Risks And Benefits of the Use of Urine-Diverting Vermicomposting Toilet Systems

Photo: Brennan Williams 2016

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Executive Summary:

This work explores the risks and benefits associated with the use of urine diverting vermicomposting toilets (UDVTs) in backcountry areas of British Columbia Parks. The benefits of these systems are well documented, and include:

- reducing the amount of solid waste produced;
- reducing operator and user exposure to pathogens and parasites; and,
- lessening environmental impacts.

The foremost risk of the use of UDVTs is the potential for the non-native red-wriggler worm (*Eisenia fetida)* to become invasive if introduced into these systems. In order to mitigate risk, this report identifies environmental conditions where *Eisenia fetida* may be used with a low potential of becoming invasive. Furthermore, it identifies measures to mitigate risk such as the use of native detritivores to facilitate decomposition and makes the following recommendations to BC Parks:

- that BC Parks continue monitoring *Eisenia fetida* use where it has already commenced;
- that moving forward, BC Parks conducts soil and temperature sampling at vermicomposting sites in order to determine whether or not the surrounding environment is conducive to the survival of *Eisenia fetida*;
- that BC Parks allow for the use of *Eisenia fetida* for vermicomposting at sites where they are already present; and,
- that native detritivores (including native earthworms) that are present at UDVT sites are used at sites where *Eisenia Fetida* has a high potential of becoming invasive.

In order to determine benefits, risks, mitigation measures, and alternatives, this work relies on a literature review in the form of a meta-analysis as well as an expert interview with Dr. Geoffrey B. Hill. The report concludes by identifying that future research should focus on structural controls to limit the possibility of worms escaping from UDVTs in order to reduce invasion potential.

Introduction:

This work explores the risks and benefits associated with the use of urine diverting vermicomposting toilets (UDVTs) in backcountry areas of British Columbia Parks. More specifically, it focuses on the risks associated with UDVTs that arise from the potential for the non-native red-wriggler earthworm (*Eisenia fetida*) to become invasive in localized environments if introduced into UDVTs. While native invertebrates may be effective in UDVTs, *Eisenia fetida* are preferred as native earth worm species in British Columbia are rare and have become extirpated from large areas within the province. Therefore, collecting native earthworm species for vermicomposting would not be feasible for most sites within British Columbia Parks. Furthermore, *Eisenia fetida* are the "earthworm species most commonly used in the composting industry [as it] thrives in the high temperatures that characterize actively decomposing organic matter" (Greiner et al. 350). **The research presented in this work indicates that based on local environmental conditions, there are sites within BC Parks where *Eisenia fetida* may be used for vermicomposting with a low risk of the species becoming invasive. Furthermore, it indicates that at sites where there is a high risk of invasion of *Eisenia fetida,* detritivores from local soils can be utilized to reduce human waste streams.**

Methods:

This study has largely been conducted in the form of a meta-analysis of the literature reviewed below. These sources were combined in order to identify the benefits associated with UDVTs. Furthermore, this allowed for the determination of the conditions that are suitable for the survival of *Eisenia fetida* in order to identify environments where there is a high degree of confidence that the species will not become invasive (e.g. environments with soils and

temperatures unsuitable for the species). This research also incorporates an expert interview with Dr. Geoffrey B Hill, who is prevalent in vermicomposting literature in the North American context and an expert on the subject, in order to identify alternatives to the use of *Eisenia fetida* in UDVTs. The analysis, findings and recommendations included in this draft have also been supplemented by internal BC Parks documents provided by Joanna Hirner, Conservation Specialist for the South Coast Region of BC Parks.

Literature Review:

Multiple studies have been conducted regarding the benefits of UDVTs over mixed latrine microbial toilets which do not divert urine (Hill et al. 2013a; Hill et al. 2013b; Hill and Baldwin 2012; Hill 2013). The studies identified that utilizing UDVTs reduces the amount of solid and liquid waste produced, reduces operator and user exposure to pathogens and parasites, and lessens environmental impacts by limiting leaching into ground and surface water. In addition, there is literature regarding the environmental impacts of urine diversion, which has been proven to be a low risk method for human waste disposal and beneficial for local plant communities as urine contains the majority of plant available nitrogen (Bethune, 2015; Hill 2016). However, very few studies have been conducted on the foremost risk associated with UDVTs - the invasiveness of non-native worm species introduced to them to facilitate decomposition. Addison (2009) reports that "the widespread invasion of exotic [non-native] earthworms into Canada's forests could have global implications" as earthworm free forests are "repositories of significant amounts of carbon, nutrients and biodiversity" (61). As UDVTs traditionally rely on earthworms to facilitate decomposition, and inevitably to function correctly, this knowledge gap is significant. However, there is an abundance of literature on

both native worm species in British Columbia and non-native worm species that may be applied in order to determine whether or not the use of non-native worm species in UDVTs risks harming native invertebrate communities (Marshall and Fender 1998).

