PROJECT TEAM

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LIST OF TERMS

Awn	Stiff hairs or bristles present on the seeds of some plant species
Dispersal	The transport of mature seeds away from the parent plant
Dormancy	A state in which seeds are prevented from germinating even under favorable conditions, intended to prevent seeds from germinating at unsuitable times, e.g. A warm fall day.
Equilibrium Relative Humidity (eRH)	The relative humidity of seeds at equilibrium with surrounding air in a sealed chamber
***Ex situ* conservation**	The conservation of biological diversity outside their natural habitat
Genetic Variation	Naturally occurring differences in a species due to variation in DNA
Germination	Development of a plant from a seed or spore
Hook	A recurved and pointed organ or appendage on seed which assists with dispersal
***In situ* conservation**	The conservation of biological diversity in their natural habitat
Individual	A single, separate organism
Intermediate seeds	Seeds which can tolerate some drying but are sensitive to low temperatures
Orthodox seeds	Seeds which can tolerate drying and storage at subzero temperatures.
Population	A group of individuals of a given species that live in a specific geographic area at a given time
Relative Humidity (RH)	The amount of water vapor in the air as a percentage of the amount needed for saturation at a given temperature.
Rhizomes	Underground plant stems which extend horizontally and can reproduce the shoot and root systems of a new plant
Recalcitrant seeds	Seeds that do not tolerate drying
Stolons	above ground plant stems which extend horizontally and can reproduce the shoot and root systems of a new plant
Target Species	The species intended to be collected

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EXECUTIVE SUMMARY

Seed collection, processing and banking is an effective and economical method for conservation of plant species, however, it requires extensive planning and consideration to be effective. It is important for seed collectors to understand the theory behind seed collection, allowing them to make ethical harvesting decisions, handle seeds properly, and store them under appropriate conditions. This document is intended to provide some of this background and help prepare seed collectors to develop a long lasting, viable collection.

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1 INTRODUCTION

Climate change continues to put pressure on the environment, especially in Northern areas. The Yukon is experiencing warming at double the rate of Southern Canada. Increased likelihood of extreme weather events, forest fires, and longer dry spells combined with increased levels of precipitation are putting the Yukon at greater risk for continued loss of biodiversity. Encroachment of shrubs into areas previously occupied by other plants, insect infestations, and the introduction of new invasive plants are threatening native plant species (Streicker, 2015). The collection and storage of wild seeds in seed banks is considered to be one of the most valuable and economical methods of safeguarding species threatened by climate change (ENSCONET, 2009; Hong, Linington, & Ellis, 1998; Way, 2003). Seed banks preserve species under conditions that increase their lifespan and provide genetic reserves for future conservation efforts. This method of *ex situ* conservation outside of native habitat has great potential to be integrated into habitat conservation efforts, or *in situ* conservation (Schoen & Brown, 2001). *In situ* conservation is cited as being most crucial to the preservation of species; however, with the threats of major weather events and disease that could wipe out entire populations or even species, it is not considered a sufficient tool alone (Cochrane et al., 2015). Wild seed collections are continually becoming more important for the conservation of genetic resources, reintroduction of lost species, and the restoration of disturbed habitat (Hay & Probert, 2013; Probert, Manger, & Adams, 2003). There are three main phases to developing a seed collection: collecting seeds from pre-determined areas; processing seeds for storage through cleaning, drying, and packaging; and storing seeds under appropriate conditions (Rao et al., 2006). Significant planning is required for this to be possible. Species must be chosen, information about species gathered, populations assessed to determine their suitability as a seed source, and collection strategies developed (Way & Gold, 2014b). Wild species differ in many ways from crop species, requiring the consideration of their distinct behavior in all steps of seed handling (Hay & Probert, 2013). This review summarizes these considerations and provides background for the development of seed collection, cleaning, and storage protocols.

