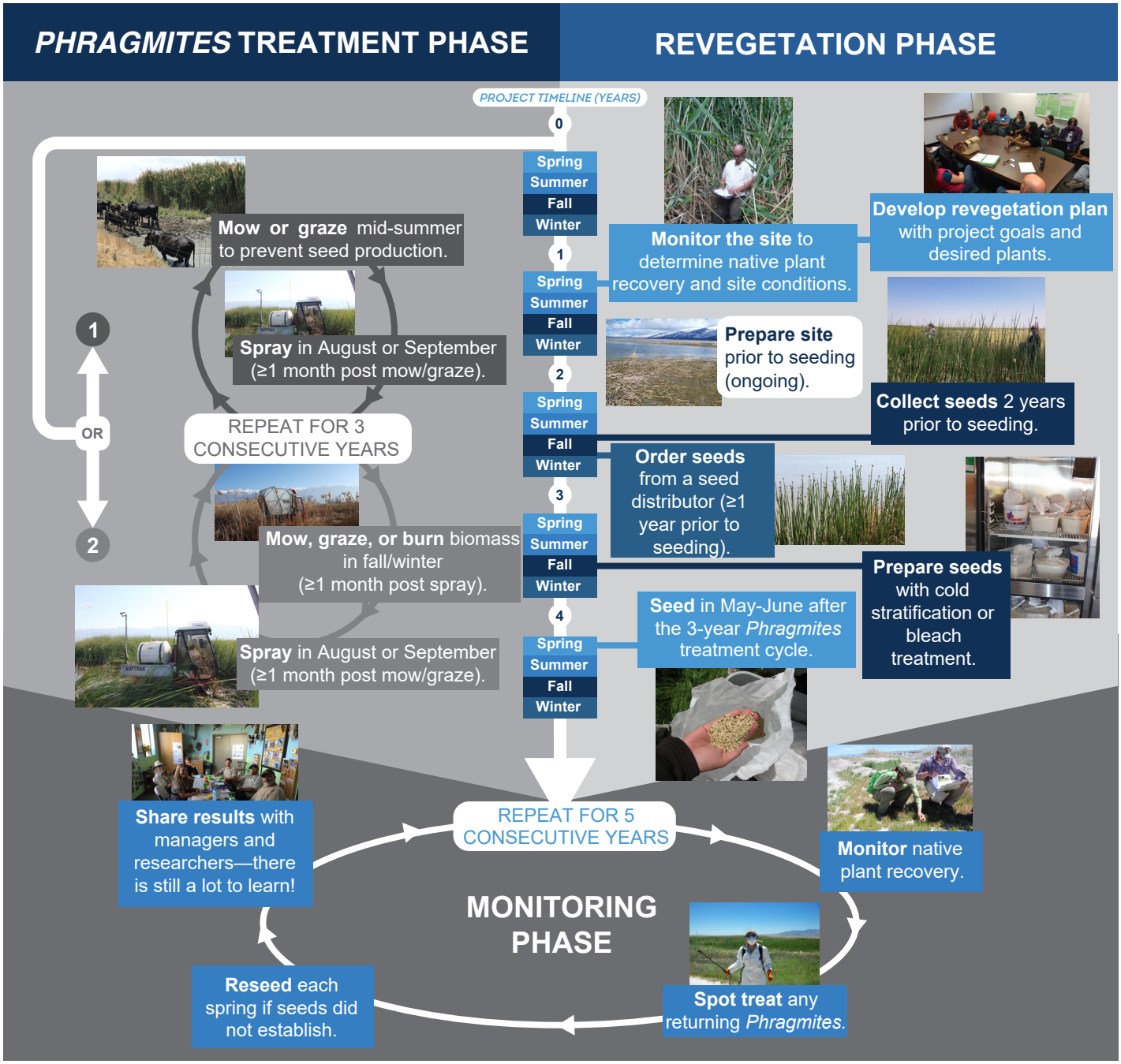
Do I need to seed?

