USING COMMERCIAL FORESTRY FOR ECOSYSTEM RESTORATION IN SENSITIVE BADGER HABITAT

by

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ABSTRACT

The American badger is endangered in British Columbia. Badgers inhabit grasslands and open forests, and badger habitat is threatened by forest ingrowth and encroachment related to wildfire suppression. Ecosystem restoration (ER) involves removing forest ingrowth and reintroducing prescribed fire. Commercial forestry can subsidize restoration work, but machinery may damage important badger burrows. We examined an ER cutblock within a designated badger wildlife habitat area. Badger burrows were placed in 5-7 m radius machine-free zones (MFZs) and surveyed before and after logging. Machine operators were trained to protect burrows, and we tested their ability to protect unmarked burrows. Pre-flagged MFZs protected almost all burrows within them (98%, n=258) from damage. Operators found only 9 of 38 unmarked test burrows, but also located and protected an additional 63 new burrows. We conclude that MFZs of 5-7 m radius were sufficient to protect badger burrows during logging operations when combined with operator training.

Keywords: badger; species at risk; ecosystem restoration; wildlife habitat; effectiveness monitoring

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GLOSSARY

ER	Ecosystem restoration
GWM	General wildlife measures
MFZ	Machine free zone
NRFL	Non replaceable forest licence
OIMFZ	Operator-implemented machine free zone
WHA	Wildlife habitat area

1: INTRODUCTION

The *jeffersonii* subspecies of the North American badger (*Taxidea taxus jeffersonii*) is listed as endangered by COSEWIC, and is red-listed in British Columbia (B.C. Conservation Data Centre 2011, COSEWIC 2010). Badgers inhabit low-elevation grasslands and open forests with high prey densities and suitable soils for digging (Adams and Kinley 2004, Rahme et al. 1995). In the Rocky Mountain Trench, within the East Kootenay region of British Columbia, continued habitat loss related to forest ingrowth and encroachment of trees into grasslands is a major threat to badgers (*jeffersonii* Badger Recovery Team 2008, Adams and Kinley 2004).

Forest encroachment into historically open grasslands and shrublands has been documented in many sites throughout southern British Columbia and the western United States, and is generally attributed to a combination of factors including changes in climate, increased grazing pressure, and the suppression of frequent wildfires following European settlement (e.g. Heyerdahl et al. 2006, Gray et al. 2004, Turner and Krannitz 2001, Miller and Rose 1999, Mast et al. 1997, Hansen et al. 1995, Arno and Gruell 1986, Strang and Parminter 1980). In the Rocky Mountain Trench, a comprehensive ecosystem restoration (ER) program exists to reintroduce fire and to restore grassland and open forest ecosystems in pursuit of both ecological and socioeconomic goals, including improving habitat for species-at-risk such as the badger (Rocky Mountain Trench ER Steering Committee 2006).

Badgers are fossorial carnivores, and their specialized front legs and other physiological adaptations make them highly efficient diggers (Rahme et al. 1995). Badgers dig to pursue underground prey such as ground squirrels, and they use underground burrows for resting, food storage, and reproduction (Adams and Kinley 2004, Michener 2000, Messick and Hornocker 1981). Despite their prodigious digging ability, badgers regularly reuse previously dug burrows (Newhouse and Kinley 2001, Lindzey 1978, Long 1973). In the East Kootenay region of southeastern British Columbia, radio-tagged badgers used older burrows 1.8 as many times as they dug new ones, and some burrows were used by more than one badger at different times (Newhouse and Kinley 2001).

Badger burrows are also an important structural habitat resource for other wildlife species. Columbian ground squirrels – an important prey species for badger – often use badger burrows (Newhouse and Kinley 2001, Michener 2000), and burrows are also used by burrowing owls (Wellicome 1997, Green and Anthony 1989), foxes (Cotterill 1997), and by spiders, amphibians, and snakes (Hoodicoff 2003, Scobie 2002). The mounds of badger burrows contribute to ecosystem processes by increasing soil heterogeneity and by influencing soil processes (Eldridge and Whitford 2009, Eldridge 2004) and can increase the complexity of plant communities by creating openings for colonization (Platt 1975). Many mammals that dig burrows are known to modify their habitat substantially (Davidson and Lightfoot 2008, Hansell 1993) and act as "ecosystem engineers", creating habitat for a range of other species (Jones et al. 1994).

Over 100,000 hectares of land in the Rocky Mountain Trench in the East Kootenay region has been identified for potential ecosystem restoration treatments aimed at increasing the area of open range and open forest (Harris 2010, Rocky Mountain Trench ER Steering Committee 2006). Badgers in the East Kootenay are strongly associated with grasslands and open forest (Apps et al. 2002, Newhouse and Kinley 2001), and ecosystem restoration is expected to improve badger habitat by reducing forest cover and increasing prey populations (Kinley and Newhouse 2008, Hoodicoff 2006a). Restoration treatments involve removing forest ingrowth and encroaching trees and applying prescribed broadcast burns over the area, and restoration activities are costly in both time and money (Harris 2010, Rocky Mountain Trench ER Steering Committee 2010).

In areas with sufficiently high volumes of merchantable timber, commercial harvesting may be an economically viable way to subsidize the cost of restoration treatments (Rocky Mountain Trench ER Steering Committee 2006, Allen et al. 2002). The heavy machinery of commercial forestry operations allows for economic efficiency but carries a risk of damage to badger habitat: burrows are vulnerable to being crushed under the tracks of the machines. As badgers reuse existing burrows frequently (Newhouse and Kinley 2001, Lindzey 1978, Long 1973), damage to burrows could have a negative effect on badger habitat quality, and could also impact other species that use burrows – including important badger prey species.

We examined a single large cutblock commercially harvested under a non replaceable forest license (NRFL) by Tembec as a component of an ecosystem restoration treatment. The treatment area overlaps with a wildlife habitat area (WHA) established by the BC Ministry of Environment for protection of badgers and badger habitat (*Government Actions Regulation* BC Reg. 582/2004). Wildlife habitat areas are authorized under the BC Forests and Range Practices Act, and include general wildlife measures (GWMs) that are established to protect important wildlife habitat by regulating resource management activities such as logging, cattle grazing, and road-building within the WHA (BC Ministry of WLAP 2004). In order for the logging treatment to proceed at the study site, an exemption was required from the GWMs restricting the building of new roads within the WHA, and from the timing restriction prohibiting harvesting activities during the maternal denning period in the spring.

The intent of these General Wildlife Measures is to prevent disturbance to badgers during sensitive periods and to prevent excessive soil compaction from roads. In response to these issues as well as additional concerns about potential machine damage to badger burrows during harvesting, Tembec proposed using the site as a pilot study to test badger burrow protection measures. An exemption was granted by the Ministry of Environment for the harvesting treatment and the trial of burrow protection measures. These measures included establishing machine free zones around burrows to prevent damage from logging equipment. Previous authors have recommended large reserves, ranging in size from 20 metre radius (Weir and Almuedo 2009, Adams and Kinley 2004) to one tree-length radius (Cooper et al. 2004) around burrows, but it is not known how large of a buffer is actually required to protect burrows from damage.

Future ecosystem restoration treatments will likely continue to overlap with badger habitat. In areas with a high density of burrows, large buffers around each and every burrow would result in very little land available for treatment. We proposed that smaller five to seven metre machine free zones might provide sufficient protection to burrows, while still allowing harvesting to proceed. We monitored burrows before and after harvest to assess compliance by machine operators, as well as the effectiveness of the machine free zones. We also trained operators to recognize and protect badger burrows during the course of harvesting, and we tested the ability of operators to find and protect unmarked burrows. We present recommendations and management guidance for future ecosystem restoration treatments in badger habitat developed from our monitoring results and from interviews with key personnel involved in the harvesting operation.

2: BADGER BURROW PROTECTION TRIAL

2.1 Background and Study Site

Our study area is in the Rocky Mountain Trench in the East Kootenay region, approximately 30 km north of the city of Cranbrook in southeastern British Columbia, Canada (Figure 1). We examined an approximately 350-hectare cutblock harvested by Tembec Industries within the Cherry – TaTa Creek range unit as part of an ecosystem restoration treatment. Over the past half-century, the forest cover in the area has changed dramatically: Figure 2 shows this change through aerial photographs of the area from 1951 and 2005. The site was identified as an area of priority for treatment under the Rocky Mountain Trench ecosystem restoration (ER) program five-year plan (Harris 2010). Our research examines the timber harvesting stage of the ecosystem restoration treatment at the site, which will be followed by slashing of remaining small-diameter trees and prescribed burning in the near future (Harris 2010).

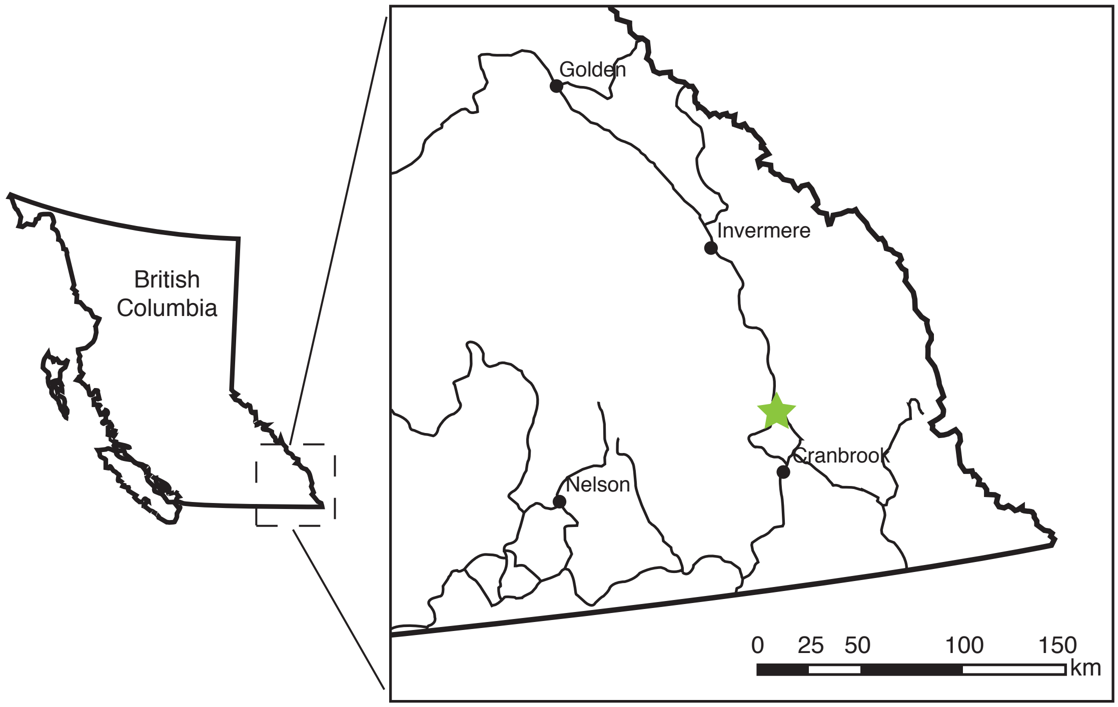

Figure 1. Map showing the general location of the study area in the East Kootenay region of British Columbia

Several badgers have been known to use the site from past radio-telemetry work (Newhouse and Kinley 2001), and the cutblock overlaps significantly with a designated badger wildlife habitat area (Figure 3). Recent monitoring of the wildlife habitat area (*WHA 4-088 Ta Ta Creek Airport North*) found a high density of badger burrows in some portions of the WHA, but the level of recent badger burrows was low relative to other badger WHAs in the region (Kinley and Page 2008).

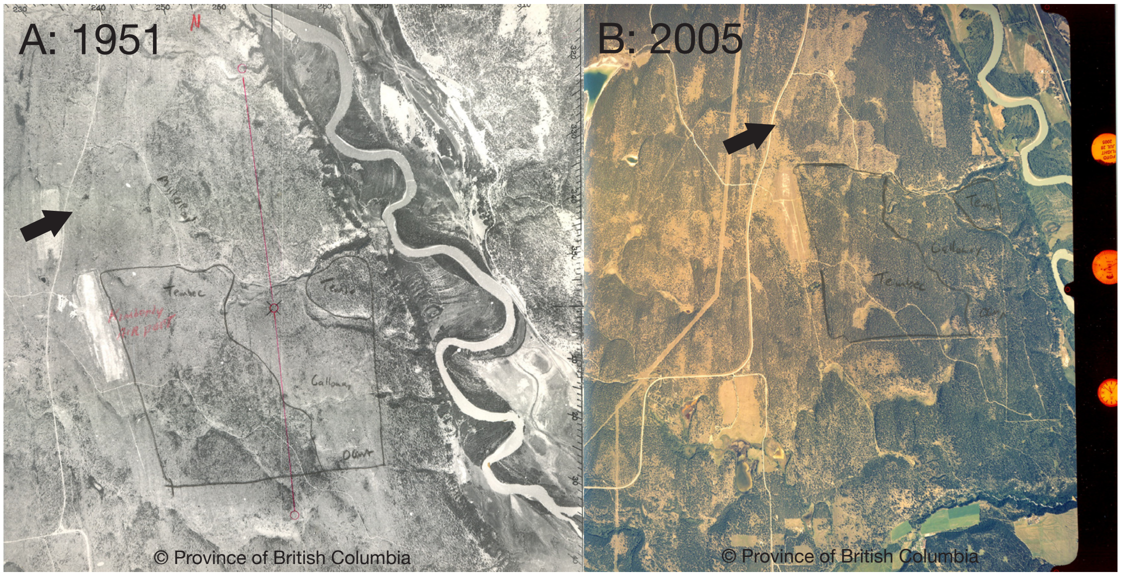

Figure 2. Air photos of the Cherry – TaTa range unit in 1951 and 2005, demonstrating the increase in forest cover. Arrows on each photo show the general location of badger Wildlife Habitat Area 4-088 and our study site. Air photos © Province of British Columbia, available from the Rocky Mountain Trench ER Program online research library (http://www.trench-er.com/library).

2.2 Terms of the WHA Exemption

The harvesting treatment received an exemption from two of the General Wildlife Measures for badger in the WHA: the restriction against developing new access roads, and the restriction against resource extraction or log hauling during the maternal period of 1 May to 15 August. To ensure that the project was in keeping with the intent of the WHA, Tembec proposed several mitigating measures intended to minimize potential harm to badgers and to existing badger habitat, including burrows. These measures included, among other things, pre-harvest surveys to identify locations of old and new badger burrows and the placement of burrows in pre-marked machine free zones; instructions to harvest and skidder operators on badger burrow identification; on-going monitoring during forestry operations for any new badger occurrences or burrows inadvertently missed in pre-work surveys; and the preparation of an effectiveness monitoring report summarizing the results of the project. The exemption was granted by the Ministry of Environment under the condition that the proposed measures be implemented, and that qualified biologists monitor the harvesting operations. See Appendix A for more detailed information about the exemption.

2.3 Proposed Burrow Protection Measures

The B.C. Identified Wildlife Management Strategy account for badgers recommends a 20-metre radius machine-free or no-development zone around badger burrows, and around ground squirrel burrows. (Weir and Almuedo 2009, Adams and Kinley 2004). Other authors have recommended a one-tree-length buffer around existing burrows (Cooper et al. 2004). Reserves or buffers around badger burrows are intended to protect the subterranean structure of burrows and to maintain the habitat value of burrows for badgers and other species, and are also meant to minimize disturbance to badgers – especially maternal groups – that may be actively using the site. We could find few measurements of the horizontal extent of badger burrows underground: in a study of three natal burrows, the deepest burrow was 2.3 metres deep but the horizontal distance was not reported (Lindzey 1976). Excavations by badgers in pursuit of ground squirrel prey tend to be less than a metre in length (Michener 2004, Murie 1992). The nest chambers of ground squirrels are reported to be up to 5 metres away from entrances (Murie 1992).