2 A BASIC UNDERSTANDING OF SEEDS

2.1 SEED STRUCTURE

To successfully evaluate a crop for collection, make appropriate post-harvest handling decisions, and determine appropriate storage conditions, a basic understanding of seed structure and function is required. The basic structure of a seed includes a seed coat, nutritive tissue, and an embryo (Banerjee, Creasey, & Gertzen, 2001). The seed coat functions as a protective shell and care should be taken not to damage this prior to storage. The embryo is the portion of the seed which will grow into a new plant and has four distinct parts: the cotyledon(s), radicle, hypocotyl, and epicotyl. Seeds with flowering plants have one (monocot) or two (dicot) cotyledons, while gymnosperm have many cotyledons. These are embryonic leaves that absorb nutrients from the nutritive tissue surrounding the embryo, providing support until the seed can develop a root system and true leaves. They emerge as the first leaf-like structures upon germination. The radicle will develop into the primary root, and the hypocotyl will develop into the stem between the primary leaves and root. The

epicotyl is the embryonic shoot which is located above the cotyledons and will give rise to the plant (Banerjee et al., 2001). The growing tip of the epicotyl is called the plumule. In monocots, nutritive tissue is stored in the endosperm surrounding the embryo. In dicots, nutrient reserves are stored in the cotyledons (ECHO, 2004). Seeds are often enclosed in fruit, which develop from a mature, ripened ovary. The fruit wall, or pericarp, can be dry or fleshy. In fleshy fruit the pericarp can often be divided into three distinct layers, the exocarp (skin), mesocarp (flesh), and endocarp (pit), which encapsulates the seed. Fleshy fruits include berries and drupes (stone fruits), as well as accessory fruit which develop from both the ovary and modified flower parts. An example of this is a rose hip. In dry fruit, the pericarp will either split to release seed upon ripening (dehiscent) or ripen without splitting (indehiscent). (Banerjee et al., 2001). The type of fruit and method of dispersal will greatly affect post-harvest handling, cleaning, and drying of the collection. It is important to have a clear understanding of this before collecting a species.

2.2 GERMINATION AND DORMANCY

Many northern seeds have factors which inhibit germination and cause dormancy. These exist in native species to prevent germination in conditions that are unsuitable for growth. For example, conditions can be similar in fall and spring, however germinating in fall would be detrimental to the survival of the plant. Dormancy mechanisms are in place to prevent this. It is important to understand these mechanisms to determine viability of collected seeds, and to ensure that the largest proportion of seeds in a seed collection can be germinated. If only a small portion of a seed collection can be germinated, valuable genetic diversity could be lost (Basey, Fant, & Kramer, 2015). Seed dormancy can be caused by physical characteristics of the seed, for example, water-impermeable seed coats which prevent water from reaching the embryo to allow for germination. This this can be broken through mechanical or physical scarification of the seed coat to make it permeable to water. Other forms of dormancy can be due to characteristics of the embryo, including under-developed embryos or physiological inhibitors present in the embryo or surrounding tissue. Several treatments can be applied to break this type of dormancy, including exposure to periods of heat, cold, and light. Seeds can exhibit both types of dormancy and require multiple dormancy-breaking treatments (C. C. Baskin & Baskin, 2014; Rao et al., 2006). When attempting to germinate seeds, it is important to note that seeds of the same species can have different germination requirements based on the location of the parent population. Environmental factors like temperature, length of daylight, amount of precipitation, and nitrogen levels can cause higher or lower levels of dormancy during seed development (Fenner, 1991). Dormancy can also vary based on storage conditions. For example, drying seeds can induce dormancy in some seeds, while others lose their dormancy during storage (Basey et al., 2015; Probert et al., 2003). Using a “move along experiment” is proposed if germination requirements are unknown or suggested germination treatments are not successful. The experiment can used to determine temperature sequence required for dormancy breaking in seeds with water-permeable seed coats by exposing them to summer, winter, or a summer-winter sequence of temperatures. If the seed coat permeability of a species is not known, it can be determined by weighing seeds before and after incubation on a wet substrate for at least one day. If the seed weight increases by 20% or more, the

seed coat is permeable to water. The experiment is carried out by taking seeds through a progression of temperatures which are chosen based on maximum and minimum air temperatures for the season in a given area. Seven sets of seeds are run. Two sets are run through a series of temperatures mimicking winter, early spring, late spring, summer, early autumn, and late autumn; one beginning and ending with winter, the other beginning and ending with summer. The seeds are exposed to summer and winter temperatures for 12 weeks and early spring, late spring, early autumn, and late autumn temperatures for 4 weeks each. The other four sets are run concurrently at winter, early spring/late autumn, late spring/early autumn, and summer conditions as controls. This also determines if winter only or summer only conditions are required (C. C. Baskin & Baskin, 1999). This approach has been successful on both fresh seeds and those that have been stored for one month or more at -20 °C. (Hay & Probert, 2013). An example of this experiment is shown in the table below, taken from Baskin and Baskin 2003.