Reestablishing native plants in wetlands can prevent invasion of unwanted species, but seeding is not always necessary. If a site has been invaded by undesirable species for a long time or native species are slow to recover naturally, there may be too few native seeds in the soil. In this case, native seeds should be sown to achieve the desired plant community.

Do not waste money on seeding if invasive species have not been sufficiently managed (e.g., *Phragmites* requires at least 3 years of herbicide treatments; see Rohal et al. (2017) for further guidance) as invaders will likely return and overtake native vegetation. During invasive species treatment, carefully observe which natives appear before deciding on next steps.

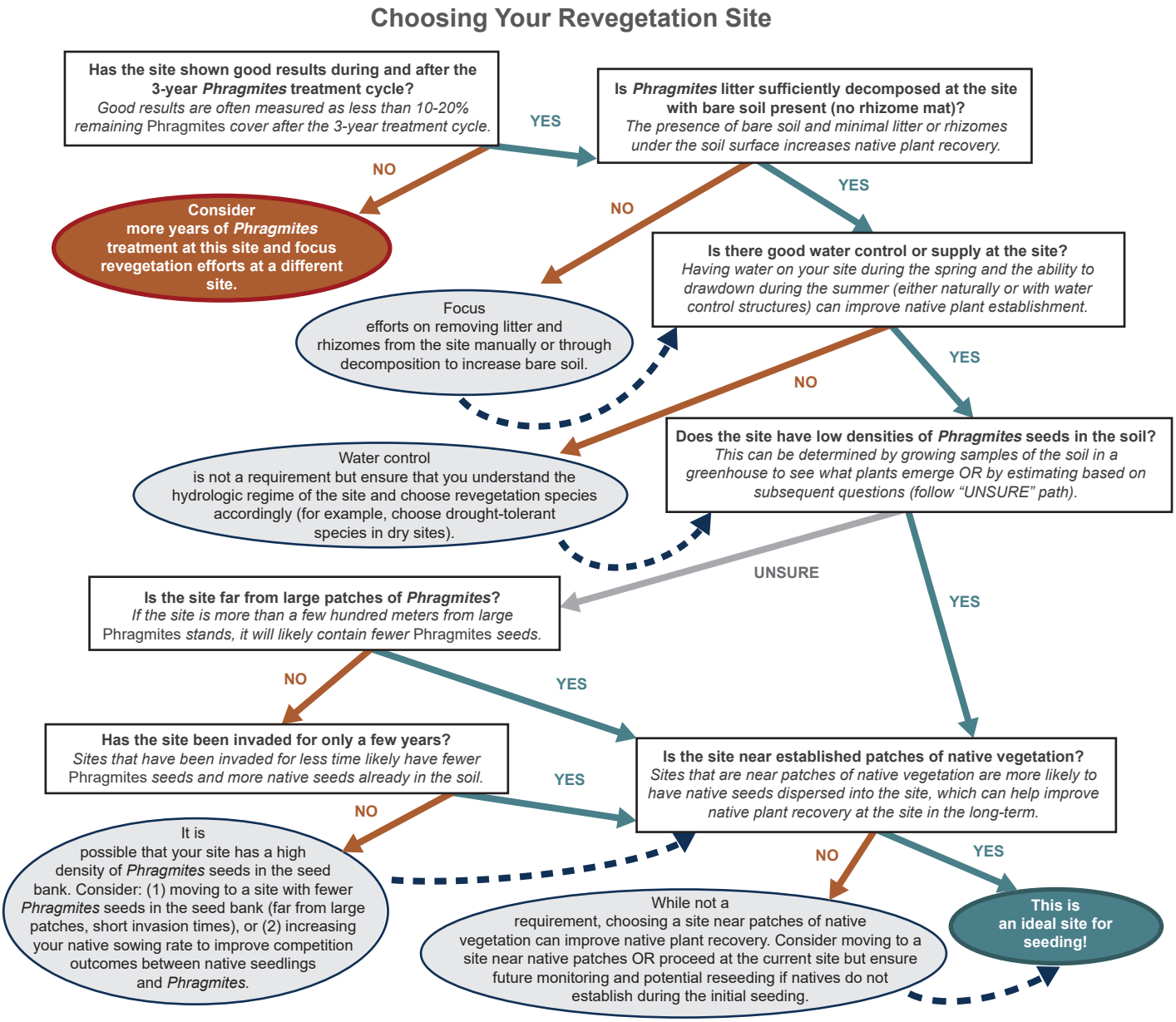
How do I plan for seeding?