At our site, the high density of badger burrows known from previous monitoring data (Kinley and Page 2008) meant that the recommended 20 metre machine free zones were not practicable: seven metres is the longest distance that a feller-buncher can reach into a machine free zone to extract timber. Such large machine free zones around each and every burrow would leave very little timber to be harvested, and would result in a higher density of stems than the target for ecosystem restoration. We wanted to examine the hypothesis that five to seven metre radius machine free zones around existing badger burrows could be sufficient to protect subterranean burrow structures from damage while still allowing the harvesting to meet economic and restoration objectives. Under this strategy, burrows that showed signs of very recent use or were suspected to be currently active would still be placed in larger 20 metre radius reserves to minimize potential disturbance to individual badgers and family groups.

2.4 Harvesting Operations

The ecosystem restoration prescription for the cutblock required a stem density of less than 76 stems per hectare, with a target of 20 stems per hectare preferably from the largest diameter classes. Harvesting was done using feller-bunchers, which are large machines with a saw attachment that can rapidly cut and gather several trees before felling them. Harvested trees were skidded to the landing, where they were chipped on site for pulp. Trees were not of sufficient size to be used for saw logs. Material that was not of sufficient quality for chips was ground into hog fuel to use at the cogeneration plant at Tembec's

Skookumchuck pulp mill. To prevent damage to the sensitive soils at the site, wood was skidded to the landings only when needed to feed the chipper. This is known as “hot logging”, and is intended to prevent the excessive soil compaction around landings that can result from the build up of logs waiting for processing. Harvesting at the site was contracted to a small local logging operator. Logging began in late April 2010 and took approximately four weeks to complete.

3: METHODS

3.1 Pre-harvest Burrow Surveys

We began our assessment by visiting known badger burrows using an existing database of burrow locations (T. Kinley 2008, *unpublished data*). This database is not a comprehensive census of the area, and while searching the area immediately adjacent to known burrows we discovered many additional burrows. During our initial surveys, we observed a higher density of burrows – and recent use by badgers – in areas with relatively lower canopy closure. Due to the size of the cutblock, it was not possible to survey the entire block rigorously before harvesting, and we chose to focus our efforts on areas where we expected to find more burrows. We used ortho photographs and forest cover maps to identify open areas, and we prioritized these areas for searches, with the intent of covering as much of the area of the block overlapping the wildlife habitat area as possible (see Figure 3 for the area of overlap). It was sometimes difficult to distinguish between older badger burrows and burrows used by Columbian ground squirrels, an important prey species. We chose to be conservative in our identification of burrows, and likely included many ground squirrel burrows in our survey. We spent approximately 70 person-hours over 11 field days from mid March to late April 2010 conducting pre-harvest burrow surveys.

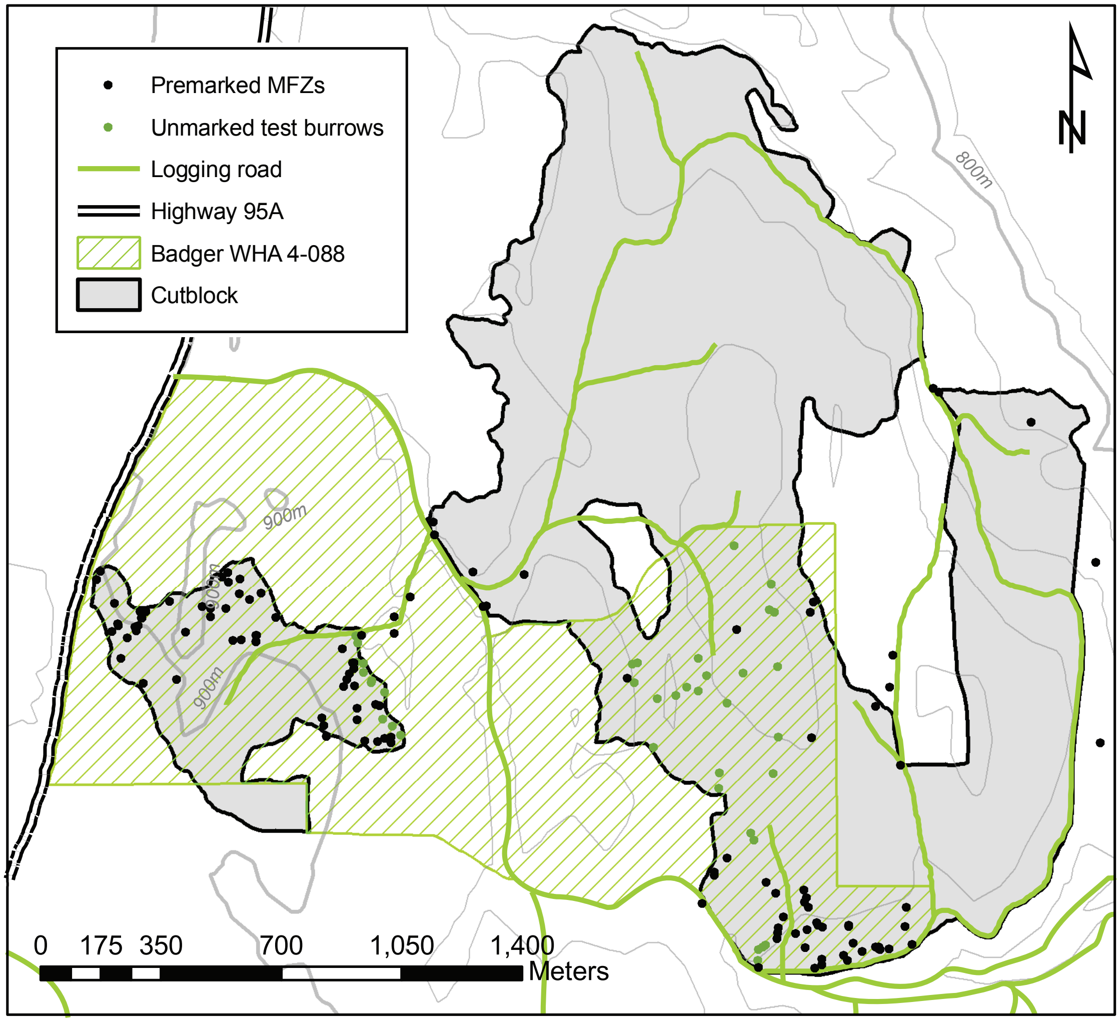

Figure 3. Detail map of the study area showing the overlap between the cutblock and the badger wildlife habitat area and the locations of all pre-marked machine free zones and unmarked test burrows.

3.1.1 Pre-marked Machine Free Zones

Most burrows found during the pre-harvest surveys were placed in Machine Free Zones (MFZs), as prescribed by the terms of the WHA exemption. Using blue and white striped flagging tape stamped with "MACHINE FREE

ZONE" we marked a buffer of approximately five to seven metres radius around each burrow. The exact size and shape of each MFZ depended on the arrangement of burrows and on the availability of suitable trees to mark the MFZ boundary. The size and shape of MFZs were highly variable, ranging from the minimum of a five metre radius to much larger. There were often several burrow entrances clumped within a five metre radius. For the purpose of flagging, we treated those burrows as a single burrow-complex and placed the entire complex in the same MFZ. We recorded the number of entrances in each complex. Depending on the terrain, some MFZs were expanded to contain more than one burrow-complex. The location of all pre-marked machine free zones in shown in Figure 3.

We photographed and recorded the general condition of each burrow. We classified the visible activity of each burrow as either "fresh", "recent", or "old" (see Figure 4 for examples). Fresh burrows were those that had been obviously dug or used that spring, evidenced by soft, loose mounds of earth and other signs of use (e.g. tracks, fur, or scat). Recently dug burrows had mounds with exposed mineral soil, and appeared to have been used within the past 1-2 years. Burrows with heavily overgrown mounds, or with vegetation or natural debris clogging the entrance were classified as "old". Signs of recent use such as freshly dug soil clearly indicate the presence of badgers, but the lack of these signs does not mean badgers are absent, as they may reuse old burrows without excavating fresh soil (RISC 2007). We recorded the UTM location of each burrow or burrow-complex, and took at least one photograph of each MFZ to assist in relocating burrows post-harvest.

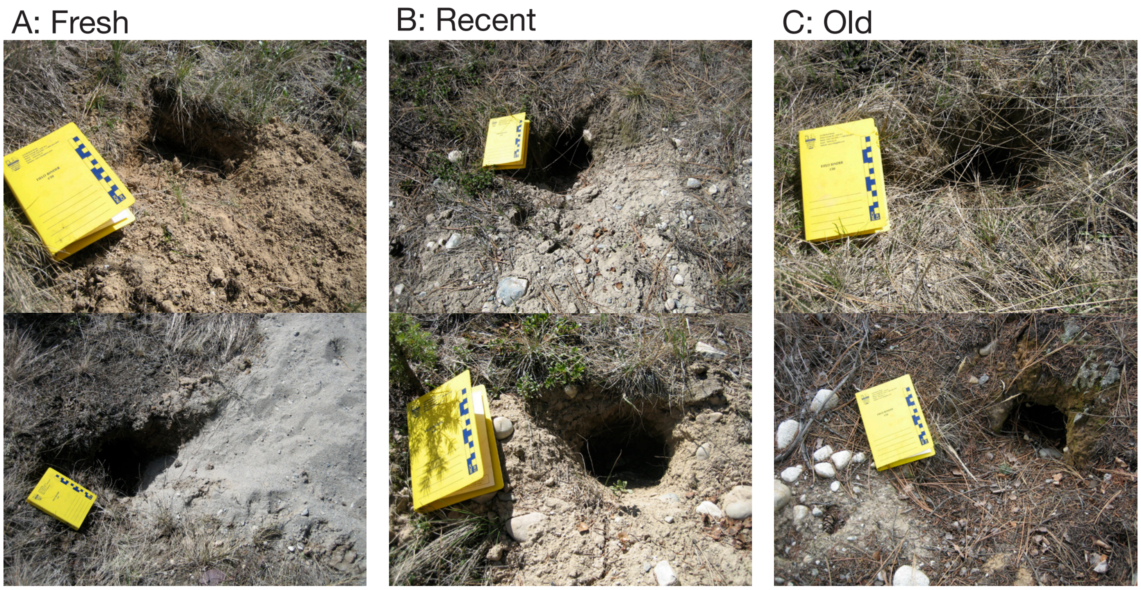

Figure 4. Representative photos for visible burrow activity classification used in pre- and post-harvest surveys. See text for category descriptions.

3.1.2 Unmarked test burrows

We quickly discovered that there were many more badger burrows on the site – both inside and outside of the WHA – than we initially anticipated. The process of locating and pre-marking burrows was very costly in time and effort, and due to time constraints we could not intensively survey the entire block before the planned harvest date. Older burrows in particular were usually not visible from beyond approximately three to five metres, and attempting to find all of these burrows would have required spacing survey transects at 10m intervals throughout the entire 350 hectare block. In order to estimate what the potential damage to burrows might be in areas where machine free zones could not be marked before harvesting, some areas of the cutblock were set aside to study harvesting impacts on unmarked test burrows. These burrows were intended to test the ability of machine operators to find and protect unmarked burrows during logging operations.

We used a loose transect protocol to find these test burrows. Transects were placed in convenient locations, generally beginning or ending at roads, landings, or easily identifiable points along the block boundary. We attempted to distribute transects evenly throughout the cutblock, however the overarching goal of the project was to protect existing high-quality badger habitat. We chose to concentrate our efforts for pre-marking MFZs in areas with high burrow densities, and placed most of our unmarked transects in areas with relatively lower badger use. The location of unmarked test burrows found on these transects is shown in Figure 3.

We walked each transect and visually searched for burrows within approximately 5 metres of the transect line. Burrows found while walking each transect were photographed and we recorded the UTM location of each burrow or burrow-complex. We also recorded the general condition of each burrow, and the visible activity as described above. We assessed how unmarked burrows might appear from the perspective of a machine operator by subjectively rating the visibility of each burrow as “poor”, “moderate”, or “good” (see Figure 5 for examples). We considered recent burrows with large, highly visible mounds and exposed mineral earth to have “good” visibility; older burrows with completely overgrown or absent mounds were rated as “poor” visibility. Visibility ratings also considered the topography around the burrow, as well as the presence of trees or vegetation obscuring the burrow from sight. We took at least one photograph of the area immediately around each unmarked test burrow.

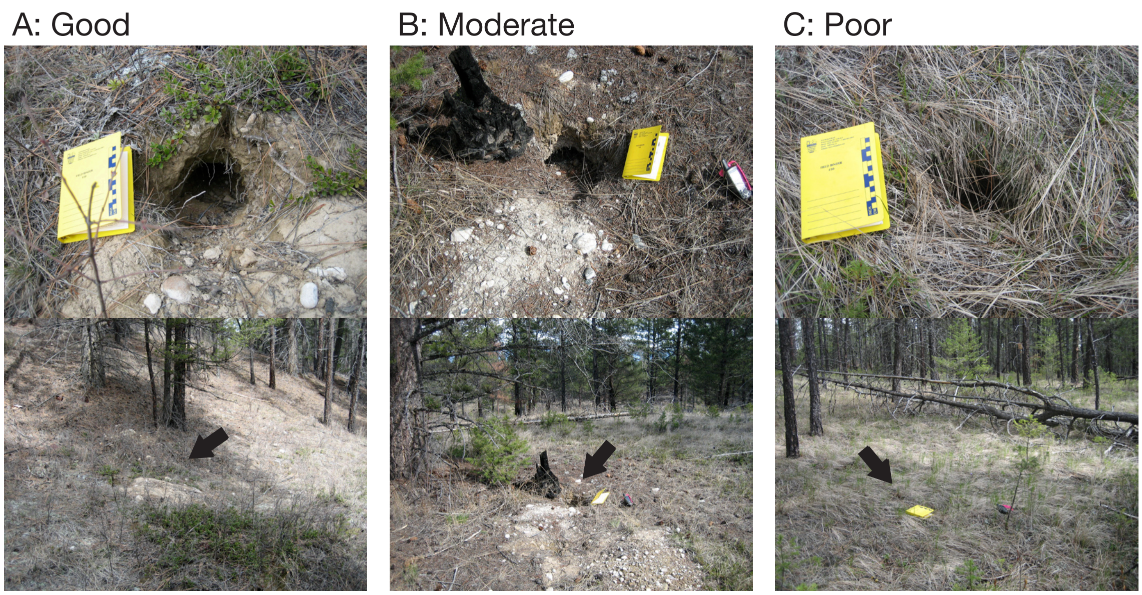

Figure 5. Representative photos of the visibility classes for unmarked test burrows. The upper images show individual burrows, and the lower images show the area immediately around each of the burrows, with arrows pointing to the actual burrow location. See text for category descriptions.

3.2 Machine Operator Education and Training

All machine operators were given an on-site orientation to the project before road-building and logging began. This pre-work training included short talk on badger biology and conservation, and the importance of protecting badger burrows. Operators were given an information package (see Appendix B) including a map of marked badger burrows; colour brochures on badgers and conservation in the East Kootenay, and on badger burrow identification; and written instructions detailing exactly what to do if a badger or a badger burrow was encountered while working. We visited badger burrows and machine free zones in the field with operators, and discussed strategies and techniques for protecting burrows. To protect burrows from logging equipment, machine operators were instructed to “high-stub” trees around the boundary of flagged MFZs and around any unmarked burrows they found. For this project, high-stubs are defined as trees that are cut approximately one to three metres above the ground that are used to delineate boundaries. They also may provide some post-harvest structure for use by birds and other wildlife (Harris 2001). High-stubbed trees provide a visible marker to enforce the machine free zones and have been used to protect burrows in previous Tembec cutblocks in badger habitat (K. Stuart-Smith, *personal comment*). We told operators about the unmarked test burrows, but we did not indicate the number of unmarked burrows or their locations.