3 CHOOSING SPECIES

When choosing species for collection and banking, there are several important considerations, both for the future restoration potential of the species and the ability to store and maintain viability of seeds. Locally occurring native species which can grow in a wide ecological range are ideal candidates for restoration of disturbed areas. Other desirable characteristics are ease of collection and propagation, as well as a strong ability to grow on disturbed sites. These characteristics are thought to facilitate the probability of long-term recovery of a population (Guerrant, Havens, & Vitt, 2014). Seeds that can grow in ecological extremes are also good candidates. Collecting seeds produced during a difficult growing year can bank genetics which are resistant to difficult environmental conditions. However, this should only be considered if enough seeds are produced that removal of seeds will not damage a population, impairing population size and diversity in future years of growth (Basey et al., 2015). Banking seeds of species with these traits can conserve valuable characteristics more likely to survive the extreme weather events and environmental changes that are predicted with climate change. Early successional species are beneficial to bank, as later successional species will often not take without organic layers built up through succession (Densmore, Vender Meer, & Dunkle, 2000). Species that are of value to local people should also be prioritized for collection, as well as species suitable for research, species which are indigenous or endemic, and species which are threatened or vulnerable (Way, 2003). Seed storage behavior should also be considered when choosing species for long term conservation as it will affect storage methods and the length of time the seeds can be stored. There are three categories of seed storage behavior, including recalcitrant, intermediate, and orthodox. Recalcitrant seeds do not tolerate drying while intermediate seeds can tolerate some drying but are sensitive to low temperatures. This makes these categories of seeds more difficult to preserve. Orthodox seeds are tolerant to drying and cold temperatures, and their longevity increases under these conditions. This makes them ideal candidates to store in conventional seed banks (Berjak & Pammenter, 2002; Hay & Probert, 2013). Most information for seed storage exists for orthodox seeds, and it is most

economical and beneficial to store seeds that have a high likelihood of retaining viability during storage.

4 PLANNING FOR SEED COLLECTION

Seed collection requires intensive planning to be practical and result in high-quality seed collections for future applications. Collectors need a good understanding of the target species prior to collection, including the method of reproduction, seed dispersal mechanisms, and appropriate timing for seed dispersal. Native species behave differently and are more complex to collect than agricultural species. Seed dispersal mechanisms vary; seeds often freely disperse when ripe, sometimes exploding from fruit (Hay & Probert, 2013). Timing of seed collection is absolutely critical. Seed quality increases late in seed development, yet the time window for collection just prior to dispersal may be brief (Probert et al., 2003). In the case of fleshy fruit, there is a high probability that fruit will be consumed if collection is postponed too long. Some species produce fruit continuously while others produce fruit only once in the season. Collecting on multiple occasions from species which produce fruit over an extended period of time allows for the capture of greater genetic variability (Bowler, 2009). Visiting a population before collection is highly beneficial. Plants are often easier to identify when they are in flower and pre-assessed populations can be GPS tagged for later harvesting (ENSCONET, 2009). It also allows collectors to better forecast harvesting time, which can vary considerably for a species based on both location and environmental factors (Banerjee et al., 2001). Timing of seed maturation depends heavily on temperature and will therefore be influenced by conditions during the growing season, as well as the elevation, latitude and aspect of a given collection site. The quality of seeds can also vary based on weather events like frosts and prolonged cold spells (Bowler, 2009). When visiting a site prior to collection, it is important to ensure correct identification of plants. The extent of the population should be determined, including the number of individual plants, the population boundaries, geographic barriers, and environmental variation within the population (Way & Gold, 2014a). If there are no clear boundaries to the population, a buffer of 10 km where there are no individual members of the species should be used to differentiate separate populations (ENSCONET, 2009). This allows for enough geographical separation for populations to most likely be exposed to different conditions and be genetically distinct.

