Guidelines for Creating Turtle Nesting Habitat in Rock Barren Landscapes

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Introduction

The availability and suitability of terrestrial habitat is essential for freshwater turtles, especially during the nesting season when they travel overland in search of nesting sites. Freshwater turtles nest in a variety of habitats including sandy beaches, soil deposits in rocky landscapes, small clearings, and even beaver lodges. If natural nesting habitat is limited, turtles may nest in anthropogenic sites such as road shoulders or agricultural fields which can negatively affect hatch success (e.g., Kolbe and Janzen, 2002; Mui et al., 2015; Thompson et al., 2018) and may expose adults and hatchlings to increased risk of predation or road mortality. Nest success can be as low as 0% in some Ontario populations (Environment and Climate Change Canada [ECCC], 2018a) which makes protecting nest habitat an important component of managing populations of at-risk turtles. Although further reduction or alteration of turtle nesting habitat is likely to have consequences for turtle population persistence (ECCC 2018a, 2018b), there continues to be widespread losses and alterations to natural turtle nesting habitat.

To increase availability of nesting habitat and provide suitable habitat away from urban threats, turtle nesting habitat can be created. One approach to nest habitat construction is to create large nesting mounds using a mix of sand and gravel. The construction of sand mounds has provided nesting habitat for a variety of turtle species. These nesting mounds have successfully produced hatchlings (Buhlmann and Osborn 2011; Paterson et al. 2013), suggesting that created habitat is able to provide appropriate temperature and moisture conditions for incubation.

Although turtle nesting mounds have been successful, the use of this technique in rock barren landscapes is inappropriate because it does not resemble natural turtle nesting habitat and a sand nesting mound will easily erode and dissipate off the open, rocky landscape. In rock barren landscapes, turtles nest in shallow soil that has accumulated in crevices and cracks in the bedrock that are dominated by lichen (*Cladonia* spp.) and moss (*Polytrichum* spp.; Litzgus and Brooks 1998; Markle and Chow-Fraser 2014). We provide guidelines for creating landscape-appropriate turtle nesting habitat for a rock barren landscape that more accurately resembles natural nesting habitat.

This guide is intended for situations where nesting habitat loss has been identified as a conservation concern for species that nest in rocky landscapes such as Blanding's turtle (*Emydoidea blandingii*), midland painted turtle (*Chrysemys picta marginata*), spotted turtle (*Clemmys guttata*), snapping turtle (*Chelydra serpentina*), and eastern musk turtle (*Sternotherus odoratus*). For example, significant nesting habitat loss after a severe wildfire (Markle et al. 2020), where nest habitat creation or augmentation is deemed appropriate. This can also be used in situations where nest habitat is being created or supplemented as a result of approved activities which will damage or destroy existing nest habitat. This guide should not be taken as support for nest habitat destruction in favour of creating new habitat in a different location. Turtles exhibit fidelity to nesting areas, and conservation and protection of existing natural nesting habitat must remain a priority. It is the sole responsibility of the user to ensure all appropriate permits are obtained before beginning habitat creation activities.

Rocky outcrops characteristic of rock barren landscapes that are used by various turtle species for nesting. © C. Markle.

Identifying a nesting area

Selecting an appropriate rocky outcrop for nest habitat creation or augmentation is critical.

1. Wetlands that support target turtle species should be within 200m of the rocky outcrop. Follow local survey guidelines for your target turtle species to confirm nearby wetlands are occupied.
2. If possible, conduct nesting surveys on the rocky outcrop to confirm target turtle species travel through the area or have used the rock outcrop for nesting in the past. This is critical to ensuring turtles will have a high likelihood of encountering the created nesting sites because, in many cases, the rocky outcrop won't be visible from the surrounding wetlands because of tree/forest cover. In these cases, select the rocky outcrop that is closest to the confirmed wetland (but no more than 200m away).
3. Collaborate with local research groups, non-profit, Indigenous communities, government agencies, or other relevant experts to help identify important turtle nesting outcrops.

Midland painted turtle (*Chrysemys picta marginata*) after nesting on a rocky outcrop. © C. Markle.

Identifying sites for nest habitat creation

Natural nest habitat in rock barren landscapes are small in size but widely distributed across a rocky outcrop. The goal is to create multiple, small nesting sites which are more representative of the natural landscape, rather than creating one single, large site.