Marshall and Fender (1998) develop a method to assess the prevalence of native and non-native earthworm species at various sites on Western Vancouver Island. Their research focuses on four distinct chronosequences (a set of forested sites that share similar attributes but are of different ages) defined by the age of trees in the area: regeneration (7-12 years), immature (29-49 years), mature (69-89 years) and old growth (>200 years). However, given the numerous biogeoclimatic ecosystem classifications (BECs) in British Columbia, this data cannot be applied to the whole of the province as it is limited to 40 sampling sites equally divided across four chronosequences. However, their findings highlight that native earthworm species have not been extirpated from the whole of British Columbia and are mainly confined to Western Vancouver Island. In addition, few studies have documented the collection of native earthworm species at sites that fall outside of the conditions of Western Vancouver Island, including sites near Squamish, BC and Bella Bella, BC (McKey-Fender and Fender 1982; McKey-Fender et al. 1994; Hocking and Reimchen 2002). These studies are helpful to my research as they prove that there are limited distributions of native earthworm species present in various BECs within BC that may be negatively impacted if non-native species are added to UDVTs and are able to escape and reproduce. Therefore, the introduction of invasive non-native earthworms not only poses a threat to biodiversity as well as carbon and nutrient cycling, but also to native earthworm populations as a result of competition for food and habitat.

Many of the backcountry climates in BC parks fall into the category of being less than ideal for the survivorship of earthworms, and determining if invasive escapees will survive climates outside of the UDVT is essential to my findings and recommendations. Addison (2009) presents twelve years of significant research on the distribution of non-native earthworm, focusing on conditions that are not optimal for the survival of earthworms. Complimentary to Addison (2009), Hill and Baldwin (2012) provide evidence that viable earthworm populations can be maintained in UDVTs at elevations as high as 2400 meters. However, neither of these studies provide clear information on the limitations for survival of earthworm species.

There is an abundance of literature on the habitat requirements of *Eisenia fetida* and distribution of this species (Reynolds 1977; Fender 1985; Ferguson 2004; Addison 2009; Reynolds and Reynolds 1992). Collectively, these studies note that the *Eisenia fetida* requires substrates high in organic matter and pH and is generally not found outside of human created environments such as greenhouses (Ferguson 2004). Addison (2009) notes that the species is frost-intolerant, but does not provide information or data on responses to temperature or conclude which temperatures cause mortality of *Eisenia fetida*. In addition, Greiner et al. (2011) provide data on the cold tolerance of composting earthworm species in order to evaluate invasion potential. However, Holstrump (2003) notes that earthworms can seek frost-free refuge by burrowing deep into the group. This presents a challenge for my research as I must determine whether Addison's (2009) terminology of 'frost intolerant' indicates that the species is incapable of burrowing in order to survive frost and subzero conditions. If the species is able to adapt to subzero air and soil temperatures in this manner, it is indicative that they may survive and reproduce outside of the UDVT regardless of ambient temperatures in that

location. Furthermore, none of these studies address the issue of whether or not the *Eisenia fetida* is capable of surviving outside of UDVTs in areas with low elevations that never, or very rarely reach sub-zero temperatures.

Results:

Benefits

As UDVTs reduce the amount of solid and liquid human waste that accumulates in holding tanks, they provide economic benefits to BC parks (Hill et al. 2013a; Hill et al. 2013b; Hill and Baldwin 2012; Hill 2013). The reduction of accumulated human waste results in lower operating costs that are associated with the removal of human waste by helicopter, and reduces the frequency at which new pits must be dug and toilets relocated. Furthermore, a reduction in operator and user exposure to pathogens and parasites has obvious benefits for human health (Hill et al. 2013a; Hill et al. 2013b; Hill and Baldwin 2012; Hill 2013). It has been largely recognized that UDVTs reduce negative environmental impacts by reducing the amount of human waste leachate in surface and groundwater (Hill 2016). However, a reduction in the amount of human and solid waste produced can also be associated with a reduced environmental impact. By reducing the number of helicopter flight hours required for the operation of backcountry pit toilets, UDVTs lessen greenhouse gas emissions from helicopters – therefore having a positive effect on our climate.