When collecting seed for long term storage, the goal is to end up with a representative sample of the species. This is especially important if seeds will eventually be used to restore populations. The larger the genetic variability in a seed bank collection, the greater the chance of successful restoration in a variety of areas. This should be considered when deciding where to collect, as different environments place varying selective pressures on populations. Planning to collect in different ecological zones can increase genetic variability in the seed bank (ENSCONET, 2009; Guerrant et al., 2014). Population size should also be considered when choosing a population for seed collection. Collecting from a large population is more conducive to a genetically diverse seed collection than collecting from a small population, which may experience loss of genetic diversity through genetic

drift, or the disappearance of certain genes due to failure to reproduce or death of an individual. This is generally experienced by populations with less than 100 individuals. Low population numbers also increase the risk of damaging a population and limit the number of seeds that can be collected (Basey et al., 2015). Understanding and pre-assessing a population will give collectors a significant advantage when seed is ready to harvest. There are still variables that will need to be assessed prior to collecting from a population, like ripeness, quality, and percentage of damaged or hollow seeds, but a general collection strategy can be developed. A population should be sampled as randomly as possible across the entire population. There are several different strategies to consider depending on the size and environmental variability within a population. For large populations with little environmental variation, systematic sampling is recommended (ENSCONET, 2009; Way, 2003). This type of sampling ensures collection across a population, however, bias can be introduced if there is periodic variation within the population (Brown & Marshall, 2006). To account for variation of environmental features in a population, stratified random sampling should be used (Way, 2003). This method is also effective if a population is not evenly distributed, allowing for areas with more individuals to be sampled more heavily than those with few (Guerrant et al., 2014). For small populations, simple random sampling is an effective sampling method. This gives all individuals an equal chance of being selected and provides a representative sample of the population. Avoid sampling plants based on their appearance, for example number or seeds or size of plant (ENSCONET, 2009). Regardless of which method was used, it is important to record detailed notes on sampling methodology (Way, 2003). This will provide future users of the population information about how seed was collected and help them understand potential limitations of the seed collection.

Table 2. Sampling strategies

Sampling Strategy	**Definition**	**When to use**
Simple Random Sampling	Any member of population is equally likely to be chosen	Use for small populations
Stratified Random Sampling	A population is divided into sub groups based on common attributes. Individuals are sampled within these groups either proportionally, where the number of individuals sampled is determined by its size relative to the entire population, or disproportionally, where the same number of individuals are sampled from each group regardless of size.	Use for populations with variability in environment, soil type, density, etc.
Systematic Sampling	An even grid or transect is used to determine individuals sampled. For example, 1 individual sampled every 3 meters along a line crossing a population.	Use in large populations with little variability

Biased Sampling	Individuals are chosen based on characteristics like size, number of seeds, etc.	Avoid using

5 SEED COLLECTION

If not carefully planned, seed collection can cause more harm than benefit. Prior to harvesting seeds, collectors should re-assess a population for ripeness of seeds and overall health. It is important to limit harvesting to populations which can withstand collection and populations that are free of invasive species. Collectors should be aware of the invasive species potentially present in the area, and insure the population chosen for collection, as well as the surrounding area, are free of invasive species. Contaminated collections risk moving invasive species into areas not previously affected, causing significant harm (Way, 2003). Collection guidelines have been developed to best estimate the number of seeds required to create a useable collection while not overharvesting seeds:

- Collectors should never remove more than 20% of the seeds present at harvesting, and collecting from the same population for several consecutive years should be avoided (Brown & Marshall, 2006; ENSCONET, 2009; Marshall & Brown, 1975; Way, 2003; Way & Gold, 2014a).
- Collectors should aim to sample between 50 and 200 individual plants, depending on the size, genetic variation, and breeding strategy of a population, as well as the purpose of the collection(Brown & Marshall, 2006; MSBP, 2001; Way, 2003)
- Collectors should sample between 5 and 50 populations to ensure adequate sampling of genetic variation in a species but avoiding excessive sampling and ensuring collecting remains feasible (Guerrant et al., 2014; Way, 2003).

