**1.0 Introduction**

Forest ecosystems cover an estimated 4.06 billion hectares of the Earth’s surface, (FAO and UNEP, 2020). Over one billion hectares are managed primarily for production with a further 749 million hectares under multi-use management that allows some production (FAO and UNEP, 2009). An additional, estimated 85 million hectares (FAO and UNEP, 2020)are covered by orchards, palm plantations and other agroforestry operations. It is vital, that with an expected increase in demand for wood products (FAO and UNEP, 2009), food (van Dijk et al., 2021) and a decline in available space (Chen et al., 2020), that these areas are managed effectively to maximise productivity and ensure sustainable sources of sought-after resources into the future.

Managers of commercial forests, plantations and orchards face numerous challenges that impact productivity (Baranowski et al., 2021; Keenan, 2015; Lehmann et al., 2020; Sturrock et al., 2011). One such adversary is browsing mammals. Heavy browsing increases seedling mortality (Neilsen and Pataczek, 1991) and can lead to crop failure. Even under light browsing pressure, where seedlings may recover, their growth is impacted (Wilkinson and Neilsen, 1995) reducing productivity. Moreover, where the apical bud is damaged seedlings can develop multiple leaders (Close et al., 2010; Gill, 1992). This increases the likelihood the seedling will be browsed again (Welch et al., 1991) and reduces the quality of the timber (Close et al., 2010). Thus, to maintain commercial viability it is critical that browsing mammals are controlled or damage mitigated.

There is a suite of lethal and non-lethal control methods available (Miller et al., 2009; Warburton et al., 2022). Lethal measures are often seen as the most efficacious way of controlling mammals. Hunting, both recreational and professional, is regularly used to control pest mammals (Bengsen et al., 2020) as well as trapping and poisoning operations (Fall and Jackson, 1998 – find a more up to date reference).

Despite their prevalence, lethal control methods are not universally successful at controlling pest mammals (Courchamp et al., 2003). For example, elk learn to alter their behaviour in response to the weapons being used by hunters(Thurjfell et al., 2017) limiting the efficacy of ballistic control.

Poisoning operations, as an alternative to ballistic control, were and still are a widely used mammal control in certain regions (Innes and Barker, 1999; Mason and Littin, 2003). They can target mammals of all sizes and when deployed from the air can reach remote areas (Morriss et al., 2016; Nugent and Morriss, 2013) where sustained shooting efforts are not possible. However, despite possible efficacies being high (Nugent et al., 2011; Twigg et al., 2005) concerns over the humaneness of some poisons (Sherley, 2007) and other collateral effects, for example secondary poisoning, have reduced the ubiquity of poisoning for mammal control. Sodium fluoroacetate, or compound 1080, (hereafter 1080) is a prime example.

1080 was adopted after the second world war to protect limited agricultural resources from pest attack. It was later widely deployed in forestry settings, especially in Australia and New Zealand as a control agent for browsers such as wallaby and possum (Eason et al., 2010; Sherley, 2007). 1080 was banned in the USA in the 1970s but remains legal in parts of Australia and New Zealand persist as the world leaders in 1080 usage (Green and Rohan, 2012), although anti-1080 sentiments are growing (Green and Rohan, 2012; Statham, 2005; Warburton et al., 2022). This trend is common across all lethal mammal control. The question of “is lethal mammal control acceptable?” is highly polarising. (Farnworth et al., 2014; Fix et al., 2010). Often the acceptability of lethal control depends on the species being targeted (Drijfhout et al., 2020), even when all species needing to be controlled are invasive (Boulet et al., 2021). The goals (for example, financial, conservation or animal welfare) of control actions are important to stakeholders when justifying the use of lethal controls (Dandy et al., 2012). Collectively, these factors dictate the acceptability of a control method and therefore need to be monitored by land managers to ensure their actions are not going to meet opposition. A common factor across two studies, one on native and one on invasive species, was that age of survey respondent was positively correlated with the acceptability of lethal control (Boulet et al., 2021; Dunn et al., 2018). Assuming that, as they age, younger generations maintain their aversion to lethal mammal control it will perpetuate a consistent decrease in the acceptability of lethal mammal control into the future, forcing land managers to shift from predominantly lethal to predominantly non-lethal mammal control. This is in line with Eason et al (2017), whoidentified a need to advance non-lethal mammal control technologies by 2030 in a review of all mammal control in New Zealand.

Current non-lethal mammal controls include but are not limited to fencing (Love et al., 2009; Palmer et al., 1985), chemical repellents with different delivery mechanisms (applied to plant tissues (Curtis and Boulanger, 2010; Dietz and Tigner, 1968), applied to the planted area (Conover and Kania, 1987; Wagner and Nolte, 2001) and applied to the soil enabling absorption into the plant tissues (Allan et al., 1984; Moser 2000)) and acoustic deterrents (Lyly et al., 2018; Ramp et al., 2011). Seedling manipulation techniques are also included, such as altering the physical characteristics of seedling stock planted (Truax et al., 2021; Yagi, 2022), changing fertiliser regimes to alter nutritional value of seedlings (Brinks et al., 2011; Close et al., 2004) or identifying genetically browsing resistant variants of tree species (O’Reilly-Wapstra et al., 2002 and 2004). Despite the range of non-lethal control methods available there is not a universally successful solution. Therefore, if a transition from lethal to non-lethal mammal control is to be affected without a loss in efficacy of control it is critical that cost effective and efficacious non-lethal control methods are identified for the different mammalian pests that exist globally. Previous work has been conducted reviewing the relative efficacies of non-lethal controls within control types such as repellents (Guerisoli and Pereira, 2020; Palmer et al., 1983) but little has been done to compare the relative efficacies between different non-lethal control methods.

These animals are globally distributed and range from megafauna such as elephants (Barnes, 1983) to rodents such as voles (Lyly et al., 2018) and hares (Sullivan and Crump, 1984). Browsing mammals also encompasses species of ungulate, including deer (Conover, 1989; Coomes et al., 2003; Suzuki et al., 2021), elk (Baker et al., 1999) and moose (Siipilehto and Heikkila, 2005) and marsupials, such as possums (Woolhouse and Morgan, 1995) and wallaby (Lawler and Foley, 1999).

Breadth of the browsing guild and growing scenarios dictate that there will be no silver bullet… therefore meta needed to find whats best in different scenarios… the aim here is to…

This meta-analysis aims to analyse the current published knowledge base to discern whether…

Non-lethal mammal browsing methods: are they up to scratch to replace lethal controls? Are we ready for the transition in certain growing scenarios rather than others? To do this we aim to answer the following questions…

1. Do different non-lethal control methods reduce mammal browsing equally?
2. Are different tree genera protected more effectively by different non-lethal control methods?
3. Are different browsing mammals controlled more effectively by different non-lethal control methods?
4. Do non-lethal control methods retain their efficacy across different spatial and temporal scales?

Furthermore, this will create a guide for growers globally to facilitate selection of the optimal non-lethal control method for their individual scenarios.