After establishing the need to seed, a revegetation plan should be developed to outline project goals and objectives, inventory site characteristics, and detail target native species and budgets. Developing a timeline of site pre-treatments, revegetation, and monitoring is also helpful in the planning process to ensure tasks are being completed on time. Below is a recommended timeline of revegetation in conjunction with *Phragmites* treatment. See Rohal et al. (2017) and Duncan et al. (2019) for more details on *Phragmites* treatments.



Which site should I seed?

Choose a restoration site that has a high likelihood of success. The decision tree below can help assess which sites are more likely to result in successful revegetation. Sites that are more challenging (more "No" paths) do not necessarily have to be abandoned. Instead, expect that more money and effort will be needed to successfully restore native vegetation. In these cases, collaborating with other organizations—to stretch limited funds, capitalize on shared knowledge, and share equipment and personnel—can improve success.



*Decision tree to identify an ideal site for seeding. We provide an example in the context of assessing a site post-*Phragmites *treatment, but this framework could be adapted to sites where other undesirable species or site disturbances necessitate seeding.*

What species should I seed?

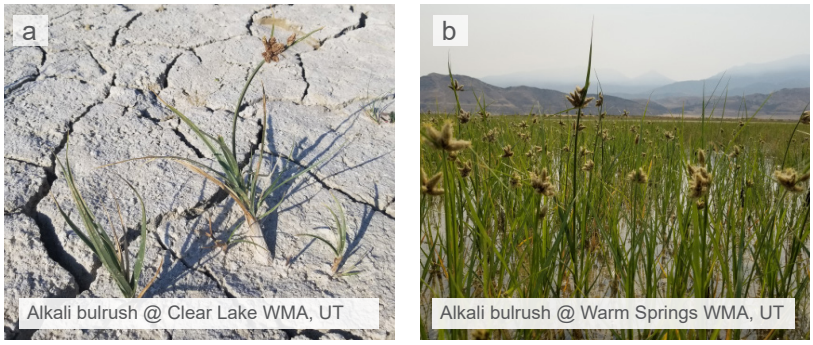
You should choose species that meet management goals, such as providing habitat for waterfowl and preventing reinvasion of undesirable species. The seed mix should be diverse and include species that:

1. Grow quickly (like annuals) to compete against *Phragmites* and other weeds,
2. Are long-lived perennials to best provide habitat, and
3. Thrive in a variety of water levels and salinity to ensure that native plants persist even if future site conditions change.

Seeding a diversity of native species is a good bet-hedging strategy to meet management goals and ensure some native plants take hold at the site. Annual plants such as (a) *Bidens cernua* (nodding beggartick) and (b) *Rumex maritimus* (golden dock) can do well to quickly occupy space and minimize *Phragmites* reinvasion. Long-lived perennials such as (c) *Bolboschoenus maritimus* (alkali bulrush) provide suitable wildlife habitat and food. You should also include species that do well in dry conditions such as (d) *Distichlis spicata* (saltgrass) and wet conditions such as (e) *Eleocharis palustris* (common spikerush) to ensure some native plants establish in many different conditions that could occur at the site.

Where should I get seeds?

Native plant vendors are a good option for getting seeds but contact them **at least one year before seeding** so that your desired species and quantities are available. Keep in mind that many annual or weedy native plants are likely unavailable through commercial vendors, so plan to either hand collect these species or discuss commercial collection with vendors well in advance of seeding.