Mitigating Risk

Eisenia fetida have a variety of attributes which make it ideal for vermicomposting in UDVTs. They withstand handling, tolerate a variety of moisture contents, thrive at high densities and have a rapid life cycle which has been reported to be 50 days from cocoon to mature adult (Dominguez 2004). Limitations to the survival of *Eisenia fetida* include propagule

pressure (a measure of the number of individuals of a species released into a region to which they are not native), soil pH, competition with other invertebrates and detritivores, soil moisture, and temperature (Greiner et al. 2011; Costello et al. 2011; Bohlen et al 2004; Lavelle 1983). Although environmental conditions (such as the pH of soil) vary a great deal between sites in BC Parks, temperature data is readily available for all regions of the province. Therefore, in order to identify sites where there is a low risk of the species becoming invasive, it is beneficial to concentrate on the response of *Eisenia fetida* to various temperatures. It has been noted that the species is largely considered to have a low invasion risk in temperate environments, notably due to the intolerance of the species to winter temperatures (Addison 2008; Tiunov et al. 2006). However, Greiner et al. (2011) explain that "regardless of whether adult earthworms survive cold temperatures, a species could regenerate in temperate regions if its cocoons remain viable after overwintering and earthworm cocoons tend to be more frost-tolerant and cold-hardy than adult earthworms" (350).

In order to analyze the cold tolerance of *Eisenia fetida*, Greiner et al. (2011) conducted an experiment where the species was subjected to a room-temperature treatment where the environment was kept at 18 °C and a cold-temperature treatment where the environment was kept at 1.5°C. The experiment found that 399 of 400 earthworms survived the room-temperature environment after a period of seven days. Alternatively, the earthworms kept in the low-temperature environment reached a mortality rate of 100% after a period of 150 hours (6.25 days). *Eisenia fetida* cocoons were subjected to the same treatment, and it was found that their cocoons were also sensitive to low temperatures and mortality increased within the low-temperature environment. However, difficulty counting and tracking cocoons resulted in a

low degree of certainty regarding the mortality rate of cocoons within the 1.5°C environment. Regardless, it has been noted that *Eisenia fetida* cocoons cannot tolerate freezing temperatures whereas other earthworm species of European decent are frost tolerant (Holmstrup et al. 1990). Although local environmental conditions may vary largely between vermicomposting sites in BC Parks, temperature can be relied upon as a factor which limits the invasion risk of the species. Therefore, *Eisenia fetida* can be utilized at vermicomposting sites where soil temperatures remain at or below 1.5°C for a period of 150 hours or longer with a high degree of confidence that they will not become invasive. In order to address uncertainty regarding the influence of propagule pressure, soil pH, competition with other invertebrates and detritivores, and soil moisture, I suggest that a conservative approach be taken and the use of *Eisenia fetida* be limited to sites where soil temperatures remain below 0°C for a period of one week. Furthermore, Ferguson (2004) notes that *Eisenia fetida* require substrates high in organic matter such as manure and compost as well as a soil pH of 6.8-7.6 to survive. Therefore, the species may be used at sites that are highly acidic or alkaline, where there is a lack of soil high in organic matter (such as high-alpine environments) and where soil temperatures reach below 0°C for a period of a week or greater with a high degree of confidence that their invasion potential is extremely low.

Mitigating Risk: Alternatives to the use of *Eisenia fetida*

Although *Eisenia fetida* is the preferred species for facilitating decomposition of human waste in urine diverting toilet systems as they facilitate rapid decomposition, there are an abundance of other detritivores that can effectively serve the same function in the setting of a UDVT. As recognized by Yang (2006) “detritivore communities influence the decomposition of detrital resources in virtually all natural systems” (522). The definition of detritus includes

decomposing plant and animal parts as well as feces. Therefore, inputs to UDVTs, including solid human waste and toilet paper, can be considered to be detrital resources.

According to Hill (2016), toilet paper makes up the majority of waste, or detrital resources, following urine diversion in UDVTS (figure 1).