Seeds of plants that self-pollinate are more likely to be similar within a population than those that cross-pollinate. This means that it is necessary to sample a larger number of cross-pollinating individuals than self-pollinating individuals (ECHO, 2004). Some species can spread through rhizomes (underground plant stems) or stolons (above ground plant stems) which extend horizontally and can reproduce the shoot and root systems of a new plant. These should be carefully observed when choosing individuals to collect from; what looks like a population could actually be one connected individual (ENSCONET, 2009; Way, 2003). If there is high variation within a population, the population is being collected for the purpose of reintroduction, or if the goal of collection is to capture genetic variation at representative frequencies, a greater number of individuals should be sampled (Guerrant et al., 2014; Way, 2003). Potential for seed loss, collection of unripe seeds, or the need to split samples for storage should also increase collection numbers (Brown & Marshall, 2006). When choosing the number of populations to collect from, genetic variation should be considered. If species grow in many different regions or are known to have high genetic variability, more populations should be sampled. When collecting seed, it is critical that as much information as possible is recorded about collection method, limitations of the collection, the

type of environment, population characteristics, and species characteristics (Way, 2003). This will maximize future use of the collection.

6 POST-HARVEST HANDLING

Once seeds have been harvested, they must be handled and stored appropriately to ensure viability is not lost before their arrival at the seed bank. Dry fruit and seeds should be temporarily stored in cloth or paper bags. If awns or hooks are present, it is recommended that heavy duty paper bags, cardboard boxes, or sturdy paper envelopes are used to prevent seeds from catching. Fruit with flesh should be collected into tubs or well-ventilated, heavy-duty plastic bags (ENSCONET, 2009; Way, 2003). It is generally recommended that collectors refrain from seed cleaning in the field, however, there are certain scenarios when it is necessary or beneficial. If fleshy fruit are very ripe or have been damaged during collection, they should be cleaned as soon as possible. This can be done by pressing fruit through a sieve under cold running water. Extracted seeds should be spread to surface-dry in well ventilated conditions, then placed in cloth bags for transport to a seed cleaning facility. If seeds can be quickly and easily removed from bulky, dry fruit it may also be worthwhile to pre-clean in the field (Way, 2003).

There are several factors that affect post-harvest handling decisions, including ripeness, type of seed or fruit, moisture content, and ambient conditions. One of the most effective tools to guide these decisions is a portable hygrometer. This device allows collectors to measure the relative humidity of air surrounding a sample of seeds in a sealed chamber, or equilibrium relative humidity (eRH). It can be done in the field and is non-destructive, except for in the case of seeds with impermeable coats which must be cut to reach equilibrium with surrounding air (Gold & Manger, 2014a). This test is ideally done prior to seed collection and based on a representative sample of what will be in the final collection. A very small number of unripe fruit can significantly skew eRH readings. It should also be noted that this test is not effective for fleshy fruit. There are basic guidelines to handling seeds based on their eRH readings. Very wet seeds with an eRH of 85-100% are often immature and best left to ripen longer. In some cases, seeds can be collected and held at conditions mimicking those they would normally be in for one to two weeks while they continue to ripen (Probert et al., 2003). It is also common for fully mature native seeds to be this wet at dispersal. If this is the case and eRH reading is above 90%, it is best to keep seeds moist until they can be properly processed. This can be achieved through storage in a partially ventilated container. If water build up occurs, seeds should be spread out until surface dry and returned to container. Seeds at the greatest risk for loss of viability are those with an eRH of 85-90%. These seeds should be dried as soon as possible by spreading in the sun or partial shade with good ventilation, or immediately brought to a drying facility. Silica gel or other desiccants can be used to speed drying by placing seeds into a sealed container with a 5:1 silica to seed ratio for very wet seeds or a 1:1 ratio for seeds that have been dried for 2-3 days prior to use of silica. Seeds with eRH readings of 50-85% should also be spread to dry, while those with eRH readings of less than 50% can be safely placed in appropriate containers for temporary storage. Seeds with an eRH of less than 30% can be safely sealed until further processing can be done (Probert, 2003).