3.3 Post-harvest Burrow Surveys

3.3.1 Pre-marked MFZs and unmarked test burrows

We re-visited all burrows within one to three weeks post-harvest and assessed the condition of each burrow as well as compliance with the machine free zones. Not all of the pre-marked MFZs were included in the area harvested this year. We visited all of the burrows within the block that were identified prior to logging, as well as unharvested MFZs close to the block boundary and adjacent to active roads in order to capture all of the potential effects on burrows by normal harvesting activities. To locate burrows we used UTM coordinates, flagging tape, and other landmarks identified prior to harvesting. Burrow identification was confirmed using pre-harvest photographs. We spent approximately 68 person-hours over 8 field days over a two-week period in June 2010 conducting post-harvest assessments.

Table 1. Post-harvest burrow condition category descriptions.

Burrow Condition	Description
Undisturbed	No obvious disturbance or damage relative to pre-harvest photos.
Minimal fine debris	No obvious significant disturbance, but small amounts of fine logging debris such as wood chips from the saw scattered around the entrance and/or mound
Partially disturbed	1. Some fine logging debris in entrance – twigs, sticks and small logs partially plugging the entrance 2. Some coarse logging debris in entrance – large logs, stumps, or rocks partially plugging the entrance 3. Entrance plugged with fine logging debris – twigs, sticks and small logs fully plugging the entrance 4. Entrance plugged with coarse logging debris – large logs, stumps or rocks fully plugging the entrance
Partially crushed	Burrow entrance or mound partially crushed by machine tracks or felled trees, but main structure of burrow still visible
Crushed	Burrow entrance and/or mound completely crushed under machine tracks.
Gone	Burrow not found in post-harvest survey, using both the GPS locations and pre-harvest photos to confirm the site. This category could include burrows that were simply obscured by superficial slash and debris, as well as burrows that were completely crushed under machine tracks and anything in between
Not harvested or unknown	Burrow not in treated area or not checked post-harvest

We assessed whether there had been any visible use by badgers since our original survey, photographed each burrow, and recorded the post-harvest condition of each burrow (see Table 1 for condition categories). We compared burrows to pre-harvest photographs to distinguish between existing debris and new debris from logging. Many burrows had small wood chips from the saw or other fine logging debris scattered around the entrance or on the mound. This debris seemed unlikely to impact how badgers use burrows, but in an effort to fully record all potential disturbances to badger burrows, we recorded the post-harvest condition of such burrows as “minimal fine debris”. The area around each burrow and within each burrow complex was thoroughly checked for evidence of collapsed tunnels or other damage.

We also assessed the level of compliance with pre-marked MFZs: we looked for the presence of high stubs, evidence of machine tracks or trees fallen into the zone, and whether trees directly supporting burrows had been cut. We photographed the post-harvest condition of each MFZ and noted any violations. For unmarked test burrows, we also noted the condition of the area around each burrow and estimated the minimum size of the buffer (in metres) left around the burrows, if present. The strategies used by operators to protect unmarked test burrows varied, and we recorded any evidence that operators had positively identified and protected burrows.

3.3.2 New burrows

During the course of harvest, machine operators also found and protected burrows that were not part of either the pre-marked MFZs or the unmarked test burrows. As with the test burrows, the strategies used by operators to protect these new burrows varied. We identified these “operator implemented machine free zones” (OIMFZs) by the presence of pink or orange flagging tape, high stubs, and/or other protective measures that were established by machine operators around burrows. We assessed whether these new burrows appeared to have been disturbed during harvest, and recorded the visible activity of burrows. We photographed each burrow and each OIMFZ, and estimated the minimum buffer left by the operators in metres.

3.3.3 Quantitative analysis

We compared the characteristics of burrows within pre-marked machine free zones and unmarked test complexes, as well as the characteristics of burrows that were successfully located by machine operators using Fisher’s exact test for count data in the open-source statistical software R (R Development Core Team, 2010). Fisher’s exact test calculates significance of the deviation from the null hypothesis exactly and is appropriate for analysis of contingency tables where expected values are small (McDonald 2009).

3.4 Key Informant Interviews

The physical badger burrow monitoring data described above does not address the operational and economic feasibility of our burrow protection measures. Strategies to protect wildlife features, like machine free zones, will only be effective if they can be successfully implemented on the ground. In particular, complying with the burrow protection measures could involve increased difficulty and decreased operating efficiency on the part of machine operators. This information is critical in assessing the feasibility of future projects, but was only known by the individual operators. To better understand the operational perspective, we conducted five key informant interviews with contractors and staff directly involved in the planning and harvesting operations.

Interviews were semi-structured, and were conducted in person in Cranbrook, British Columbia. Interview participants included skidder and feller-buncher operators, as well as staff involved in planning and layout. Each interview lasted approximately 45 minutes and consisted of mainly open-ended questions (see Appendix C). We asked participants about their personal experience working on the project, including the difficulty and cost of complying with the burrow protection measures, and their overall impressions and suggestions for improvement. Interviews were recorded electronically, and we transcribed each interview verbatim. We reviewed interview transcripts using an iterative process to identify major themes and important lessons.

4: RESULTS

4.1 Pre-harvest Burrow Surveys

We found 334 badger burrows during pre-harvest surveys distributed in 155 burrow complexes. Of these, 281 burrows within 117 complexes were flagged in 85 machine free zones. We left 38 of the surveyed burrow complexes, containing 53 burrows, unmarked and unprotected to test the ability of operators to find and protect burrows. Most of the burrows we found did not show signs of recent or fresh use (Table 2). Most complexes contained only one or two burrows, with relatively few very large complexes (Figure 6).

Burrows left as unmarked test burrows were not randomly distributed through the block, and the complexes left as unmarked test burrows were not representative of the total population of burrows found during pre-harvest surveys (Table 2). In particular, unmarked test burrow complexes had significantly fewer burrows per complex than pre-marked machine free zones (two-sample t (df=130.78) = 4.5672, $p = 0.00001$). Unmarked test burrows also had a significantly higher proportion of old burrows relative to fresh and recent burrows than pre-marked machine free zones ($p = 0.0016$, two-sided Fisher's exact test). These differences introduce a bias to the sample of unmarked test burrows, however main priority of the project was to protect existing badger habitat, and in particular to prevent disturbance to any burrows that were potentially being used by individuals or family groups. For these reasons, burrows with signs of fresh use were not left unmarked, even when they were encountered along transects.

Table 2. Characteristics of burrows found during pre-harvest surveys within pre-marked machine free zones (MFZs) and in unmarked test burrow-complexes.

	Within pre-marked MFZs	**Within unmarked test complexes**	**All burrows found pre-harvest**
Total burrows	*281*	*53*	*334*
Total complexes	*117*	*38*	*155*
Complex size:	*Mean number of burrows per complex (SD)*		
	*2.41 (1.83)**	*1.40 (0.89)**	*2.16 (1.71)*
Visible burrow activity:	*Number of burrows (% of total)*		
Fresh	*7 (2.5%)***	*0***	*7 (2.1%)*
Recent	*76 (27.0%)***	*4 (7.6%)***	*80 (24.0%)*
Old	*195 (69.4%)***	*49 (92.4%)***	*244 (73.0%)*
Unknown	*3 (1.1%)*	-	*3 (0.9%)*

* unmarked test burrow complexes had significantly fewer burrows per complex than pre-marked machine free zones (two-sample t (df=130.78) = 4.5672, $p = 0.00001$).

** unmarked test complexes contained a significantly different proportion of old burrows relative to fresh and recent burrows than pre-marked machine free zones ($p = 0.0016$, two-sided Fisher's exact test).

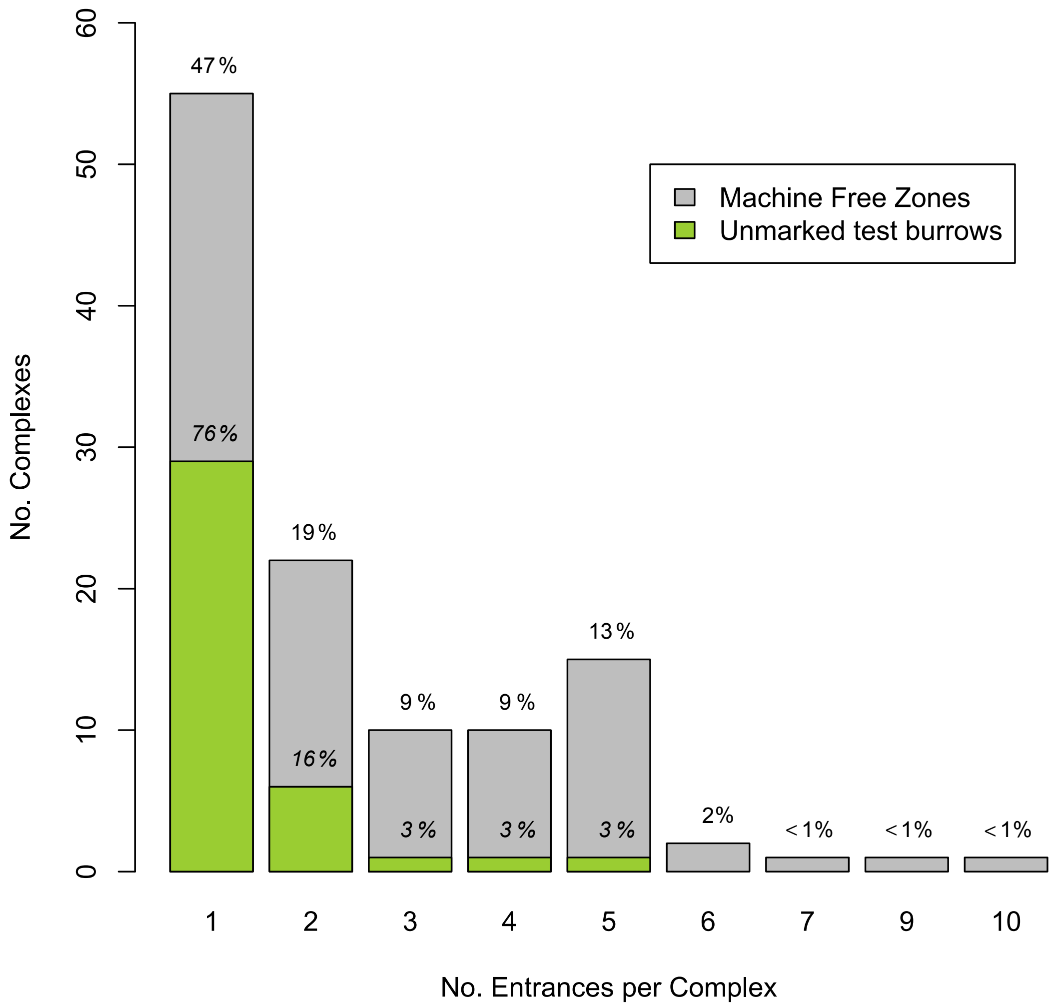

Figure 6. Distribution of burrow-complex sizes (number of entrances per complex) for all burrows surveyed pre-harvest. Grey bars show complexes in pre-marked Machine Free Zones; green bars show complexes left as unmarked test burrows. Percentages do not add to 100 due to rounding.

4.2 Post-harvest Burrow Surveys

We surveyed 381 burrows post-harvest, including 63 burrows that were found by operators during harvesting. An additional 25 known burrows were not surveyed, either because they were outside the harvested area or due to survey errors. Most (87.9%, see Figure 8) of the 381 burrows surveyed were undisturbed by logging or had only negligible amounts of fine logging debris (e.g. small woodchips from the saw) scattered around the burrow entrance. See Table 1 for descriptions of the post-harvest condition categories and Figure 9 for example photos.

Figure 7. Post-harvest scene showing several machine free zones (MFZs) delineated by high stubs. MFZs appear as greener areas, and reclaimed skid trails and other machine tracks are visible in the disturbed ground between the MFZs. The arrow points to the visible mound of a protected badger burrow.

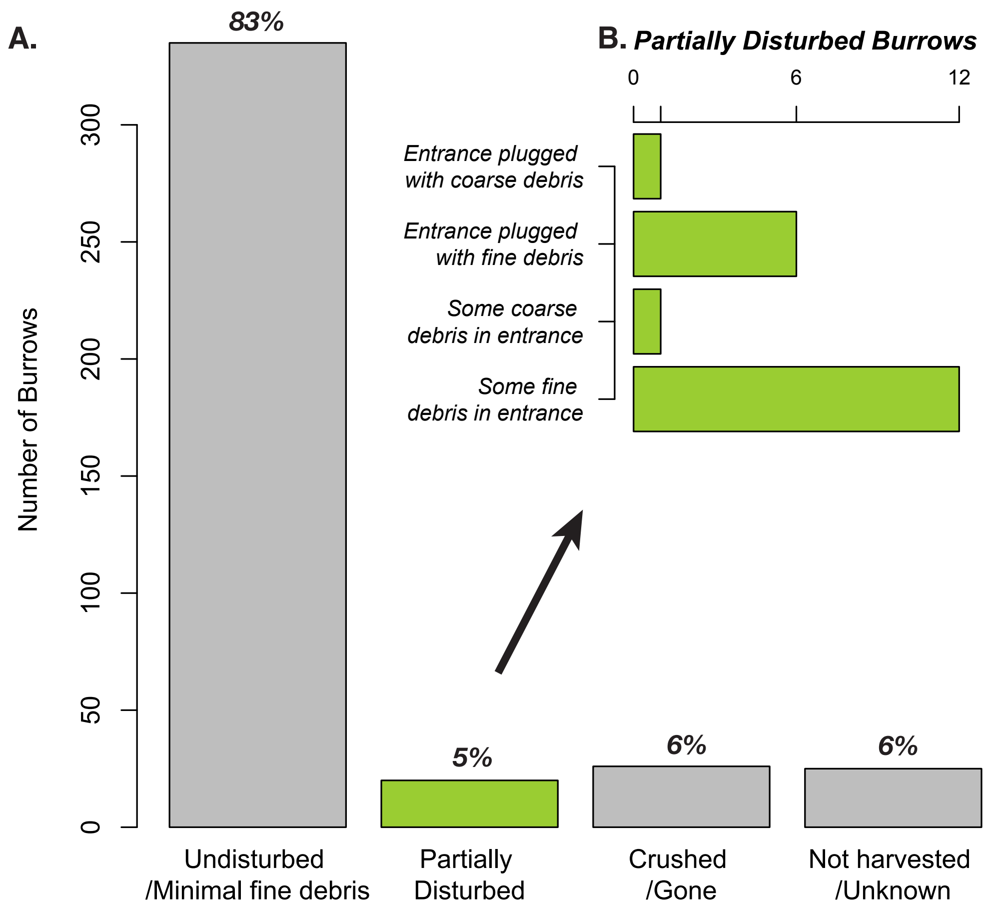

Figure 8. Post-harvest condition of all 406 burrows, including unmarked test burrows and new burrows found by operators during harvesting. 114 burrows had negligible amounts of fine logging debris (such as small wood chips from the saw) scattered around the burrow entrance and are shown grouped with undisturbed burrows. The inset figure *B.* (in green) shows a detailed breakdown of the condition of the 20 partially disturbed burrows (column two of the main figure).