Determining the number of nesting sites:

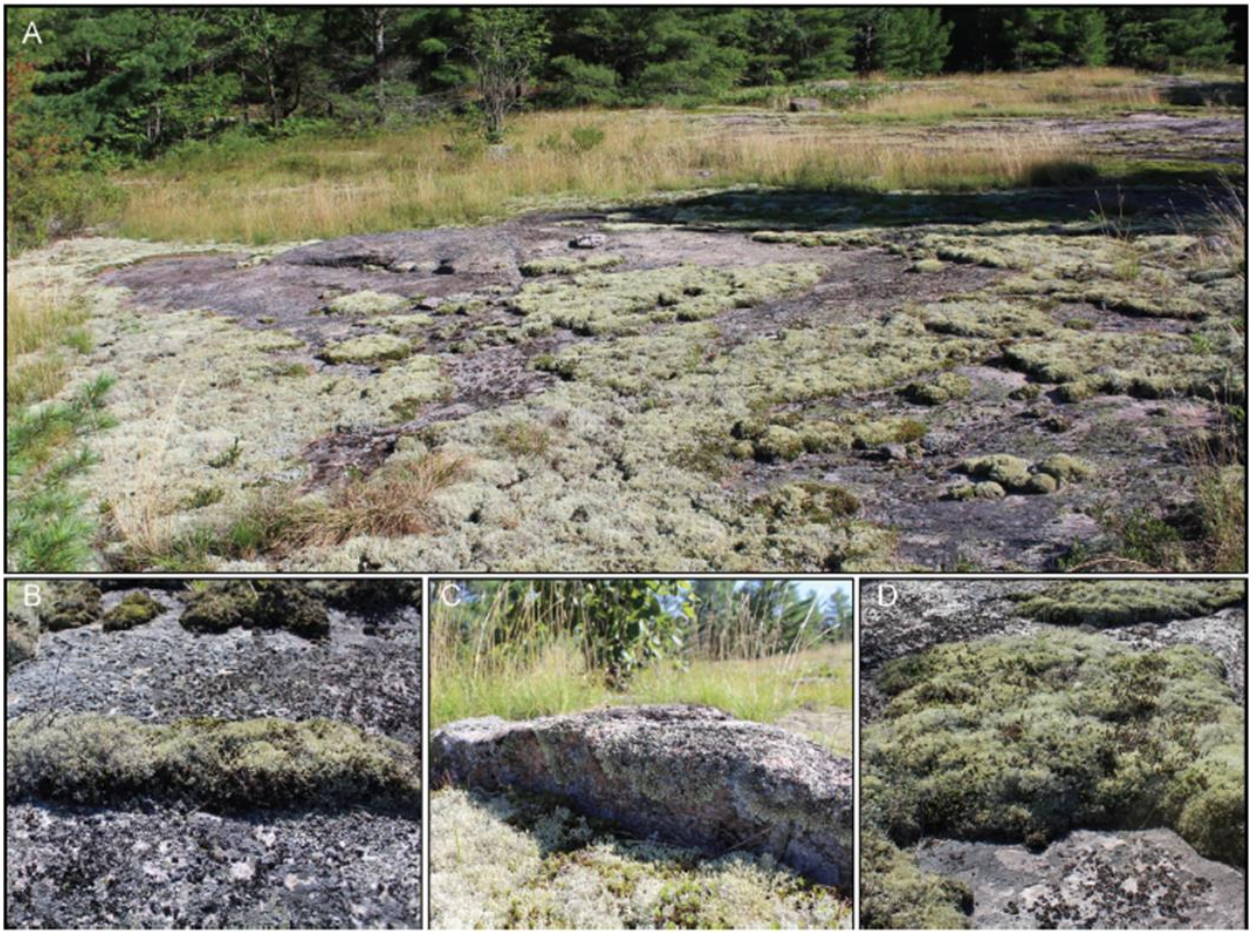
Multiple small (~1m^2) nesting sites will be created on a single continuous rocky outcrop. Rocky outcrops range in size (areal extent), so the amount of nesting habitat or number of nesting sites created will vary. In a relatively pristine rock barren landscape, natural nesting habitat comprises about 11% of the rocky outcrops (Markle et al. 2021). This can be used as a general guideline for identifying the amount of nesting sites to create.

Selecting a nesting site:

1. Once the rocky outcrop has been selected (see “Identifying a nesting area” above), select a site on the rocky outcrop that has an open canopy and receives direct sunlight throughout the day.
2. The created or augmented nest site should be approximately 1m x 1m (~1m^2), but the size of each site will vary slightly depending on the location. Examine the bedrock morphology (see below). It is best to select an existing crevice or ledge as this will allow you to create a deeper site with improved thermal dynamics (Markle et al. 2021).
3. Examine the bedrock slope. It is best to select a site that will encourage drainage during rainfall because nests with higher hatch success are known to have better drainage rates (Markle et al. 2021). Avoid creating a nest site on a flat or bowl-shaped bedrock where water is likely to pool and may drown the eggs.