If you are collecting seeds from the wild, choose plants that are growing in different conditions to capture plenty of genetic diversity. For example, collect from plants that are growing in (a) dry conditions (or other harsh sites) and (b) wet conditions.

If you choose to collect seeds on your own, harvest seeds from 50–200 individual plants at three or more distinct sites to increase genetic diversity in seed mixes, which will improve establishment and survival. Don't limit yourself to pristine sites. Plants growing in harsh sites have unique adaptations and will produce seeds that can also withstand challenging conditions at the restoration site. Seeds should be collected when ripe, which is often mid to late summer into early fall, depending on the species.

What kind of preparation and treatments do my seeds need before seeding?

Seed Cleaning

- If possible, clean seeds to enhance **germination** and allow for better estimates of seeding rate.
- Seed cleaning is usually done with sieves or an air column separator.
- If purchasing seeds, this step is often done for you.

Seed Viability

- Determine the **viability** of your seeds to calculate sowing rates, based on **pure live seed** (PLS).
- Viability can be determined with a tetrazolium analysis completed by an independent laboratory. If purchasing seed, viability tests will often be done for you.
- If outsourcing seed-testing is too costly and there are no in-house viability testing options, a germination test can be an imperfect way to assess viability.
- Viability tests should be repeated on older seeds (>1 year since the last test), as viability can decrease over time.

Seed Dormancy

- Determine **dormancy** breaking requirements for your species. Many sedge and bulrush species (e.g., *Schoenoplectus* spp.) require 6 or more weeks of **cold stratification** prior to seeding, while others (e.g., *Bolboschoenus* spp., *Eleocharis* spp.) require a **chemical scarification** prior to seeding (Table 1).
- For species with unknown dormancy breaking requirements, USDA plant guides (plants.usda.gov) may provide some information for certain wetland species.
- If no information is found, cold stratification is recommended. Cold stratification has the added benefit of enhancing germination, and it is much easier to cold stratify all seeds together in a mix.
- Seeds can be sown “as-is” in the fall without any stratification so that dormancy break can occur naturally over the winter. However, we recommend breaking dormancy under controlled conditions and then seeding in the spring to minimize seed loss under field conditions.

Key Seed Terms

- **Chemical scarification**. This method of breaking dormancy often uses a chemical (e.g., acid or bleach) to break down hard seed coats (such as with alkali bulrush or common spikerush).
- **Cold stratification**. Cold stratification mimics the natural overwintering process of buried seeds in the soil, which allows for germination the following spring. Many species need to be cold stratified to break dormancy. To stratify seeds, wrap them in permeable material (like a paint strainer), bury the wrapped seeds in a bucket of moist sand, then place the bucket in a refrigerator (at 35–40 °F).
- **Dormancy**. Even if a seed is alive (viable), it can be dormant and not able to grow. There are various ways to treat dormant seeds to trigger germination. These dormancy breaking treatments usually mimic winter conditions (“cold stratification”) or animal digestion (“chemical scarification”), conditions a seed might experience in nature.
- **Germination.** The first stage of plant growth is germination when the young plant starts to sprout from the seed.
- **Pure live seed**. The percentage of a seed lot that is alive (viable seeds) and pure (only the seed, not sticks or other debris). The rate of seed sowing should be based on pure live seed.
- **Seed bank**. Dormant seeds that are shed from a plant can accumulate in nearby soil and form the seed bank. Seeds remain in the seed bank until environmental conditions are ideal for germination and dormancy is broken.
- **Viability**. Not all seeds are living. Tetrazolium staining can be used to test viability and determine if seeds are alive (viable).

Seeding Implementation

How do I prepare my site for seeding?

Prior to seeding, remnants of invasive species that might inhibit native plants should be largely gone. For instance, *Phragmites* litter and the rhizome mat should be largely decomposed as a result of routine flooding after mowing during the 3-year *Phragmites* treatment cycle. Keep in mind that some litter may be left on the site and that is okay. Small amounts of litter can be helpful in keeping seeds in place and retaining moisture for seed germination. Ultimately, it is important to see bare soil at the site so native seeds have good seed-to-soil contact and are exposed to light.