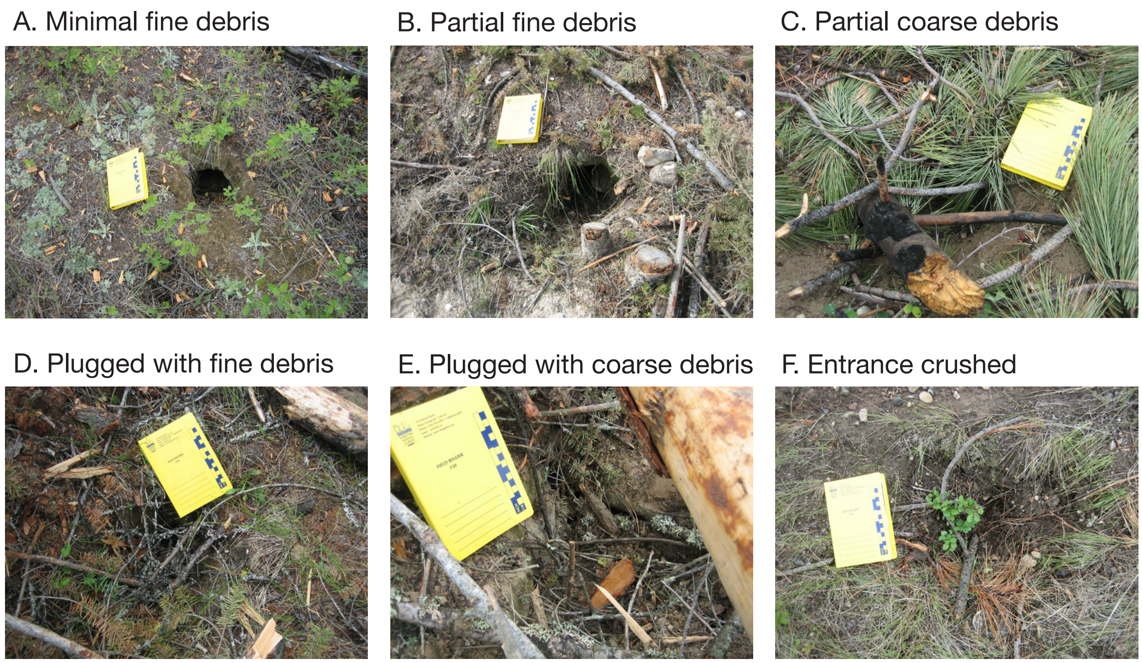

Figure 9. Example photos of post-harvest burrow condition categories. Only debris that originated from logging activity was included in the post-harvest condition

4.3 Pre-marked Machine Free Zones

4.3.1 Compliance with MFZs

Eight of the 85 pre-marked MFZs were outside of the area harvested in 2010, and were not surveyed. Most (89.6%, see Figure 10) of the remaining pre-marked MFZs were found to be in full compliance, however we did find six minor violations, and two more serious violations (Figure 10). The six minor violations consisted of three instances where machine tracks cut across the corner of the MFZ, two cases where small trees were accidentally felled into the machine free zone and left on the ground, and one burrow where one of two supporting trees at the burrow entrance was cut.

We also encountered more serious violations: two of the larger MFZs were significantly disturbed by machine traffic. In the most severe case, one entire side of the pre-marked zone was disregarded, crushing one burrow in a complex of four old burrows. The remaining burrows were unharmed. The other major violation involved a very large MFZ with two distinct burrow complexes joined by a narrow strip. Both complexes showed signs of fresh badger use during pre-harvest surveys, and we had marked out a 20-metre buffer around the fresh burrows. We found a reclaimed skid trail running between the two burrow complexes and through the middle of the MFZ. None of the burrows in either complex were damaged. Comments from operators in post-harvest interviews suggest that the violations may have been related to confusing ribbons (see section 4.5 for more details).

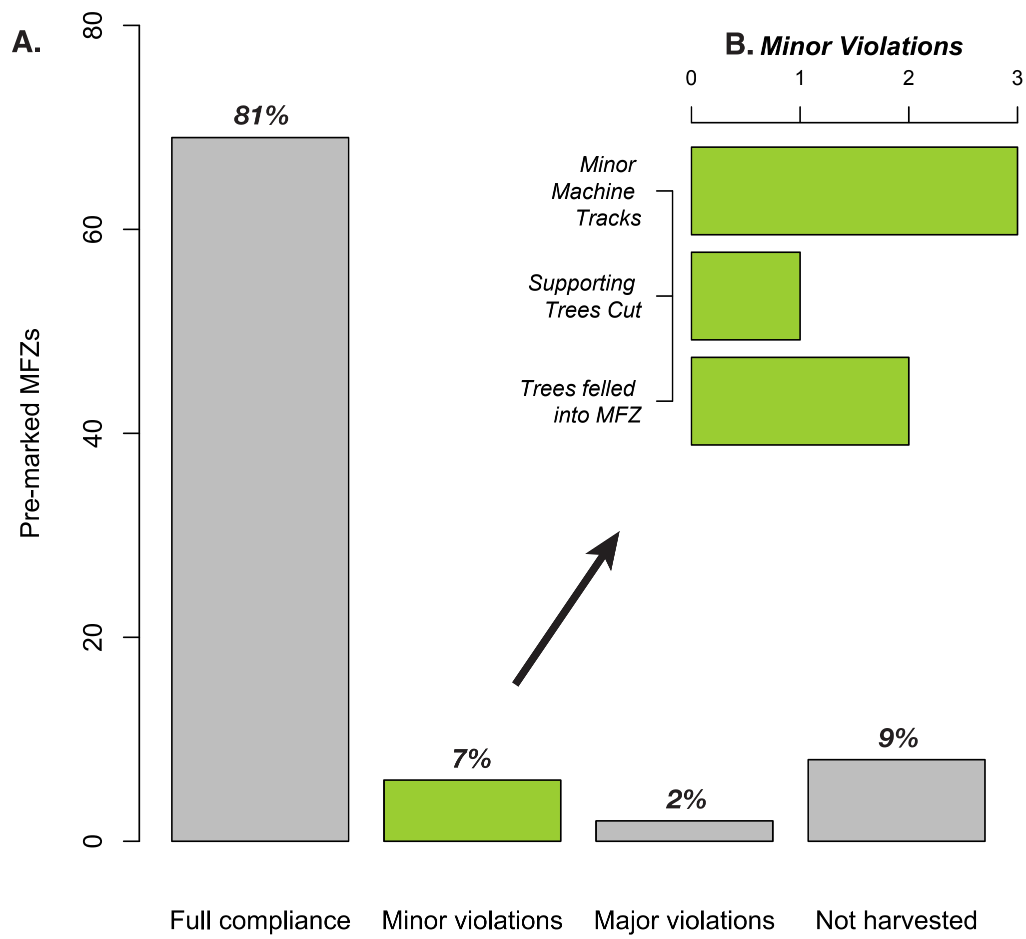

Figure 10. Observed compliance within 85 pre-marked machine free zones. Eight of the pre-marked zones were in areas that were excluded from the harvesting in 2010, but will likely be harvested in 2011. The inset figure *B.* (in green) shows a detailed breakdown of the 6 minor violations shown in column two of the main figure. Percentages do not sum to 100 due to rounding.

4.3.2 Effectiveness of MFZs in protecting burrows

The pre-flagged MFZs successfully protected almost all burrows from visible damage when implemented correctly. Within the 69 MFZs where operators were in perfect compliance with the prescription, only three out of 204 burrows (1.5%) were disturbed during harvesting (Figure 11). The three disturbed burrows had some fine logging debris in the entrances or on the mound, but were otherwise unaffected.

Even without perfect compliance, very few burrows were actually disturbed by logging: within all of the pre-marked MFZs – including those with minor and major violations – only six out of 258 burrows (2.3%) were disturbed by harvesting, and most of the disturbance was minor (Figure 12). Four of the six disturbed burrows had some fine logging debris in the burrow entrance, and one burrow was fully plugged with fine logging debris. All of the logging debris was removed from the burrows during the post-harvest surveys. Only one burrow of the six disturbed burrows was seriously damaged: as described above, the MFZ was partially violated, crushing a single burrow in a complex of four older burrows.

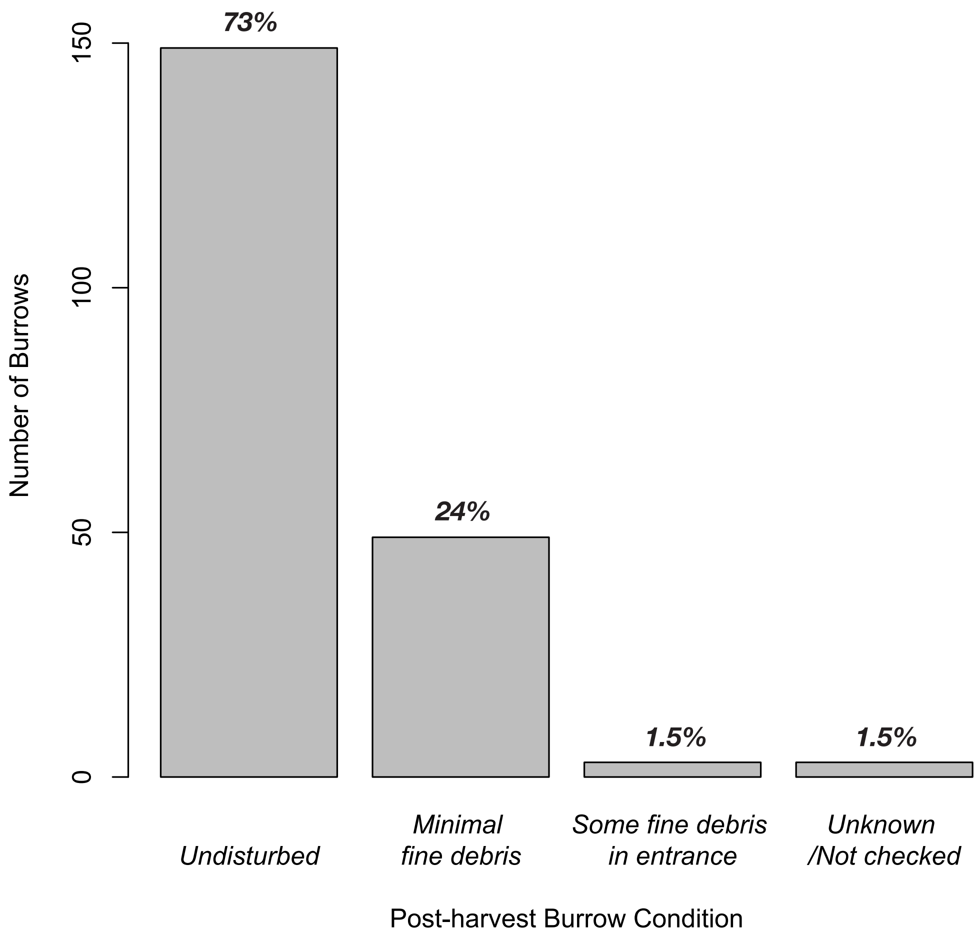

Figure 11. Post-harvest burrow condition for burrows within the 204 MFZs with perfect compliance.

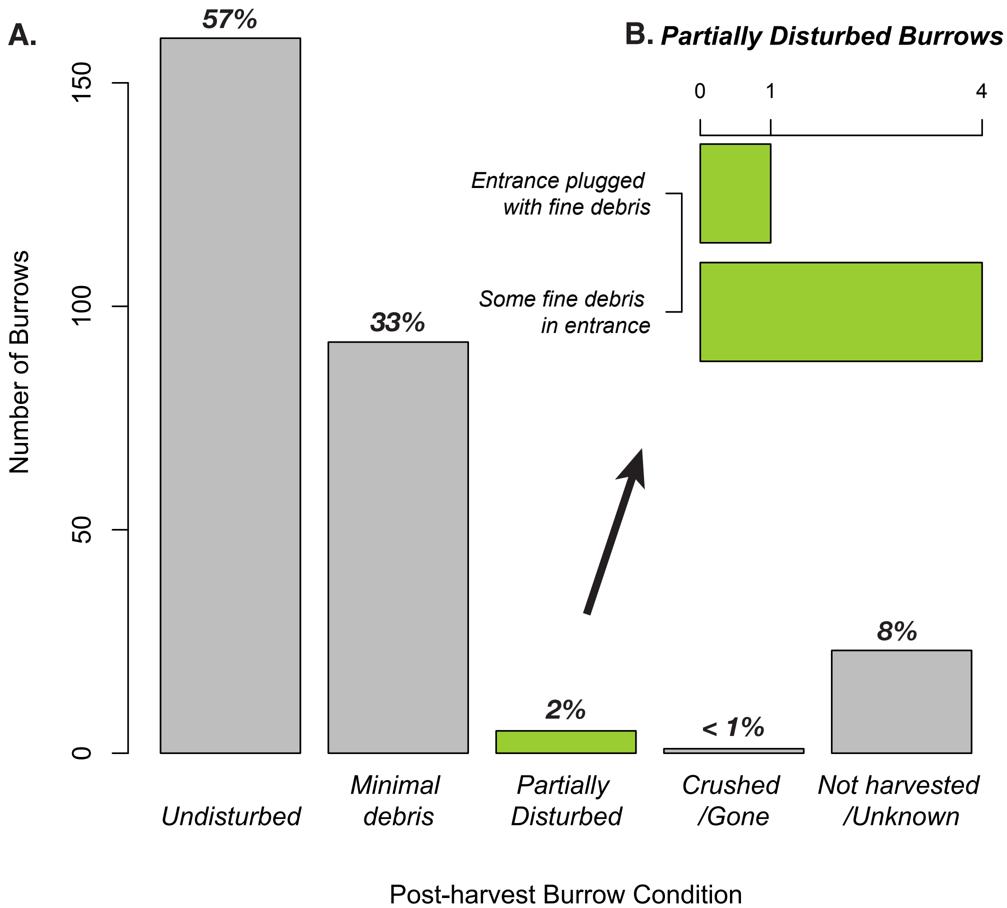

Figure 12. Post-harvest burrow condition for all pre-marked MFZs, including the eight violations. The inset figure *B*. (in green) shows a detailed breakdown of the condition of the five partially disturbed burrows (column 3 in the main figure). Percentages do not sum to 100 due to rounding.

4.4 Unmarked Burrows

4.4.1 Unmarked test burrows

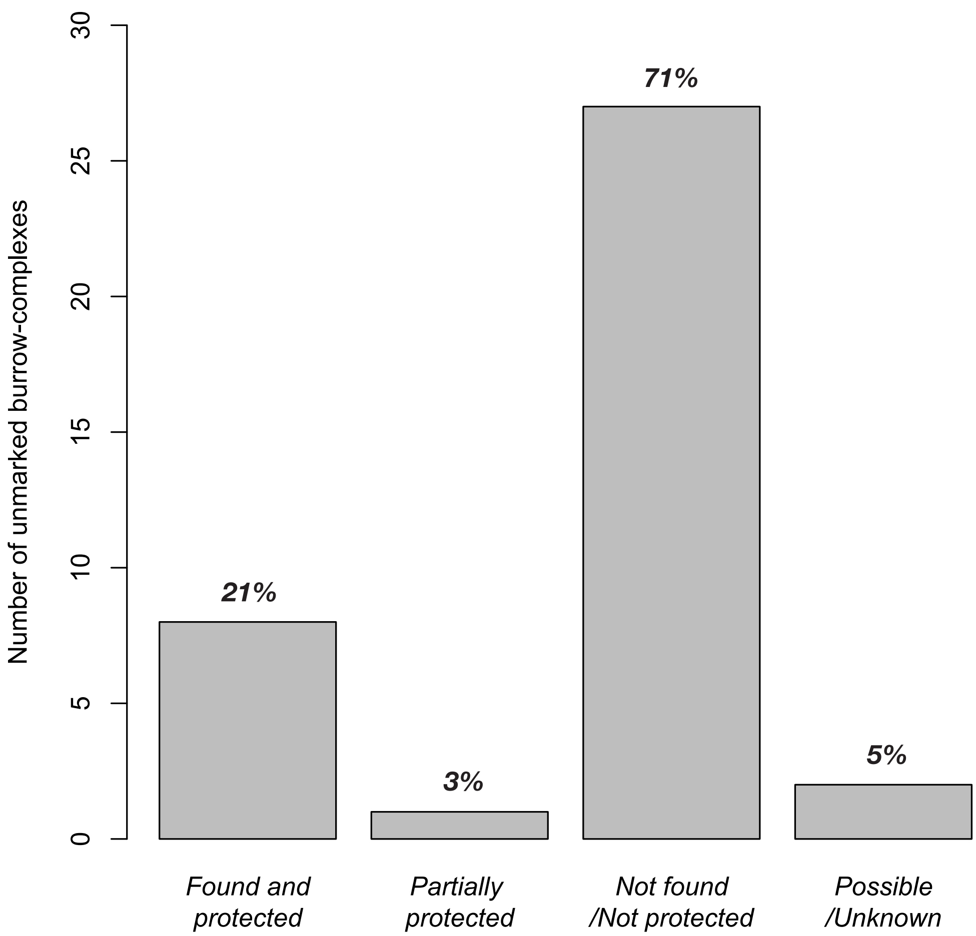

Figure 13. Protection of unmarked test burrow complexes during harvesting.