Bedrock morphology types:

Crevice	Soil accumulated within a crack in the bedrock or between larger rocks/boulders. The crack can be 20cm or more in width.
Ledge	Soil accumulated up against the side of the bedrock or larger rock/boulder.
Flat	Soil accumulated on gently sloping bedrock



Example of a rocky outcrop (A) where turtles nest in shallow soil deposits underlain by bedrock which can be classified as having either a crevice (B), ledge (C), or flat (D) morphology. Reproduced from Markle et al. 2021.

Identifying the donor sites

Soil requirements

When creating and testing this protocol, soil was used from the same landscape. In situations where nest habitat is being removed or destroyed, soil can be collected and stored from the donor site and used for habitat creation. In a rock barren landscape that has experienced severe wildfire, soil from nearby valley bottom forests (containing deep soil deposits) could be used as a soil donor. For each project, consult with local experts and knowledge holders to determine the best options for soil acquisition. We strongly caution against transplanting soil from different landscapes, areas, or regions because of the risk of spreading invasive plant species.

Soil properties are critical because they directly influence the temperature and moisture dynamics of a nesting site. Soil properties for created nesting sites are as follows. Sandy loam soil with:

- Organic matter 7–10%
- Inorganic particle density ~2560 kg m^{-3} (note that clean quartz sand is 2650 kg m^{-3})
- Soil bulk density 700–1000 kg m^{-3}

A soil mix could be purchased and created following the specifications above, although the success of this approach has not been tested in this context.

Surface cover requirements

Lichen (*Cladonia* spp.) and moss (*Polytrichum* spp.) are the primary surface cover of natural nesting sites. In-tact transplants are used to cover the nest sites, although other methods that require less donor material are undergoing testing.

In-tact lichen and moss patches should be harvested and transplanted from the site that is being impacted (donor site), to the newly created site. If you are working on a site that does not have access to a donor site (e.g., post-wildfire), nearby patches of moss and lichen should be assessed for transplant. Lichen is very slow growing and identifying the donor site should be done in consultation with local experts and knowledge holders to ensure habitat is not damaged.

Example of *Cladonia* lichen and *Polytrichum* moss used as surface cover for created turtle nesting habitat. © C. Markle.

General recommendations:

- Nesting sites should be created in the spring, before nesting season has begun to avoid disturbing active nesting areas.
- We recommend conducting activities 1–2 days after rainfall to ensure the lichen and moss are in good condition for transplanting. If the lichen is too dry, it will break and disintegrate during harvest and transplant, damaging the lichen and reducing transplant success.
- Activities should also be avoided in the rain. Creating nest sites and moving soil in the rain can make it difficult to control erosion and maintain the correct soil bulk density (mass of a volume of dry soil).
- Donor lichen should be patches that have grown directly on bare rock. Taking a lichen patch that is already on deeper soils (>5 cm) is likely to damage or destroy existing habitat.
- Moss recovers quickly, so suitable donor patches can be identified at nearby rocky outcrops on variable soil depths. Donor moss patches should be located in open canopy, sunny areas. Moss transplanted from shady, wetter areas tend to have lower success when placed on open, sunny nesting sites.
- Donor moss patches should also be no thicker/taller than 20 cm. Moss can grow in taller hummocks and having a thick moss cover is not suitable for turtle nesting habitat.

- Avoid selecting transplants that have large, well-established grass, sedge, rush, or shrub species. Although vascular plants will grow on the site, minimizing the amount during the transplant phase is important for ensuring the nest site remains lichen/moss dominated, at least during the short term (~5 years).

Example of a *Cladonia* lichen patch that would make a good candidate for transplant to a constructed turtle nest site. Note that the *Cladonia* lichen patch has formed directly on flat bedrock (accumulated soil <5 cm) and has no vascular vegetation. © Danielle Hudson.

Example of a *Polytrichum* moss cushion (left) and mixed *Polytrichum/Cladonia* mat (right) that would make a good candidate for transplant to a constructed turtle nest site. Note that the *Polytrichum* moss cushion height is less than 20 cm, has no vascular vegetation, and is in a sunny area with an open canopy. © Chantel Markle.