Figure 1: Pit at a UDVT site in Smith Rock State Park prior to decomposition
Source: Hill (2016)

Toilet paper is rich in available carbon which has been demonstrated to encourage the growth of detritivores (Tiunov and Scheu 2004). Therefore, they may be used to effectively reduce the solid waste stream from UDVTs. Detritivores are present in virtually all soils and a large variety of detritivorous species have been well documented in British Columbia whose primary ecosystem function is to decompose organic materials, including: *Zapada cinctipes*, *Z. haysi*, *Malenka californica*, *M*. *cornuta*, *Capnia* sp., and *Lepidostoma roafi*, *Despaxia augusta, Harpaphe haydeniana,* and *Brillia retifinis* (Richardson 2001; Cárcamo et al. 2001, Cárcamo et al. 2000). Therefore, adding soil from the local area to UDVTs can facilitate the decomposition of solid waste streams in the context of the varying environments of BC Parks. This has been witnessed by Hill (2016) in Smith Rock State Park, where local soil from a streambed was added

to a UDVT. After 4 months of processing under a plastic sheet, and with the addition of water for moisture, decomposition had occurred to the point that tree root growth was visible throughout the solid waste (figure 2).

Figure 2: Waste after 4 months of decomposition with detritivores at Smith Rock State Park
Source: Hill (2016)

As detritivores are present throughout, and native to, British Columbia's soils, they can easily be added to UDVTs with no risk of them becoming invasive. Therefore, at sites where temperature and soil conditions may allow for *Eisenia fetida* to become invasive, such as sites which do not reach temperatures below 0°C for a period of greater than a week or that have a pH of 6.8-7.6, native detritivores may be used to facilitate the decomposition process in order to reduce the amount of waste produced by UDVTs. This would result in the same benefits as the use of *Eisenia fetida* in these systems, including a reduction of the amount of waste produced, a reduction in operator and user exposure to pathogens and parasites and a reduced environmental impact.

However, it is worth noting that detritivores are less abundant in alpine environments that are dominated by glacial ice, snow, ice-rock interfaces and rock surfaces and fissures (Nagy 2009). Therefore, the use of native detritivores at alpine locations may be challenging. Conversely, locations dominated by these features most frequently occur at altitudes that reach sub-zero temperatures for long periods of time during the winters of British Columbia. Therefore, instead of native detritivores, *Eisenia fetida* can be introduced to alpine UDVTs in order facilitate decomposition with a high degree of certainty that they will not become invasive.

Recommendations:

Currently, BC Parks has retained a third party consulting firm to conduct monitoring at sites where *Eisenia fetida* have been introduced to UDVTs. This method for monitoring relies on periodically checking these sites to determine whether or not *Eisenia fetida* have spread outside of the UDVTs. Due to it's nature, this type of monitoring is both time consuming and expensive. As the habitat attributes required for the survival of *Eisenia fetida* are well documented, I recommend that BC Parks continue monitoring at sites where it has already commenced. However, I recommend that moving forward, BC Parks conduct soil and temperature sampling at vermicomposting sites in order to determine whether or not the surrounding environment is conducive to the survival of *Eisenia fetida*. For example, if pH levels fall well outside the range of 6.8-7 and temperatures reached 0°C for a period of greater than a week during the year, it could be concluded with a reasonable amount of certainty that any escapees from the UDVT would not survive.

Furthermore, I recommend that native detritivores (including native earthworms if present) are used at sites where *Eisenia Fetida* has the potential to become invasive. This can be accomplished by simply gathering wet mucky soil from the site, or a nearby stream bed, and adding it to the UDVT.

Finally, at sites where populations of *Eisenia fetida* have already been established, I recommend that BC Parks allow for the use of the species for vermicomposting as they are already present in the area, and their introduction to the UDVT is unlikely to result in further harm to the local environment.

Suggestions for Future Research:

This research focuses largely on the environmental conditions required for the survival of non-native earthworm species in order to determine their potential to become invasive. I suggest that any future research on the topic of the use of *Eisenia fetida* in UDVTs should focus on structural controls to limit the number of escapees from the system. If structural controls are economically feasible and practical to install at vermicomposting sites throughout BC Parks, and can be proven to be effective at ensuring there are no escapees, BC Parks will be able to forego expensive monitoring at these sites and implement vermicomposting with an even lower invasion potential. Hill (2016) notes that various pit designs in UDVTs already exist, including open pit, pits lined with pressure treated timber, plastic bags and concrete boxes. Each of these designs has advantages and disadvantages, with some being more secure than others. However, the construction of more secure pits (such as concrete pits) may not be feasible in remote areas of BC Parks.

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