Machine operators successfully identified nine out of 38 unmarked burrow complexes (23.7%), however the majority of unmarked test burrows were not found by operators, and were not protected (Figure 13). One of the unmarked test burrow complexes was only partially protected by operators: three of the five burrows were obviously seen by operators and retained within a patch of uncut trees and high stubs. The other two burrows were at the edge of the complex and were crushed under the machine track and plugged with logging debris – these burrows were likely not seen during harvesting. This partially protected complex is included the ‘found’ column of Table 3, as the main complex was successfully identified by operators.

Machine operators successfully found a significantly higher proportion of burrow complexes that contained two or more burrows ($p = 0.03348$, two-sided Fisher’s exact test). There was no difference in the proportions of burrows within the visibility rating or burrow activity classes that were found by operators during harvest. We were unable to determine whether operators actively protected two other unmarked complexes: these complexes had small trees and some possible high-stubs around them, but no ribbon or obvious signs that operators had seen and purposefully avoided burrows. These complexes are excluded from Table 3.

Table 3. Characteristics of unmarked test burrows that were either successfully found by operators, or not found/not protected.

		Found	Not Found	
		Number of burrow-complexes (% of total)		**Total**
	All unmarked test complexes:	9 (23.7%)	27 (76.3%)	36*
Visibility Rating	Good	3 *(50%)*	3 *(50%)*	6 *(16.7%)*
	Moderate	4 *(30.1%)*	9 *(69.9%)*	13 *(36.1%)*
	Poor	2 *(11.8%)*	15 *(88.2%)*	17 *(47.2%)*
Burrow Activity	Recent	2 *(50%)*	2 *(50%)*	4 *(11.1%)*
	Old	7 *(21.9%)*	25 *(78.1%)*	32 *(88.9%)*
Complex Size**	Single burrow	4 *(14.3%)*	24 *(85.7%)*	28 *(77.8%)*
	2+ burrows	5 *(57.1%)*	3 *(42.9%)*	8 *(22.2%)*

**Operators found a higher proportion of unmarked test burrows-complexes with two or more burrow entrances (*p=0.03348*, Fisher's Exact test).

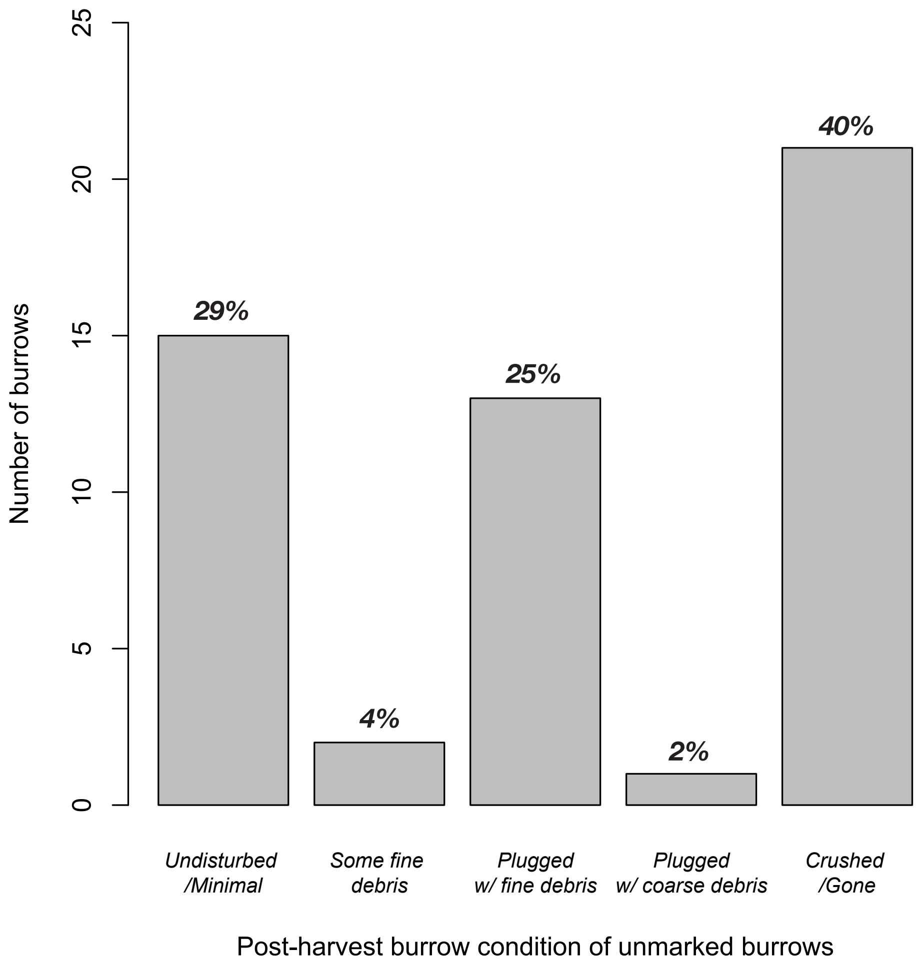

Figure 14. Post-harvest condition of all unmarked test burrows.

4.4.2 Operator-Implemented Machine Free Zones

In addition to the unmarked test burrows, machine operators also found and protected 63 new burrows within 27 complexes. These burrows had not been found during pre-harvest surveys, and were located post-harvest by the presence of new flagging and/or high stubs, and by speaking to the operators. The distribution of burrows in the three activity classes (fresh, recent, and old) was significantly different for operator-implemented machine free zones (OIMFZs) than for pre-marked burrows (*p = 0.03709*, two-sided Fisher's exact test). This difference is due to a higher proportion of fresh burrows relative to recent burrows within operator implemented machine free zones (*p = 0.01814*, Fisher's exact test). There was no difference in the number of burrows per complex for operator-implemented MFZs and pre-marked MFZs (Table 4).

Table 4. Relative characteristics of burrows protected by operators during harvesting (OIMFZs) and burrows protected during per-harvest surveys. The OIMFZ column includes the 18 unmarked test burrows that were successfully identified by operators as well as the 63 new burrows found during harvesting.

	Operator Implemented MFZs	**Pre-marked MFZs**
Visible Burrow Activity:	*Number of burrows protected (% of total)*	
Fresh	6** *(7.4%)***	*7*** *(2.5%)***
Recent	14** *(17.3%)***	*76*** *(27.0%)***
Old	58 *(71.6%)*	*195* *(69.4%)*
Not badger	3 *(3.7%)*	-
Not recorded	-	*3* *(1.1%)*
Total burrows	81	281
Complex Size:	*Mean number of burrow entrances per complex (SD)*	
	2.28 *(1.88)*	2.41 *(1.83)*
Buffer Width:	*Mean actual width (SD)*	*Target buffer width*
	3.097 *(1.29)* metres	5 – 7 metres

** The proportion of fresh burrows relative to recent burrows was significantly higher in operator-implemented MFZs than in pre-marked MFZs (*p = 0.01814*, Fisher's exact test)

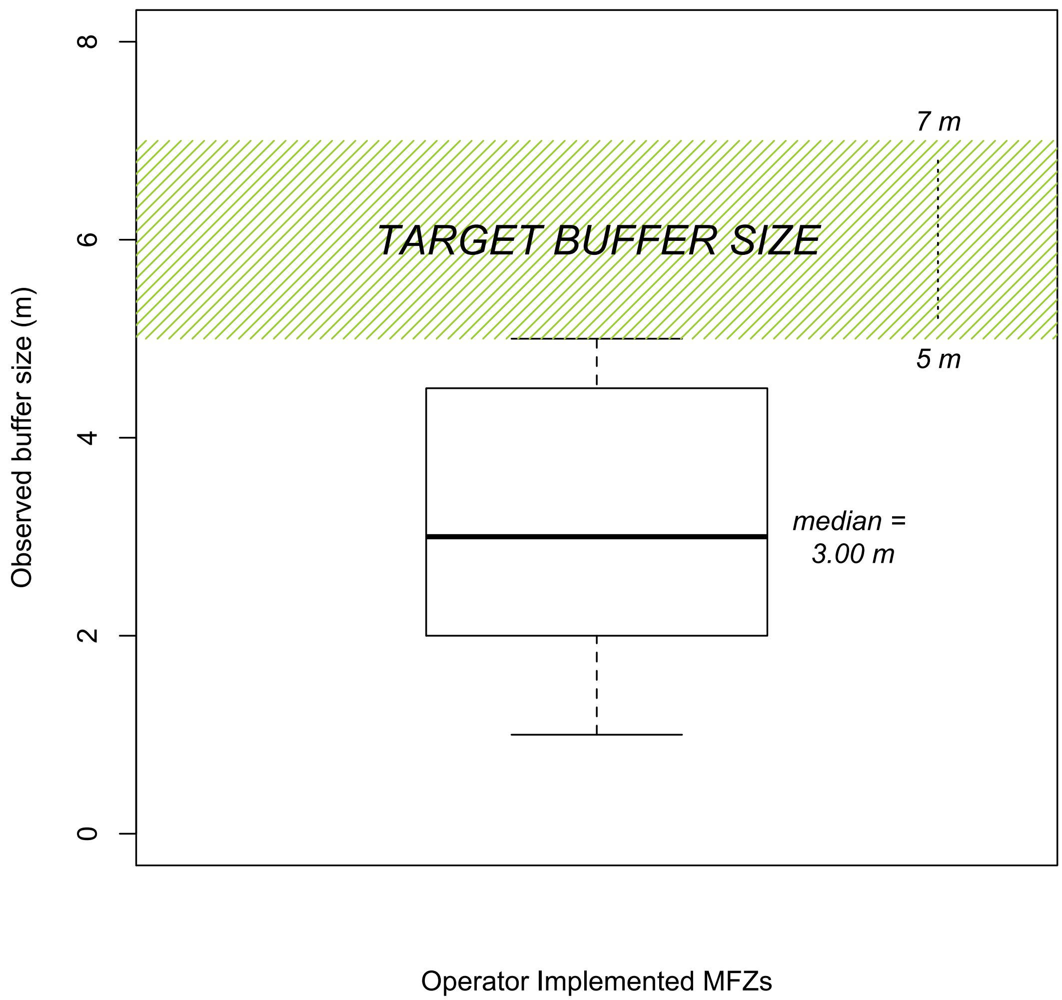

Figure 15. Boxplot of the observed distribution of buffer widths in Operator Implemented MFZs relative to the target buffer width of 5 - 7 metres for pre-marked MFZs.

Twenty-seven of the 36 (75%) operator-implemented machine free zones (OIMFZs) had smaller buffers around burrows (mean = 3.097m, SD = 1.29) than the target buffer width of five to seven metres for pre-marked MFZs (Figure 15, Table 4). We did not record the actual buffer widths of the pre-marked machine free zones. Operators successfully protected 58 older burrows as well as six fresh and 14 recent burrows within the 36 OIMFZs (Table 4). Many of these operator-implemented MFZs were in areas with few trees available for high-stubbing, and operators showed creativity and initiative in protecting burrows. We found several OIMFZs with artificial high stubs – created by forcefully placing a log upside-down into the earth – marking the area around burrows.

4.5 Key Informant Interviews

4.5.1 Overview

We conducted five interviews with contractors and staff directly involved in the planning and harvesting operations. Interview participants included both skidder and feller-buncher operators, as well as staff involved in planning and layout. All interviewees had at least several years experience in their field, and several had over ten years experience. Although all of the machine operators we interviewed had plenty of harvesting experience, none had previously worked in badger habitat, and they had limited knowledge of badger biology and habitat needs. In contrast, the planning staff interviewed had a greater prior knowledge of badgers and badger habitat requirements, and had experience working on similar projects.

All respondents were generally quite positive about the project and about their experience. A common sentiment was that protecting badger burrows was not as difficult as expected and all interviewees felt that the project was a success.

4.5.2 What did it cost to protect burrows?

Effectively protecting badger burrows required extra effort and care by planning and operations staff and by machine operators throughout the course of the project. This extra work included obtaining the WHA exemption and developing the burrow protection strategies, locating burrows and flagging Machine Free Zones, site visits and pre-work training with operators, and the actual work of complying with the MFZs and protecting burrows during harvesting. The time required to perform these tasks was expected to increase the costs of harvesting – perhaps significantly – and several interviewees indicated they were initially quite concerned about these potential costs.

Despite their initial worries, most interviewees said that the increased costs during harvesting were not as high as they had feared. The machine operators we interviewed estimated their costs as an approximately 15 to 20% loss in production in areas with a high density of burrows. They stated that this loss in production was mainly a result of the additional time spent by operators walking each section prior to logging, getting out of their machines to investigate potential burrows and flag new MFZs, and moving more slowly than usual around burrows and flagged MFZs. According to many interviewees, these increased costs were somewhat balanced by easy ground elsewhere: large sections of the block north of the WHA were more densely forested and had relatively few badger burrows. These areas were referred to by several machine operators as "golden", and they allowed operators to work efficiently over the scale of the entire block. Some interviewees felt that without this balance between "easy" areas with few badger burrows and "hard" portions with more burrows, the project would not have been economically feasible for them.

From a planning perspective, the personnel we interviewed estimated that this project required approximately 30% more time than similar cutblocks. This estimate included the extra time spent on administration, meetings, and field tours related to the WHA exemption, site visits and pre-work training with the logging contractors, as well as the hours spent surveying for burrows and laying out Machine Free Zones. Since most of the pre-harvest survey and MFZ layout work was done as part of this research (see section 3.1), we also have more precise estimates for the amount of time required for this component: we spent approximately 70 person-hours on-site actively searching for burrows and ribboning Machine Free Zones, and 68 person-hours conducting post-harvest assessments. This may be a slight underestimate, however, as layout staff also spent time looking for burrows. Much of the time spent on the pre- and post-harvest surveys was due to photographing and assessing each burrow individually.

Another cost mentioned by interviewees was the delay in starting the harvesting operations. Harvesting was delayed by one to two weeks while pre-harvest burrow surveys were completed, and interviewees also noted the definite risk of more significant delays and associated costs: if, for example, active maternal burrows had been found on the site, the entire operation would have been forced to shut down until the family group left the area or the kits dispersed in August. Some sections of the original proposed block were dropped from the final treatment area because of the anticipated cost of protecting burrows. According to interviewees, these areas were in need of restoration treatments, but had marginal wood quality and too high a density of burrows to be economically feasible under the WHA exemption terms.

A large portion of the extra planning time required for this block was related to securing the WHA exemption and developing the strategies for protecting badgers and badger burrows. Several interviewees felt there was some confusion and uncertainty around this process, and that it took extra time to build the necessary trust and understanding between the players. This was the first time that this kind of project had been attempted in a badger WHA in British Columbia, and interviewees felt that uncertainty and conflicting goals may have slowed down the approval process. Most interviewees were hopeful that the lessons learned from this project would allow the process to be quicker and more straightforward in the future.

4.5.3 Operator training and learning

An important component of the project was the on-site training given to machine operators prior to harvesting. All interviewees felt that this training was interesting and useful, especially the walks through the block to look at burrows and MFZs. The operators we spoke to all mentioned that they had kept the hand-outs and maps in the cab of their machines for reference, and they were confident that their training was sufficient to allow them to fully comply with the burrow protection strategies.