Example of a thick *Polytrichum* moss cushion that would not make a good candidate for transplant to a constructed turtle nest site. © C. Markle.

Constructing the nest sites

Once your nesting area (rocky outcrop) and nest site have been identified:

1. Use the desired soil bulk density and volume of the nesting site (~1m x 1m x 0.2m = 0.2m^3) to calculate the volume of soil needed to pack the site at the correct bulk density. Measure your nesting site to get a more accurate soil volume estimate. Packing the site too loosely will result in soil settling and eventual compression which will reduce the depth of the nesting site. Packing the soil in the site too densely may deter nesting and will alter thermal and moisture dynamics.

2. Depending on the project context (e.g., post-wildfire, pre-construction harvest), small loose rocks may be available to use to help build up the side(s) of the nesting site.

Example of a nest site where small, loose rocks repositioned to build up the far side of the site. Rocks along the sides were already naturally positioned and provided a good opportunity for creating a nest site. © C. Markle.

Example of a nest site where only naturally positioned rocks were used. © C. Markle.

Example of a natural site that could be augmented with soil and lichen/moss cover to create a turtle nesting site in a crevice. © Danielle Hudson.

3. Build up the soil in the site to a depth of 20cm. The depth will vary throughout the site based on the underlying topography, so some deeper or shallower areas are ok. Every 5cm, following a grid pattern, take the depth of the soil. The average of the site should be 20cm. Add/remove soil if and where needed.

Adding soil to the created nest site and measuring total soil depth. © C. Markle.

Top-down view of a created nest site filled with soil.© C. Markle.

4. **In-tact lichen transplant.** Once the donor site has been identified, use your hands to gently lift the lichen from the rock. The lichen will easily lift off. Using your hands or a flat lifter, lift the transplant in one piece and move it to the created site. Try to keep as much of the lichen patch intact, but small patches can be transplanted and combined at the nest site.

Demonstration of how to gently lift the lichen transplant from the bedrock. © Chantel Markle.

5. **In-tact moss transplant.** Once the donor site has been identified, gently use your hands to get to the moss-soil interface. If needed, use a peat knife (small serrated blade) to help extract the moss patch. Using your hands or a flat lifter, lift the transplant in one piece and move it to the created site. Try to keep as much of the moss patch intact, but small patches can be transplanted and combined at the nest site.

Demonstration of how to gently lift the *Polytrichum* moss transplant from the bedrock. © Chantel Markle.

6. Place the in-tact transplants on the created nest site, making sure to cover all the bare soil. Create either a 100% lichen site or a 50/50 mix of lichen and moss. If using a mix of lichen and moss, intersperse the two.

First few patches of lichen placed using the in-tact transfer method. © C. Markle.

All lichen patches placed on created nest site using the in-tact transfer method. © C. Markle.

Example of a lichen-only constructed turtle nesting site. © C. Markle.

Example of a constructed turtle nesting site with a lichen-moss mix. © C. Markle.

Monitoring and Adaptive Management

A well-designed effectiveness monitoring and research program are important to evaluating the success of habitat creation and informing adaptive management to improve existing techniques. As part of the design and testing, we confirmed the nesting habitat created following these guidelines were encountered by turtles, was used by Blanding's turtles, and egg hatching success was significantly better than natural nesting sites (see Markle et al., in prep).

Creating turtle nesting sites should be monitored to confirm the target species are encountering and using the site, and that nest hatching success is comparable to or better than natural nesting sites.

Monitoring use of created nesting habitat:

- Setup camera traps at nesting habitat to capture turtles moving near or nesting on the site.
- Conduct visual nesting surveys during the early morning and evenings during the nesting season (late May to early July) to confirm turtle use of nesting sites.
- Conduct surveys during the daytime for evidence of depredated nests (presence of eggshells).

Monitoring nest success in created nesting habitat:

- Monitor egg hatching success and hatchling fitness in created nesting sites to confirm it is comparable to, or better than, hatching success and hatchling fitness at nearby natural nesting sites (see Paterson et al. 2013 and Markle et al., in prep for study design).

Monitoring vegetation cover of created nesting habitat:

- Active management should not be required frequently. During the design and testing phases of this nesting habitat design, only some sites required maintenance after 5 years whereas others did not.
- It is recommended that the sites be inspected every two years. If grass, rush, and sedge cover exceeds 30% of the nesting site and shrub cover exceeds 15%, the vegetation should be removed in early spring (before nesting season). The removal areas can be lightly raked with a small hand tool and additional in-tact lichen or moss transplant(s) may be added.

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