7 SEED DRYING

The most important factor influencing seed longevity is storage moisture content. Before drying, seeds can be screened through a coarse screen to remove excess large debris and stems. This will allow the seeds to dry more quickly (Pahl & Smreciu, 1999). It is recommended that seeds are dried to about 15% eRH, or 3-7% of initial fresh weight moisture content (Linington & Manger, 2014b). This prolongs storage of seeds by slowing the aging process, and allows for tolerance of sub-zero temperatures. The potential for infestation and damage by insects, fungi and other microbes also decreases significantly when seeds are dried below 9% moisture content (Mummenhoff, n.d.). When seeds are brought to the seed bank, they should be dried in a well-ventilated area with a relative humidity of around 10% to 15% and a temperature range of 10-25°C (Probert, 2003). Higher ambient temperatures speed drying, but there must also be ventilation to remove humidity produced by drying and prevent the movement of moisture back to seeds. Seed size, shape, and type of seed coat also influence drying. For example, seeds with larger diameters have significantly longer drying times, while seeds with porous seed coats can dry too quickly causing damage (Probert, 2003). The low relative humidity in the Yukon is favorable for seed drying given enough ventilation. Incubator-drying can also be a useful method for small-scale seed collections. Although incubators are generally used for germination, they can be set to provide optimal drying conditions. This method has been successfully used by the Millennium seed bank to dry very wet seeds (eRH 99%) in approximately 4 weeks. Seeds can also be dried with silica gel in a ventilated container. The container should be large enough to be filled approximately 20% with silica while maintaining a 1:1 weight ratio of silica to seeds. Seeds are placed in cloth or paper bags and hung in the container to dry. For slightly larger scales, drying cabinets can be built in lieu of a large-scale drying room (Sutcliffe & Adams, 2014). These cabinets can accommodate a relatively large number of seeds and maintain constant conditions required for drying.

8 SEED CLEANING

Once dry, seeds should be cleaned to remove unnecessary bulk. The methods used to clean seeds vary significantly between species, however there are some basic methods that can be chosen based on the structure and durability of seeds (Terry & Sutcliffe, 2014). It should be noted that native seeds are often not uniform in size, making their cleaning more complex than that of agricultural species. It is important to ensure that cleaning methods do not select for seeds based on size as this can remove valuable genetic diversity (Basey et al., 2015). Many automated processes inflict damage to seed, and are often not able to handle the wide variation in structure and size. Cleaning species may require some level of experimentation, which should be tested on small sample of the collection. Often, following protocols of similar species can help determine cleaning methods for a new species. It is important to balance cleaning efforts with a reasonable end point, and consider that in some cases, storing bulkier collections can be more cost and time effective (Terry & Sutcliffe, 2014).

For fleshy fruits, the pulp must be removed prior to drying. This should be done as soon as possible to prevent loss of viability. There are several options for this depending on the size and durability of

seeds. Fruit can be gently crushed in water with a potato masher or similar tool. Very small (e.g. blueberry) or hard (e.g. rose hip) seeds can be macerated in a blender with water. Blender blades should be rubberized, taped, or dulled to prevent damage to seeds and very low speeds in short bursts should be used. The mixture can either be wet sieved with a spray nozzle or allowed to sit so the heavier seeds sink to the bottom and the lighter pulp and debris can be floated off the top (J. M. Baskin, 2009; Schoonmaker, Marenholtz, Sobze, & Smreciu, 2014). Some methods suggest achieving this separation by pouring the pulp mixture slowly into a bucket of water so the seeds sink into the bottom of the bucket and the pulp remains floating on top (Bowler, 2009). Hot water should never be used when cleaning seeds. Once seeds have been separated from the pulp, they can be spread to dry on a nylon mesh or sieve at ambient conditions for a minimum of two weeks prior to moving to conditions to promote drying. Once seeds are dried to low moisture content, they should be further cleaned using methods for dry seeds (Terry & Sutcliffe, 2014).