In addition to the knowledge gained through the pre-work sessions and site visits, interviewees emphasized that the entire project was a learning experience. All of the machine operators we spoke to said they had never worked with this type of project before: usually they are only asked to work with one or two flagged wildlife tree patches or riparian zones and they had no experience actively searching for burrows or other features on the ground. The sheer number of flagged Machine Free Zones in the block – there were 85 – was initially intimidating to several interviewees, but they said that working around the MFZs became easier as they became more experienced. Finding and protecting unmarked burrows was particularly difficult at first, but operators felt that they quickly became more skilled at spotting new burrows, once they knew what they were looking for.

Interviewees were in disagreement about the long-term effects of this training. While all of the operators stated that the project had made them more aware of the presence of badgers in general, several interviewees felt that learning process would likely need to be repeated again if they were to work on similar projects in the future. In contrast, other interviewees – including both machine operators and planning staff – felt that it would be relatively easy for experienced operators to remember or relearn how to deal with burrows. All interviewees were very positive about the knowledge they had gained about badgers and about badger burrows, and most mentioned – without prompting – ways that they had shared this knowledge with family and friends.

4.5.4 Challenges

Protecting badger burrows added stress and difficulty to the regular work of the machine operators. Interviewees mentioned that they felt pressure from the "public eye" to do a good job, and that the newness of the task was initially intimidating. They found that this stress dissipated somewhat as they learned how to navigate their machines around MFZs and burrows. This was the most difficult for the feller-buncher operators: they are the first machines through the block, before the skidders, and need to balance the usual concerns of harvesting with consideration for badger burrows. Protecting badger burrows required feller-buncher operators to identify and enforce pre-marked MFZs by high-stubbing trees around the boundary, as well as searching for unmarked burrows. In general, interviewees felt that respecting pre-marked MFZs was relatively straightforward and easy, if somewhat slower than normal unconstrained harvesting.

Complying with pre-marked machine free zones did present some operational challenges. In areas with large numbers of burrows, operators of both feller-bunchers and skidders said they were forced to change their usual pattern of movement through the block to comply with the MFZs. According the operators, avoiding MFZs meant that the machine traffic was often concentrated in narrow corridors between the ribbon boundaries. The feller-bunchers were also forced to turn more often in order to extract the wood and place it in a way that would be accessible to the skidder operators. Interviewees felt that these constraints to movement created more soil disturbance in these areas. We had marked MFZs around burrows using blue-and-white striped flagging tape, stamped “MACHINE FREE ZONE”. Several interviewees felt this flagging tape was not very visible and suggested that a brighter colour would help operators identify burrows and MFZs more quickly. We asked all interviewees if they remembered anything about the eight violations that occurred, and the two serious violations in particular, but our interviews were conducted several months after harvesting was completed and interviewees were not sure of exact details. Operators did remember that they had found some of the ribboning confusing in the area around the violations, and they felt that this was the most likely explanation for why certain MFZs were not fully respected.

Searching for unmarked burrows was more difficult for both feller-buncher and skidder operators. The view from inside the cab of their machines did not allow operators to see much of the ground directly ahead of them. Machine operators said that they tried to compensate for this restricted view by walking through each area at the beginning of each shift, but the timber was sparse and they usually covered more ground each day than could be easily walked. Machine operators also found that the view of burrows on the ground was quickly obscured by timber that was already cut and by small diameter trees that were knocked down as part of harvesting. The requirements of on-site whole log chipping meant that two shifts were run each day, and operators worked in darkness in the early morning and in the evenings to ensure a steady supply of logs for the chipper. In anything less than full daylight, operators said that burrows were almost impossible to see unless their headlights happened to point directly into the entrance hole. Operators were instructed in pre-work sessions to avoid working in areas with high burrow densities in the dark, but this advice was only meaningful for mapped burrows.

Working with the sensitive soils found in the block presented additional constraints. Machine operators expressed that they would usually prefer not to work in the dark, but in order to reduce compaction around landing sites – while still providing wood for the chipper – it was necessary to run two shifts instead of decking wood around landings. Interviewees also felt that the concentration of machine traffic into narrow corridors between machine free zones may have contributed to a higher level of soil disturbance than usual.

4.5.5 How can we do a better job?

All of the interview respondents gave suggestions for improving future ecosystem restoration projects in badger habitat. These suggestions ranged from practical ideas on how to make it easier to comply with machine free zones to thoughts on how to create better processes. Key suggestions that emerged from the interviews are presented in Table 5.

Table 5. Suggestions for improvement from key informants

1. **Document the process, results, problems & improvements:**

- It took time to build trust and understanding between players
- Important to record and share the process and results in order to build a strong knowledge base for adaptive management
- The freedom to make some mistakes is necessary for learning

2. **Make Machine Free Zones more easily visible:**

- Use brighter, more visible ribbon colour to reduce confusion
- Use stakes to hang ribbon in areas with few trees

3. **Create interpretive signs/outreach programs about the project:**

- High-stubbed trees left around the burrows may appear wasteful
- This is an opportunity to share knowledge and educate the public about badgers and about forestry practices
- This is a project that the operators can be proud of

4. **Involve machine operators/logging contractors in the MFZ layout:**

- Operators have intimate knowledge of their abilities and constraints
- Working together with biologists to ribbon MFZs would be more efficient and effective

5. **Support the capacity of operators to find and protect burrows:**

- Spend more time walking and looking at burrows with operators, especially during harvesting
- Provide more feedback during and after harvesting, so operators know whether they are doing a good job
- Communicate any areas with high densities of burrows so operators can avoid working in these areas at night or in low light

5: DISCUSSION

5.1 Machine Free Zones can effectively protect burrows

We hypothesized that five to seven metre radius machine free zones could effectively protect badger burrows from damage during commercial harvesting. Our results support this hypothesis: overall, we found that very few badger burrows within machine free zones were damaged during logging. Only six of the 258 burrows (2.3%) within the 85 pre-marked MFZs were noticeably disturbed. The disturbance to most of these burrows was not irreparable: five of the six disturbed burrows had fine logging debris either partially or fully plugging the burrow entrance. We removed this debris, which consisted mainly of branches and bark, during our post-harvest surveys, and it seems reasonable that the average badger would also be able to remove it. Badgers are strong diggers, and are known to drag objects such as wooden blocks and rocks into the entrances of ground squirrel burrows when hunting (Michener 2004). Only one of the six disturbed burrows was crushed due to a violation of the MFZ boundary, which was probably related to confusing ribboning. Larger zones around burrows potentially could have prevented any disturbance to burrows, however this would have likely resulted in sections of the block being dropped from the treatment unit for economic reasons: seven metres is the longest distance that a feller-buncher can reach into a machine free zone to extract trees.

We were not able to assess the subterranean condition of burrows after harvesting, although we did survey the ground around entrances for evidence of possible collapsed tunnels or other damage. Tunnels could theoretically extend further from the entrance than seven metres, and underground collapses might not be visible from the surface. Even if machine tracks do not directly disturb tunnels, it is possible that the vibrations from the machine could collapse the underground structure. We could not find any practical way to assess this type of damage in the field.

5.2 Educated machine operators can protect more burrows

Machine operators were able to learn to find unmarked burrows, and they successfully protected 63 burrows in operator implemented MFZs (OIMFZs). Operators even found additional burrows in areas that had been extensively surveyed before harvesting. Two lessons are apparent from this: first, that with proper training and motivation, machine operators are able to do a very good job of locating burrows during harvesting and second, that in areas with a high density of burrows, it may be practicably impossible to find every burrow – either in pre-harvest surveys or during harvesting. Although operators found and protected such a large number of burrows, they did not find them all: only 24% of the unmarked test burrow-complexes were successfully found. Operators are constrained by the competing goals of efficiently getting wood out while protecting burrows, and by the limitations of their equipment. We consider that it would be unreasonable to expect machine operators to be able to find more burrows than they did.

Only four of the unmarked test burrow-complexes had recent visible use by badgers, but operators successfully found half of those complexes. This suggests that operators are more successful at locating recent burrows than older burrows. Burrows with recent signs of use are likely to be more visible to operators due to larger mounds with exposed mineral soil, and operators mentioned in interviews that the fresher burrows were easier to see. If this is the case, we would expect that the burrows successfully found by operators and protected in operator implemented MFZs (OIMFZs) would have proportionally more recent and fresh burrows. The distribution of fresh, recent, and old burrows within OIMFZs is similar to the distribution of burrow ages we found in our pre-harvest surveys (Table 4) however this likely reflects that fact that recent burrows were also easier to find during our pre-harvest surveys.

The training given to operators for this project extended beyond the job site. Machine operators shared the knowledge they learned about badgers and badger conservation with their family and friends, and seemed genuinely excited to learn more. In this way, the pre-work training functions as a type of extension to support conservation (Sutherland and Leech 2007). The people who carry out management actions on the ground are integral to the success or failure or the management strategy: the best-laid plan on paper will fail if it is not carried out correctly. Improving management for conservation values requires that we engage all of the actors within the management system, including those at the operational level (Lertzman 2009). Engaging machine operators in the assessment of the success of the project was also critical. The people who actually run the machines have an intimate knowledge of their abilities and operational constraints, and this perspective is essential for developing strategies that are operationally – and economically – feasible and efficient. One operator commented that he was excited to take part in the post-harvest interviews because he wanted to know how well he did at finding the unmarked test burrows; logging contractors usually only get feedback about their work if they do something wrong.

5.3 Are all burrows equally important to protect?

Badgers are known to reuse older burrows regularly (Newhouse and Kinley 2001, Lindzey 1978). Badgers expend more than three times more energy digging than they do at rest (Lampe 1976), and reusing burrows may represent significant energetic savings. Badgers also may encounter potential prey in older burrows and tunnels, and they regularly investigate existing burrows, especially at the edges of their home range (Messick and Hornocker 1981, Lindzey 1978). Burrows are important habitat features for other species (Michener 2000, Green and Anthony 1989), and contribute to landscape heterogeneity (Eldridge 2004). Burrow systems in other fossorial mammals are known to persist as landscape features over several decades as a result of continued use (Whitford and Kay 1999).

For this project, we assumed that burrows of all ages were important to badgers, and we tried to protect as many burrows as possible. This conservative approach meant that very old burrows with many years worth of natural litter and debris plugging the entrance were given the same level of protection as burrows used within the past several years. It is impossible to tell the subterranean condition of these burrows, but many of these older entrances had narrowed and collapsed over time. There is no standard system for classifying the age of badger burrows, and previous studies that refer to burrow reuse appear to classify any burrow that was dug prior to the time of use as an “old” burrow (Newhouse and Kinley 2001, Messick and Hornocker 1981, Lindzey 1978). These studies have typically only included burrows that were actually used by badgers during the study. There may exist a threshold point at which an old burrow is significantly decayed and is therefore no longer useful to badgers, but these very old burrows would not be found in radio-telemetry studies of burrow use.

It is not clear how significant the energetic costs of digging new burrows are to badger populations in British Columbia. Badgers are physiologically well adapted to deal with food shortages (Harlow 1981), and reports of malnourished badgers are rare in British Columbia (Hoodicoff 2006a, Newhouse and Kinley 2001, Weir et al. 2003). In the summer months, a badger may dig a new burrow every day (Sargeant and Warner 1972), and badgers are known to displace more than 180 litres of soil at predation sites (Lampe 1976). Other authors have suggested that the energetic cost of excavating and maintaining a shallow burrow system is probably not high compared to the other metabolic costs for a mammal (Reichman and Smith 1990). The condition of the soil for digging may be a more important factor than the presence of pre-existing burrows: the distribution of badger burrows is strongly linked to the presence of certain soil types (Apps et al. 2001), and the availability of suitable soils for digging is identified as a key habitat requirement for badgers (Adams and Kinley 2004, Rahme et al. 1995).

In our area, badgers range over large areas: the average home range in the East Kootenay is estimated as 35 km^2 for females and 301 km^2 for males using 100% minimum convex polygon methods (Kinley and Newhouse 2008). Given the high density of burrows on the site relative to the somewhat low estimated use of the area by badgers (Kinley and Page 2008) and the large average home range size, it is unlikely that the current badger population is utilizing every existing burrow. This may mean that damage to certain burrows would not necessarily negatively impact badgers, especially if the damage to existing burrows does not affect the ability of badgers and their prey to dig new burrows at the site. We do not have nearly enough information to determine which burrows are more or less important, or the effects of damaging existing burrows on badgers.

5.4 Ecosystem restoration in badger habitat

Habitat loss related to forest encroachment and ingrowth is identified as a threat to badger populations in British Columbia (Weir and Almuedo 2010, *jeffersonii* Badger Recovery Team 2008, Adams and Kinley 2004). While badgers use a diversity of habitats across their range in BC, they are mainly found in grasslands, open forests, and rangelands (Adams and Kinley 2004, Hoodicoff 2003, Apps et al. 2002, Rahme et al. 1995). In the East Kootenay, badgers were negatively associated with forested habitats and forest cover, and positively associated with open range (Apps et al. 2002). Predicted suitable habitat for badgers in the East Kootenay is largely coincident with highways and developed private lands and is minimally represented in protected areas (Apps et al. 2002). As a result, most opportunities for conserving and improving badger habitat are on public rangelands managed for timber and grazing. In addition to habitat loss related to human use and development, over 160,000 hectares of land in the Kootenay region is estimated to be affected by forest ingrowth and encroachment (Kirby and Campbell 1999, cited in *jeffersonii* Badger Recovery Team 2008), and an additional 1500 to 3000 ha of open forest and grassland is estimated to be lost annually (Rocky Mountain Trench ER Steering Committee 2006).

Ecosystem restoration to reduce forest ingrowth and encroachment is likely to improve habitat for badgers. The recovery strategy for badgers in British Columbia recommends increasing grassland and open forest restoration to meet recovery objectives for the species (*jeffersonii* Badger Recovery Team 2008). Mechanical thinning and prescribed burning for ecosystem restoration is also expected to encourage colonization by early-successional prey species such as

Columbian ground squirrels (Hoodicoff 2005), and the preferred diet of these prey species overlaps with the type of forage that the restoration program is attempting to improve (Hoodicoff 2006a, Rocky Mountain Trench ER Steering Committee 2006). Dense, ingrown forests may also be at risk for uncharacteristically severe wildfires (Allen et al. 2002), which could negatively affect habitat for badgers or for their prey. Reducing the fuel load through thinning and prescribed burning can also reduce the risk of high intensity wildfire (Agee and Skinner 2005). The ecosystem restoration program in the Rocky Mountain trench has been operating since the late 1990s, and some monitoring results show increases in forage production following harvesting and harvest/burn treatments (Ross 2000, Ross 2009), however other sites monitored in the first years following treatment have not achieved some of the intended goals (Page et al. 2005).

Ecosystem restoration is not without controversy, and research from other areas of southern British Columbia suggests that restoration programs based on the premise of a widespread low-severity fire regime are not supported by historical climate and fire records (Klenner et al. 2008). Few fire history studies have been undertaken in the Rocky Mountain trench, but all have found fire return intervals ranging from 14 to 19 years consistent with a mainly low-severity fire regime (Gray et al. 2004, Wong et al. 2003). Klenner et al. (2008) identify the complex, incised topography of the Kamloops Forest District as a key factor limiting the spread of low-severity fires in that area, and recommend that ecosystem restoration not be used as a blanket treatment to create a homogenous landscape based on what is assumed to be a historical reference condition. In contrast, the Rocky Mountain trench (the location of this study) is a broad and wide valley, with relatively gentle topography surrounded by montane forests, and the area of the Rocky Mountain trench proposed for ecosystem restoration is small relative to the entire East Kootenay region. Researchers studying the mixed-severity fire regimes in the montane spruce biogeoclimatic zone at higher elevations in the East Kootenay region have found many sites where the current time since last fire is well outside the historic range of variability for the site, suggesting that wildfire suppression is also noticeably affecting the condition of forests outside of the dry open forests of the Rocky Mountain trench (Daniels et al. 2007).