Aim for (a) as much bare soil as possible when preparing your site. This means letting the (b) litter and (c) rhizomes from unwanted species decompose (or manually remove them). However, (d) some litter left behind is okay—small amounts can keep seeds in place and improve germination in some cases.

How do I sow seeds onto the site?

Broadcast seeding (i.e., without water or tackifier, an adhesive to bind seeds to soil) can be an efficient seeding method in areas where seeds are unlikely to wash away, especially on larger sites as the cost of tackifier application (and added logistical complications) can add up quickly. Seeds can be broadcast by hand or with a broadcast machine mounted on wetland-capable equipment. In areas where seeds are likely to wash away, a tackifier is recommended. Seeds can be mixed with tackifier and hydroseeded onto the site using a Softrak or another wetland machine. Use higher concentrations of tackifier (3–5x the recommended rate of the specific tackifier being used) in areas with high wave action or fluctuating water levels. The addition of mulch to the hydroseeding mix is not recommended as wetland seeds often need high light to germinate.

Seeds can be sown on the site through broadcast seeding either (a) by hand or (b) with a broadcast machine mounted on a Softrak or other wetland-capable machinery. Alternatively, in sites with high wave action, seeds can be (c) mixed in a tackifier slurry and applied from (d) a tank with internal agitation mounted on a wetland-capable machine.

What seeding rate should I use?

- Sowing seeds at the region's commonly used wetland seeding rates, approximately 150–200 seeds/ft^2 (1,938 seeds/m^2; 15 lbs/acre) has been found to yield more native plants versus relying entirely on the seed bank.
- However, many wetlands will likely need higher seeding rates than commonly used rates, especially in areas where there are a lot of invasive plant seeds in the soil or invaders are growing nearby.
- If the budget allows, choose to sow seeds at a higher rate of 500–1,000 seeds/ft^2 to greatly increase native cover. The added costs associated with higher seeding rates may mean choosing to seed a smaller area to maximize native cover.

When should I sow seeds?

- Sow seeds when peak spring flooding has dissipated and bare, saturated soil is exposed.
- Seeds will begin to germinate when temperatures fluctuate between 60–90 °F.
- The earlier you seed within the germination window, the better. Aim to sow seeds before weeds start to emerge, typically in May or June, so native plants can still receive sufficient light.

What should site conditions be during and immediately after seeding?

The specific conditions will depend on the site and species you use.

In areas prone to *Phragmites* reinvasion:
Our research suggests that drier soil (water table 2–5 cm below the soil surface) can better suppress *Phragmites* growth especially when "drier" native species (like saltgrass) are part of the seed mix.

In areas targeting saltgrass and alkali bulrush establishment:
These species do particularly well with moist soil during sowing followed by a summer drawdown.

In areas where water control is possible:
Aim to prevent extreme drought or high flooding, particularly during the first 1–2 months after seeding when new plants are most vulnerable to environmental conditions.

In areas where salinity may be high:
Some wetland plant species can tolerate fluctuating salinities as adults, but seedlings may not be able to tolerate high salinities. Native plants typically do well in freshwater to slightly brackish conditions (0–5 ppt).

What conditions should I maintain on my site?

The long-term hydrology and salinity conditions of the restoration site need to be suitable to support the survival, growth, and reproduction of native plants.

- Sparsely vegetated playas require high salinity and shallow (2–5 cm; 1–2 in), temporary flooding.
- Meadow communities are sustained by seasonal, shallow flooding (< 5 cm; < 2 in) or saturated soils and fresh to brackish water.
- Emergent wetlands are seasonally to semi-permanently flooded with deeper water (5–30 cm; 2–12 in) and the occasional drawdown (e.g., every 3–5 years). Emergent plants tolerate fresh to brackish conditions.