There is substantial variability in the structure of dry fruit and seed. Many seeds can be cleaned by sieving with a variety of different sieve sizes. If durable enough, seeds can be rubbed or crushed against the sieve to remove appendages like wings. Sieve size should allow seeds to pass through while catching debris. It is recommended to begin with a large size and move to smaller sizes, with the last sieve capturing seeds but allowing small particles to pass through (Terry & Sutcliffe, 2014). If the debris are likely to be smaller than the seed, a sieve with holes too small for seed to pass through can be used, and debris can be crushed against the sieve until they pass through. Sieving has the potential to damage delicate seeds and should be used with caution (Royal Botanic Gardens Kew, 2009). Seeds can also be cleaned using an aspirator. This can lift lighter, hollow seeds and debris away from heavier full seeds, or lift very light seeds away from heavier debris (reverse aspiration) (Terry & Sutcliffe, 2014). A simple box fan can be used to separate seeds with air flow. The fan should be placed at the base of a tarp and seed can be poured in front of the fan. Lighter items will fall further from the fan than heavier items, effectively separating them. Fan speed can be adjusted to the size and weight of different seed collections (Tallgrass Prairie Centre, 2009). If seeds are in bulky pods, they can be hand cleaned or placed in a bag and shaken to remove seeds from pods. This method works to release many seeds from their structures, for example, birch seeds from catkins. For very small collections, hand sorting can be used to separate seeds. For seeds that have sticky or oily coatings, wood ash can be used to make seeds more manageable and prevent clumping prior to sieving (Terry & Sutcliffe, 2014). Sealed vacuum cleaners can be used to separate fluff (pappus) away from seeds. The heavier seeds will fall into the vacuum bin while the pappus will get stuck in the filter. An ash vacuum is recommended for this purpose (O'Neill, Dostie, Sobze, Kaur, & Goehing, 2016). These methods are just a few of many that exist to clean native seed. Many protocols exist for specific, species, while other species will need to be cleaned by looking at the protocols of similar species as well as trial and error.

9 SEED STORAGE

It is critical that seeds retain low moisture content when being stored, as gaining even 1% of moisture during storage can halve the lifetime of a seed collection. This can be accomplished by storage of seeds in air-tight containers. There are several options for sealed storage, however, The

Millenium Seed Bank Project, Kew (2014) found that glass storage jars with rubber seals and clamped lids, as well as sealed tri-laminated foil bags were the most effective method of maintaining low moisture during storage. A second important consideration is the presence of oxygen during storage. Studies show that exposure of dried seeds to oxygen can significantly reduce their longevity. When packaging seeds for long term storage, oxygen proof containers should be used, and oxygen inside the containers should be minimized. This can be done by vacuum packing or gas-flushing of storage containers. Many seed banks successfully accomplish this using vacuum sealed, laminated foil packaging. It should be noted that this only works for seeds that have been dried to low moisture content (Groot, De Groot, Kodde, & Van Treuren, 2015). A third factor influencing the longevity of seeds is storage temperature. Seed collections exposed to high temperatures will quickly loose viability. A general recommendation for long term storage temperature is between -18°C and -20°C (Hong et al., 1998; Rao et al., 2006; Royal Botanic Gardens Kew, 2009; Schoonmaker, Sobze, Fraser, & Marenholtz, 2014; Terry & Sutcliffe, 2014). Seeds can be relatively simply stored at below 0°C temperatures if they have been appropriately packaged. Many small-scale seed banks use deep freezers which can be cooled down to -20°C. These are relatively affordable, making them easy to replace and good for small scale seed banking operations. If seed volume is expected to exceed $10m^3$, a cold room is recommended. These cost more and require maintenance but can be more efficient and offer much more space than a traditional deep freezer (Linington & Manger, 2014a). Whatever method is used, it is important that collections are clearly labelled, and that as much information about the environment where the collection was sourced, the limitations of the collection, and species characteristics is associated with the collection. A collection has far greater use for restoration when this information is included. If a population of a species needs to be restored in an area where no collection exists, the best possible match from different collections of that species can be chosen.

10 CONCLUSION

With the pressures of climate change altering ecosystems and causing the loss of plant species, conservation efforts are essential. The collection and banking of seeds is an economical and useful resource for genetic conservation, especially paired with habitat management (ENSCONET, 2009; Hong et al., 1998; Schoen & Brown, 2001; Way, 2003). Careful planning and consideration are required to successfully collect and store seeds (Banerjee et al., 2001; Guerrant et al., 2014). Although much information exists on the collection and banking of native species, protocols can vary depending on location, and there are still many gaps in knowledge. Increasing the understanding of how to collect and bank native species in the Yukon will help conserve these species, as well as provide research opportunities for climate change adaptation strategies.

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