In our research, ecological goals were balanced with the need for the project to be economically feasible. Commercial harvesting using large machinery allowed the block to be economically viable but created a risk of damage to badger burrows. Obviously, damaging or destroying existing badger burrows is not compatible with ecosystem restoration goals. But there is also a danger in taking an overly conservative approach: restoration treatments that rely on the economic subsidy of commercial logging may be compromised by unnecessarily large machine free zones around every burrow, or by not treating areas at all. Areas that remain untreated will not remain in a static condition; the process of forest encroachment and ingrowth is on-going (Rocky Mountain

Trench Ecosystem Restoration Steering Committee 2006) and unless the process is abated, habitat for badgers will continue to decline.

The ecosystem restoration program in the Rocky Mountain Trench is currently funded through a diverse multi-stakeholder partnership, but current funding levels are not sufficient to treat all of the priority areas given the cost estimates for treatment (Rocky Mountain Trench ER Steering Committee 2010). Our results show that implementing machine free zones around burrows and educating machine operators to identify and protect burrows can allow commercial logging operations to achieve restoration objectives with minimal damage to existing badger burrows. The larger question is whether we as a society require ecosystem restoration projects such as this one to be economically self-sufficient.

The true success of restoration work in badger habitat must be measured with the response of the badgers themselves. Our research is built on the assumption that existing badger burrows are an important habitat resource for badgers, and that protecting the physical structure of burrows will maintain the quality of the resource for badgers. We have no measures of actual use by badgers, although we did observe evidence of fresh badger use at the site within a week after harvesting. Fortunately, an effectiveness monitoring program has already been developed to measure the functioning of badger Wildlife Habitat Areas (Kinley 2009, Newhouse et al. 2007, Hoodicoff 2006b). The WHA in our study was assessed for functionality as badger habitat in 2008 (Kinley and Page

2008), and this data should be used as a baseline to assess the short- and long-term effects of this restoration treatment on use of the wildlife habitat area by badgers. The range of data available for our study site from both this research and pre-existing studies makes it a particularly good candidate for establishing a long-term effectiveness monitoring program for both ecosystem restoration and badger habitat use.

6: RECOMMENDATIONS

6.1 Protect burrows using pre-marked machine free zones

We found that five to seven metre radius machine free zones protected most badger burrows from damage. Only 1.5% of burrows within pre-marked machine free zones with perfect compliance showed evidence of disturbance, and that disturbance was limited to fine logging debris in the entrance of the burrow. The exact size of the buffer around a given burrow should vary depending on the terrain, the arrangement of burrows, and the density of trees: in more open areas, larger buffers can be left without leaving too many trees out of reach of the feller-buncher. Larger machine free zones around burrows also protect the soils and grass communities within the zone from machine damage. To prevent disturbance to badgers much larger machine free zones (minimum 20 metres or one tree length radius) should still be used around maternal burrows and freshly dug dens.

Compliance with pre-marked machine free zones was high (90%), but there were some violations. Some operators found the flagging around machine free zones in some areas to be confusing, and difficult to see. We recommend using a brighter colour of flagging tape for machine free zones to increase the visibility to operators. In areas with a high density of MFZs and/or burrows, harvesting should be restricted to daylight hours to increase the visibility of burrows, and the area to be harvested should be surveyed on foot before the beginning of each shift. We provided machine operators with an overview map of known burrow locations to assist in identifying areas of concern. Involving operators in the layout of MFZs in complex terrain could also cut down on confusion and encourage a higher rate of compliance.

6.2 Educate and engage machine operators

Operators found and protected 63 burrows that had not been found in pre-harvest surveys, and many of these were in intensively surveyed sections of the block. The pre-work training provided operators with a strong base of knowledge, and they learned quickly. The special skills required by operators to successfully protect burrows took time to develop. For future projects, preference should be given to logging contractors that have experience working in badger habitat and have displayed a high level of competence.

The capacity of operators to protect burrows should be developed further. Biologists could spend more time walking and looking at burrows with operators, especially during harvesting. This would allow for greater interaction between the separate processes of flagging and implementing MFZs, and would provide feedback to operators to speed up the learning process. The knowledge that there are unmarked test burrows may also provide an incentive for operators to watch more carefully for burrows.

6.3 Prioritize areas of high badger use

For large treatment areas, pre-marking every existing badger burrow may not be feasible due to the time required for extensive burrow surveys. We suggest that preference should be given to establishing machine free zones in areas with a higher frequency of potential use by badgers. Indicators of use could include evidence of fresh badger diggings, presence of scats, tracks or fur, or a high density of either badger or ground squirrel burrows (RISC 2007, Hoodicoff 2006b). This quick and dirty approach should not be used to estimate the rate of actual use by badgers, but can help to prioritize critical areas when time is limited.

Involving machine operators in the layout of machine free zones may also increase efficiency. Biologists may not have a strong understanding of the challenges faced by machinery moving through the block. In areas of complex terrain, time could be saved both before and during harvest by biologists pre-marking burrows with only a single ribbon or stake; operators and biologists could then walk the site together before road-building and harvesting to adjust the final MFZ boundary. Spending more time walking the block and looking at burrows with biologists during harvesting will also help operators learn how to identify burrows more quickly, and will increase their efficiency at protecting unmarked burrows.

6.4 Future projects and long term monitoring

A large portion of the time required for this project was spent surveying burrows after harvesting was complete. We photographed each burrow before and after harvesting and painstakingly matched up photographs and GPS locations in order to accurately assess the effects of harvesting on individual burrows. For future harvesting operations in badger habitat, we suggest that extensively surveying and photographing every machine free zone to assess damage to burrows is unnecessary. Disturbed burrows were rare, and were obvious even without pre-harvest photos for comparison. Burrows that were not identified in pre-harvest surveys will be even more difficult to locate after harvesting, unless they were found and protected by operators. After harvesting, slash and other logging debris obscures any evidence of burrows that might have been missed.

Compliance with pre-marked machine free zones was much faster to assess post-harvest than individual burrow condition: there were fewer MFZs than burrows, and the presence of high-stubs and ribbon was easy to check. Almost all (99.5%) of burrows in MFZs with perfect compliance were undamaged by harvesting. The rate of compliance with pre-marked MFZs was almost 90%, and the few violations resulted in very little damage to burrows. For future treatments, spot checks of compliance with MFZs and of burrow condition – both during and after harvesting – could provide a quick and easy way to measure the success of burrow protection measures.

Due to the large amount of existing data, our study site is an ideal choice for continued research. A long-term monitoring program should be established for the site, expanding on the existing WHA effectiveness monitoring program. We were only able to assess the short-term effects of harvesting on the physical structure of burrows; future monitoring should assess the frequency of use of burrows by badgers. The site should also be surveyed before and after prescribed burning occurs to assess any damage to burrows.

LITERATURE CITED

Adams, I.T., and T.A. Kinley. 2004. Badger (*Taxidea taxus jeffersonii*). In Accounts and measures for managing identified wildlife: Accounts V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, B.C. www.env.gov.bc/wld/frpa/iwms/documents/Mammals/m_badger.pdf (Accessed October 2010).

Agee, J.K., and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211:83-96 DOI:10.1016/j.foreco.2005.01.034

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications 12(5):1418-1433.

Apps, C.D., N.J. Newhouse, T.A. Kinley. 2002. Habitat associations of American badgers in southeastern British Columbia. Canadian Journal of Zoology 80: 1228-1239. DOI: 10.1139/Z02-119

Arno, S.F. and G.E. Gruell. 1986. Douglas-fir encroachment into mountain grasslands in southwestern Montana. Journal of Range Management 39(3):272-276.

B.C. Conservation Data Centre. 2011. Conservation Status Report: *Taxidea taxus*. B.C. Ministry of Environment. www.a100.gov.bc.ca/pub/eswp (accessed January 2011).

B.C. Ministry of Water, Land and Air Protection. 2004. Procedures for Managing Identified Wildlife – V. 2004. B.C. Ministry of Water, Land and Air Protection, Victoria, B.C. www.env.gov.bc.ca/wld/frpa/iwms/procedures.html (accessed January 2011).

Cooper, J.M., C. Steeger, S.M. Beauchesne, M. Machmer, L. Atwood, and E.T. Manning. 2004. Habitat attribute targets for red and blue listed species and plant community conservation. Prepared for the Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C. 95 pp.

COSEWIC. 2010. Canadian wildlife species at risk. Committee on the Status of Endangered Wildlife in Canada. www.cosewic.gc.ca/eng/sct0/rpt/rpt_casr_e.cfm (Accessed October 2010).

Cotterill, S.E. 1997. Status of the swift fox (*Vulpes velox*) in Alberta. Alberta Environmental Protection, Wildlife Management Division, Wildlife Status Report No. 7. Edmonton, AB. 17 pp.

Daniels, L.D., J. Cochrane, and R.W. Gray. 2007. Mixed-severity fire regimes: regional analysis of the impacts of climate on fire frequency in the Rocky Mountain Forest District. Report prepared for Tembec, Inc., BC Division; Canadian Forest Products, Radium Hot Springs; and the Forest Investment Account of British Columbia. 36 pp.

Davidson, A.D. and D.C. Lightfoot. 2008. Burrowing rodents increase landscape heterogeneity in a desert grassland. Journal of Arid Environments 72:1133-1145. DOI:10.1016/j.jaridenv.2007.12.015

Dixon, K., and K. Stuart-Smith. 2009. Effectiveness monitoring of badger den protection in CP 001-001 Airport Pasture. Tembec Industries, Ltd. *Unpublished report*. 14 pp.

Eldridge, D.J. 2004. Mounds of the American badger (*Taxidea taxus*): significant features of North American shrub-steppe ecosystems. Journal of Mammalogy 85(6): 1060-1067.

Eldridge, D.J., and W.G. Whitford. 2009. Badger (*Taxidea taxus*) disturbances increase soil heterogeneity in a degraded shrub-steppe ecosystem. Journal of Arid Environments 73: 66-73.

Gray, R.W., E. Riccius, and C. Wong. 2004. Comparison of current and historical stand structure in two interior Douglas-fir sites in the Rocky Mountain Trench, British Columbia, Canada. Tall Timbers Fire Ecology Conference Proceedings 22:23-35.

Green, G.A., and R.G. Anthony. 1989. Nesting success and habitat relationships of burrowing owls in the Columbia Basin, Oregon. The Condor 91(2):347-354.

Hansell, M.H. 1993. The ecological impact of animal nests and burrows. Functional Ecology 7(1):5-12.

Hansen, K., W. Wyckoff, and J. Banfield. 1995. Shifting forests: historical grazing and forest invasion in southwestern Montana. Forest Conservation and History 39:66-76.

Harlow, H.J. 1981. Torpor and other physiological adaptations of the badger (*Taxidea taxus*) to cold environments. Physiological Zoology 54(3):267-275.

Harris, B. 2001. Observations on the use of stubs by wild birds: A 10-year update. BC Journal of Ecosystems and Management 1(1):19–23.

Harris, R.J. 2010. Rocky Mountain Trench ecosystem restoration project NDT4 five year plan: 2010-2015. Rocky Mountain Forest District, B.C. Ministry of Forests and Range, Cranbrook, B.C. 127 pp.

Heyerdahl, E.K., R.F. Miller, and R.A. Parsons. 2006. History of fire and Douglas-fir establishment in a savanna and sagebrush-grassland mosaic, southwestern Montana, USA. Forest Ecology and Management 230:107-118. DOI:10.1016/j.foreco.2006.04.024

Hoodicoff, C.S. 2003. Ecology of the badger (*Taxidea taxus jeffersonii*) in the Thompson region of British Columbia: implications for conservation. M.Sc. Thesis, University of Victoria. 114 pp.

Hoodicoff, C.S. 2005. Badger recovery science: best management practices for prey enhancement. Prepared for B.C. Ministry of Water, Land and Air Protection, 100 Mile House, B.C. www.badgers.bc.ca/pubs/Hoodicoff_2005_BMP_prey_enhancement.pdf (Accessed December 2010).

Hoodicoff, C.S. 2006a. Badger prey ecology: the ecology of six small mammals found in British Columbia. B.C. Ministry of Environment, Victoria, B.C. Wildlife Working Report WR-109. 31 pp.

Hoodicoff, C.S. 2006b. Questions and indicators for evaluating the effectiveness of badger wildlife habitat areas. Prepared for B.C. Ministry of Forests, Victoria, B.C. 33 pp.

Jeffersonii Badger Recovery Team. 2008. Recovery strategy for the badger (Taxidea taxus) in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, B.C. 45 pp.

Jones, C.G., J.H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69:373-386.

Kinley, T.A. 2009. Effectiveness monitoring of badger Wildlife Habitat Areas: summary of current areas and recommendations for developing and applying protocols. Prepared for Forest and Range Evaluation Program – Wildlife Resource Value, B.C. Ministry of Environment and B.C. Ministry of Forests and Range, Victoria, B.C. 21 pp.

Kinley, T.A. and H. Page. 2008. Effectiveness evaluations for the Lost Dog South, North Kikomun Creek, Sheep Creek, South McGinty Lake, Ta Ta Creek Airport North and West Yahk River badger Wildlife Habitat Areas in 2007. Prepared for Forest and Range Evaluation Program – Wildlife Resource Value, B.C. Ministry of Environment and B.C. Ministry of Forests and Range, Victoria, B.C. 53 pp.

Kinley, T.A. and N.J. Newhouse. 2008. Ecology and translocation-aided recovery of an endangered badger population. Journal of Wildlife Management 72(1):113-122. DOI: 10.2193/2006-406

Kirby, J. and D. Campbell. 1999. Forest in-growth and encroachment: a provincial overview from a range management perspective. B.C. Ministry of Forests, Forest Practices Branch, Victoria, B.C. *Unpublished report.*

Klenner, W., R. Walton, A. Arsenault, and L. Kremsater. 2008. Dry forests in the southern interior of British Columbia: historic disturbances and implications for restoration and management. Forest Ecology and Management 256:1711-1722. DOI:10.1016/j.foreco.2008.02.047

Lampe, R.P. 1976. Aspects of the predatory strategy of the North American Badger (*Taxidea taxus*). Ph.D. thesis. University of Minnesota, St. Paul, MN.

Lertzman, K. 2009. The paradigm of management, management systems, and resource stewardship. Journal of Ethnobiology 29(2):339-358. DOI: 10.2993/0278-0771-29.2.339

Lindzey, F.G. 1976. Characteristics of the natal den of the badger. Northwest Science 50(3):178-180.

Lindzey, F.G. 1978. Movement patterns of badgers in northwestern Utah. Journal of Wildlife Management 42(2):418-422.

Long, C.A. 1973. *Taxidea taxus*. Mammalian Species 26:1-4.

Mast, J.N., T.T. Veblen, and M.E. Hodgson. 1997. Tree invasion within a pine/grassland ecotone: an approach with historical aerial photography and GIS modeling. Forest Ecology and Management 93:181-194.

McDonald, J.H. 2009. Handbook of Biological Statistics (2nd ed.). Sparky House Publishing, Baltimore, Maryland. pp. 308-313.

Messick, J.P., and M.G. Hornocker. 1981. Ecology of the badger in southwestern Idaho. Wildlife Monographs 76:3-53.

Michener, G.R. 2000. Caching of Richardson's ground squirrels by North American badgers. Journal of Mammalogy 81(4):1106-1117.

Michener, G.R. 2004. Hunting techniques and tool use by North American badgers preying on Richardson's ground squirrels. Journal of Mammalogy 85(5):1019-1027.

Miller, R.F., and J.A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management 52(6):550-559.