See Downard et al. (2017) for a detailed description of site conditions that support Great Salt Lake wetland plant communities by habitat type.

How should I monitor my site?

Keeping track of how a restoration site is doing after seeding is critical to increase seeding success and inform future management of the site.

How to Monitor

- Monitoring does not need to be complicated. Annual photopoints or walking/driving a site to look for native plant regrowth and problematic invaders may be sufficient. For sites that are hard to access, consider using alternative monitoring methods (like a drone).
- When monitoring, be sure to take good notes of how plants are responding at the site. These notes can help inform future revegetation efforts and improve understanding of seed-based wetland restoration.

Why to Monitor

- At some sites, seeding in multiple years may be required because of highly variable site conditions and high plant mortality. Monitoring will help identify if seeding efforts have failed (necessitating another year of seeding) or if environmental conditions at the site require different species to be seeded next season. **Ideally, seeding budgets should include a financial buffer for reseeding costs.**
- Monitoring can determine if any invasive species return that require attention. Invasive species will *always* be a problem in wetland restoration, but long-term issues can be avoided if small patches of invaders are treated promptly. This monitoring is especially important in Great Salt Lake wetland habitats that are more susceptible to *Phragmites* invasion (such as fringe wetlands on the edges of Great Salt Lake). In these areas, managers will need to be more vigilant with their monitoring to avoid future headaches.
- Seed-based restoration of wetlands is less commonly practiced, so restoration practitioners and scientists still have a lot to learn. Continued collaboration between scientists and practitioners is critical to ensure learning continues and restoration practices improve.

Table 1

Characteristics of Commonly Used Restoration Species in Great Salt Lake Wetlands

Species	Common name	Growth form (USDA Plant Profiles)	Family	Habitat type (Downard et al. 2017)	Wetland indicator status	Dormancy breaking requirement
Bidens cernua	Nodding beggartick	Annual forb	Asteraceae	Meadow	Obligate	None required
Bolboschoenus maritimus	Alkali bulrush	Perennial, rhizomatous graminoid	Cyperaceae	Emergent/Meadow	Obligate	24—48 hour 3% bleach solution scarification
Distichlis spicata	Saltgrass	Perennial, rhizomatous graminoid	Poaceae	Meadow/Playa	Facultative	Cold stratification for at least 6 weeks
Eleocharis palustris	Common spikerush	Perennial, rhizomatous graminoid	Cyperaceae	Emergent/Meadow	Obligate	24 hour 3% bleach solution scarification
Epilobium ciliatum	Fringed willowherb	Perennial forb	Onagraceae	Emergent/Meadow	Facultative-wet	None required
Puccinellia nuttalliana	Nuttall's alkaligrass	Perennial, rhizomatous graminoid	Poaceae	Emergent/Meadow	Facultative-wet	Cold stratification for at least 6 weeks
Rumex maritimus	Golden dock	Annual/Biennial, rhizomatous forb	Polygonaceae	Emergent	Facultative-wet	None required
Schoenoplectus acutus	Hardstem bulrush	Perennial, rhizomatous graminoid	Cyperaceae	Emergent	Obligate	Cold stratification for at least 6 weeks
Schoenoplectus americanus	Threesquare bulrush	Perennial, rhizomatous graminoid	Cyperaceae	Emergent	Obligate	Cold stratification for at least 6 weeks

Note. Seed mixes should include a broad mixture of species that exhibit different habitat requirements and growth forms (see Key terms).

Key terms: **perennial** - a plant that lives more than two years; **annual** - a plant that completes its life cycle in one year; **biennial** - a plant that completes its life cycle in two years; **graminoid** - grasses and grass-like plants; **rhizomatous** - a plant that produces horizontal underground stems, i.e., rhizomes; **forb** - non-grasslike and non-woody herbaceous plant; **obligate** - almost always occurs in wetlands; **facultative-wet** - usually occurs in wetlands; **facultative** - occurs equally often in both wetlands and uplands.

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