Murie, J.O. 1992. Predation by badgers on Columbian ground squirrels. Journal of Mammalogy 73:385-394.

Newhouse, N.J. and T.A. Kinley. 2001. Ecology of badgers near a range limit in British Columbia. Prepared for Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C. and Parks Canada, Radium Hot Springs, B.C. 20 pp.

Newhouse, N.J., T.A. Kinley, C. Hoodicoff, and H. Page. 2007. Protocol for monitoring the effectiveness of badger wildlife habitat areas. Prepared for Ministry of Forests and Range, Victoria, B.C. 35 pp.

Page, H.N., E.W. Bork, and R.F. Newman. 2005. Understorey responses to mechanical restoration and drought within montane forests of British Columbia. BC Journal of Ecosystems and Management 6(1):8-21. www.forrex.org/jem/2005/vol6/no1/vol6_no1_art2.pdf (Accessed March 2011).

Platt, W.J. 1975. The colonization and formation of equilibrium plant species associations on badger disturbances in a tall-grass prairie. Ecological Monographs 45(3):285-305.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Rahme, A.H., A.S. Harestad, and F.L. Bunnell. 1995. Status of the badger in British Columbia. Ministry of Environment, Lands, and Parks, Victoria, B.C. Wildlife Working Report No. WR-72. 51 pp.

Reichman, O.J., and S.C. Smith. 1990. Burrows and burrowing behavior by mammals. Chapter 5, in H.H. Genoways, ed. Current Mammalogy. Plenum Press, New York and London. p. 369-416.

Resources Inventory Standards Committee. 2007. Inventory methods for medium-sized territorial carnivores: badger. Standards for Components of British Columbia's Biodiversity No. 25a. Ministry of Environment Victoria, B.C. 55 pp. www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/medcarn/ Badger.pdf (Accessed October 2010).

Rocky Mountain Trench Ecosystem Restoration Steering Committee. 2006. Blueprint for action 2006: principles, strategy, progress. Rocky Mountain Trench Ecosystem Restoration Program, Cranbrook, B.C. 28 pp.

Rocky Mountain Trench Ecosystem Restoration Steering Committee. 2010. Blueprint for action update 2006-2009: a supplement to the *Blueprint for action 2006.* Rocky Mountain Trench Ecosystem Restoration Program, Cranbrook, B.C. 4 pp.

Ross, T.J. 2000. Plant community response following dry forest ecosystem restoration. Rocky Mountain Trench Natural Resources Society, Kimberley, B.C. Science Council of BC. 89 pp.

Ross, T.J. 2009. Waldo North grassland restoration pilot project monitoring program. Rocky Mountain Trench Natural Resources Society, Kimberley, B.C. 89 pp.

Scobie, D. 2002. Status of the American Badger (*Taxidea taxus*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 43, Edmonton, AB. 17 pp.

Sargeant, A.B., and D.W. Warner. 1972. Movements and denning habits of a badger. Journal of Mammalogy 53:207-210.

Strang, R.M. and J.V. Parminter. 1980. Conifer encroachment on the Chilcotin grasslands of British Columbia. The Forestry Chronicle 56(1):13-18.

Sutherland, K.A., and S.M. Leech. 2007. Increasing the effectiveness of conservation in British Columbia through the use of extension. In Proceedings of the “Monitoring the Effectiveness of Biological Conservation” conference, 2-4 November 2004, Richmond, B.C. www.forrex.org/events/mebc/papers.html (Accessed December 2010).

Turner, J.S. and P.G. Krannitz. 2001. Conifer density increases in semi-desert habitats of British Columbia in the absence of fire. Northwest Science 75(2):176-182.

Weir, R. D., Davis, H., and Hoodicoff, C.S. 2003. Conservation strategies for Badgers in the Thompson and Okanagan regions: Final Report, March 2003. Habitat Conservervation Trust Fund, Artemis Wildlife Consultants, Armstrong, BC.

Weir, R.D., and P.L. Almuedo. 2010. British Columbia’s southern interior: badger wildlife habitat decision aid. B.C. Journal of Ecosystems and Management 10(3):9-13. www.forrex.org/publications/jem/ISS52/ vol10_no3_art2.pdf. (Accessed November 2010).

Wellicome, T.I. 1997. Status of the burrowing owl (*Speotyto cunicularia hypugaea*) in Alberta. Alberta Environmental Protection, Wildlife Management Division, Wildlife Status Report No. 11, Edmonton, AB. 21 pp.

Whitford, W.G., and F.R. Kay. 1999. Biopedturbation by mammals in deserts: a review. Journal of Arid Environments 41:203-230.

Wong, C., H. Sandmann, and B. Dorner. 2003. Historical variability of natural disturbances in British Columbia: a literature review. FORREX – Forest Research Extension Partnership, Kamloops, B.C. FORREX Series 12 www.forrex.org/publications/forrexseries/fs12.pdf. (Accessed March 2011).

APPENDICES

Appendix A: Terms of the WHA Exemption

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EXEMPTION OBLIGATION TO COMPLY WITH GENERAL WILDLIFE MEASURES ASSOCIATED WITH BADGER WILDLIFE HABITAT AREAS #4-088 AND #4-090 (ROCKY MOUNTAIN FOREST DISTRICT)

This exemption is given under the authority of sections 92(1) (b) of the *Forest Planning and Practices Regulation* (B.C. Reg. 14/2004).

The Regional Manager, Kootenay Region, Environmental Stewardship Division, Ministry of Environment, orders that:

"Tembec Ltd." is hereby exempted from the obligation to comply with the two following general wildlife measures (GWM) for WHAs 4-088 and 4-090, established on December 4, 2006, to allow for timber harvest, processing (debark and chip trees), hauling and road-building within portions of both WHAs that occur within the Non Replacement Forest License (NRFL) as shown on the attached map (NRFL A84742 Badger WHA Variance), subject to the following conditions.

Exempted General Wildlife Measures:

- Do not develop any new road access unless an exemption is provided by the delegated decision maker.
- No resource extraction or log hauling during the maternal period (1 May – 15 August).

Exemptions subject to the following conditions:

1). Use existing roads and trails to the fullest extent possible;

2). Locate new roads, skid trails and landings outside of the boundaries of the WHAs as much as practicable;

3). Cease construction activities during wet site conditions in order to minimize the risk of increased soil compaction;

4). All landings and new roads will be deactivated and de-compacted by ripping, and seeded with a suitable seed mix determined in consultation with the MOE biologist (in order to reduce the risk of road mortality of badger, to prevent the establishment or spread of invasive plant species, and to hasten restoration of these sites to suitable habitat conditions for badger and their small mammal prey);

5). Deactivation and decompaction of roads will be conducted to a level that will result in no net increase (+/- 0.5%) in the amount of existing roads within the WHAs over pre-harvest levels. Within each WHA, Tembec has estimated this pre-harvest level as 4.5% to 5.0%, and that an additional 1% of each WHA area is required for roads. A map must be provided by Tembec showing the locations of existing roads and trails that are to be used (i.e., the 4.5% to 5.0%) and of new roads and trails to be constructed within each WHA, prior to commencement of road building and upgrading within a WHA;

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6). To reduce the risk of road mortality of badger, during the sensitive maternal period of 1 May to 15 August ensure slower than usual vehicle speeds, and instruction to, along with a consideration of erecting associated road signage, all equipment and vehicle operators to be alert to the possibility of adult and juvenile badger presence;
7). All road, trail and landing building and/or upgrading, as well as harvest, debarking, chipping, and hauling will be conducted outside of this sensitive time period as much as practicable, and any work conducted within WHAs during this sensitive time period should avoid as much as practicable the especially sensitive portion of this period for female with young kits of 1 May to 15 June;
8). Protect and do not render ineffective important badger habitat, to include old and new badger burrows, either of which may serve as maternal dens for females and kits. This could be achieved in principle by implementing the mitigation measures outlined in the attached GWM exemption request form which include measures to protect existing badger habitat (burrows and soil conditions) by such actions as (but not limited to):

- pre-construction and harvest surveys to identify burrow locations and their protection by marked Wildlife Tree Patches or No Machine Zones;
- instructions to harvest and skidder operators;
- on-going monitoring during forestry operations for any new badger occurrences or burrows inadvertently missed in pre-work surveys; and,
- qualified biology personnel to monitor adherence to these measures.

9). Since the current plan is to conduct these forestry operations in WHA 4-088 in 2010 and in WHA 4-090 in 2011, prior to harvesting and chip processing and hauling operations commencing in WHA 4-090, Tembec and MOE will meet to review performance of planning and operational mitigation measures, as outlined in Tembec's exemption application and/or in these conditions, to jointly develop corrective measures and adjustments if required to ensure effective protection of badger and current badger habitat conditions.

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Signed this 18 day of Dec, 2009
Greg Chin, A/Regional Manager
Environmental Stewardship Division
Kootenay Region
Ministry of Environment

Appendix B: Pre-work Training & Information Handout

China North Badger and Snag Pre-Work Information For Logging and Skidding Crews

Kari Stuart-Smith, Forest Scientist, Tembec Industries
April 22, 2010

The China North/Lost Springs NRFL contains many badger dens and a Wildlife Habitat Area (WHA) established for the badger.

Much of the block has been walked and badger burrows identified and GPSed. Both old and new burrows have been flagged with Machine Free Zone (MFZ) of roughly 5-7 m diameter. A map of the burrows is being given to you.

The NMZ is mainly to protect the burrow from collapse by heavy machinery. You may cut the trees within the NMZ by reaching in with the buncher unless the burrow is within roughly 1 m of the tree or you think the tree is important in supporting the burrow – in this case keep the tree closest to the burrow. Fall outside the NMZ. On no occasion is a machine to enter a marked NMZ.

Trees on the boundary of the NMZ should be high-stubbed so that the burrows are not skidded over.

If you see any badger burrows that are not flagged or marked on your map, apply a visual NMZ and high stub around them. I could not cover every inch of the block so some burrows will have been missed. There are also lots of ground squirrel burrows in the area, these are smaller and rounder and do not need to be protected unless you see fresh diggings or actual ground squirrels on the den mounds. ***If in doubt, put a visual NMZ and high stub around it.***

If you see any dens with mounds of fresh dirt stop work in the area and inform your supervisor immediately. The supervisor is to contact the Tembec Supervisor who will contact Kari Stuart-Smith within 24 hours (preferably as soon as possible). Kari will come out and evaluate the den. If the Tembec Supervisor cannot be reached call Kari directly. These dens could have badgers inside them. A 20 m NMZ or WTP is required around dens with fresh excavations according to the terms of our exemption.

If you see a badger inform your crew supervisor immediately. The supervisor is to contact the Tembec Supervisor (Andy McCuaig) who will contact Kari Stuart-Smith immediately. If Andy is not available call Kari directly.

Watch for badgers and their kits (young) crossing roads. Travel more slowly than usual on the roads in this permit, including Millar Road, so you can stop quickly if you see a badger.

Snags – there are some Class 7 and 8 wildlife trees within the block. These are not ribboned. Reserve as many as you **safely** can, following Tembec's safe work procedure for wildlife trees Class 7 and 8. If they must be felled for safety reasons, high stub them and leave the log on the ground – do not bring the log into the landing pile. If you encounter a very high value snag of Class 3-6 (> 40 cm dbh, > 10 m tall, bird cavities, Py, Fd, or Lw) stop work in the vicinity and tell you supervisor, who will contact Tembec and get someone out ASAP to assess the snag and ribbon out a WTP if required.

Handouts: East Kootenay Badger Project brochure, Badger Burrow ID sheet, site plan map with burrows marked (April 22 2010 version), Tembec safe work procedure for Wildlife Trees.

Appendix C: Key Informant Interview Question Protocol

Semi-structured interview of key informants: the questions listed below will be used as a guide during each interview to ensure that all key topics are covered. Interviews will be recorded with informed consent of the participant (refer to Participant Information and Consent Sheet). Brief notes will be taken during the interview, and each recording will be reviewed as soon as possible after each interview to make a more detailed summary.

Questions/Script:

[Go over info sheet about the project. Give terms of confidentiality and allow any questions from participant. Discuss purpose of the interviews, format and timing. Ask whether the interview can be recorded.]

Do you have any questions before we begin?

Background and context:

[Start with review of the project and the block, go over the original map & handouts together]

What was your role? (e.g. feller buncher operator, skidder, etc)
What were your responsibilities? Were you supervising other workers?
What is your level of experience in this job? (ie how many years experience?)
Have you ever worked with this type of project before?
Were you aware of badgers and their burrows prior to the pre-work training?

Difficulty:

How difficult was it to comply with the pre-ribboned MFZs? What additional work did you need to do in order to comply with the MFZs (eg walk the area beforehand, daylight logging, other?)
You were asked to look for unmarked badger burrows during the course of normal operations, and to protect those burrows where you found them. Did this additional task make your job more stressful than usual? More interesting? Frustrating?
Was it easier or harder than complying with the pre-marked ribbons? How much easier/harder?
Did you feel that your ability to identify unmarked burrows and protect them improved over time? Was it easier to see/find burrows in certain areas of the block? Why?

Cost:

Can you estimate both the time and $$ cost of complying with the pre-ribboned MFZs you encountered? (percent above average for a similar block is fine)
What about the increased time/$$ of identifying and protecting unmarked burrows during operations?
During the pre-work training, we asked that operators avoid working in areas with a high density of burrows at night. Was this difficult to comply with?
Do you think that this requirement was necessary?
Do you think that it was easier to identify unmarked burrows during daylight hours? If you had been required to do all of the work (feller buncher and skid) for the block during daylight hours, can you estimate the cost (time or $)/difficulty of doing so?

Pre work training and information:

[Give overview/reminder of the pre-work training sessions that we did; will have copies of the brochures/maps/info sheet to remind the operators]
Did you find the pre-work information and training helpful for the work you were required to do?
Did you feel confident in your ability to comply with the requirements of the WHA exemption? (remind operator of the terms of the exemption and the requirements discussed at the pre-work if necessary) (what about other workers?)
Can you think of anything that would have improved this training?
Do you feel that you are more aware of badger habitat because of this training?

Transects:

Were you aware that Tembec and MoE had identified unmarked/unribboned burrows on transects prior to harvest as a test of the ability of operators to detect and protect burrows?
Did you feel qualified/capable of finding those burrows as a part of your normal job?
Do you think that this was a effective test? Why or why not? Suggestions for imporvement?
Overall, the success rate for protecting the transect burrows was quite low (go over graphs and map of all burrows). Our data suggest that this is closely related to the visibility of the burrows, and may also be linked to whether harvesting was performed during daylight hours, and to the learning process of operators. What do you think? Were burrows easier to find in the more open areas? (look at ortho map, talk about pattern of harvest)
We found 28 new burrow complexes (not identified before harvest and not part of the transects) that were protected during harvesting. Most had high stubs, and ribbons. Were you involved in creating these on-the-fly MFZs? How did you find that work? Satisfying? Frustrating? Time-consuming? Stressful? Boring? Other?

Compliance:

In our post-harvest assessment, we found one major violation of a pre-marked MFZ, in SU2 near the highway (show on map, describe the MFZ). There was a skid trail cutting through the MFZ, but no burrows were damaged. Do you remember this area? (remind that operators won't be held liable for infractions discovered as a result of this study). Were you aware of the violation? Do you know why the violation occurred? (eg operational constraints, didn't see ribbons, confusing ribboning, other?)
Can you think of anything that would have prevented this violation? (eg better ribboning/different colour, daytime logging, better training, walking the area beforehand?) Or was the MFZ just not operationally feasible?
Do you think that the presence/amount of MFZs affected the soil disturbance levels on the site? (eg by concentrating skid traffic in spaces between burrows) Or was soil disturbance more related to the wet weather conditions?

Summary:

Given the overall time/cost/etc and the results, do you think the work you did was worthwhile?
Would you want to work on a similar block in the future?
Do you have any other comments about your experience or about the project?