Effects of Trains and Railways on Grizzly Bears

An Evaluation of the Effects of Increased Train Traffic on the Burlington Northern Santa Fe & Montana Rail-Link Railways, Montana-Idaho

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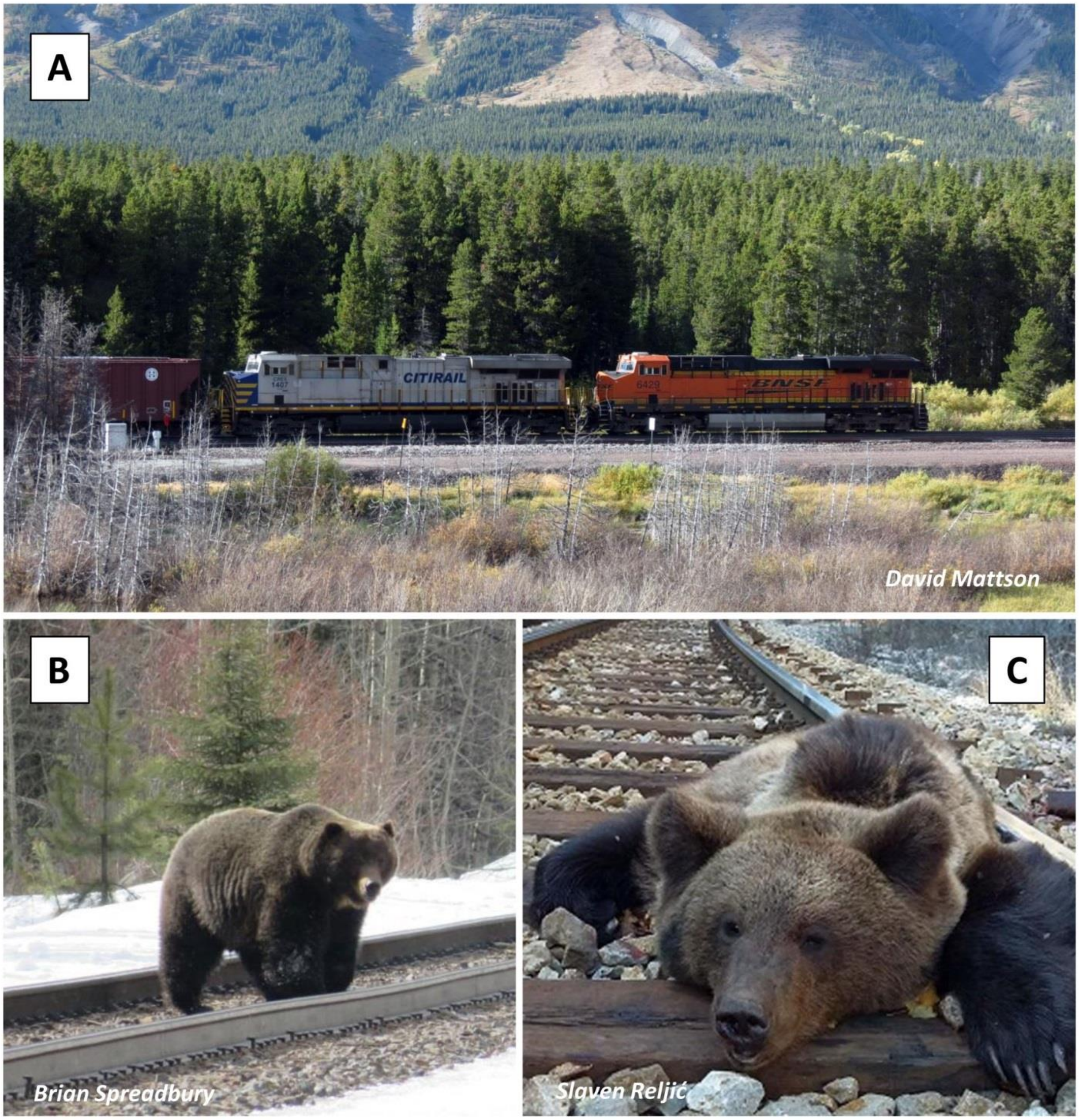

Figure 1. Photos emblematic of the complex relations among trains, railways, and grizzly/brown bears: (A) the potentially lethal locomotives at the front end of a train along the Burlington Northern Santa Fe railway near Marias Pass along the southern boundary of Glacier National Park, USA; (B) a grizzly bear traveling along the Canadian Pacific Railway during spring in Banff National Park, Canada; and (C) a brown bear killed by a train along a railway in Croatia.

1. Introduction

This report summarizes and interprets research available as of 2019 pertaining to the effects of trains and railways on grizzly bears. The review encompasses all research reported from the Northern Hemisphere pertaining to *Ursus arctos*, a species that includes brown bears in Eurasia and grizzly bears in North America. Animals of this species living on the two continents consist of closely related genetic lineages represented by Clade 1 in Europe and Clade 4 at mid-latitudes in North America (see https://www.allgrizzly.org/evolution). Insofar as behaviors and morphology are concerned, differences are minor, which legitimizes extrapolation of research focused on European brown bears to grizzly bears in North America, with obvious contingency on particulars of the natural and human environments.

Despite the broad geographic scope of this review, virtually all of the in-depth research on effects of trains and railways comes from just three areas: (1) the US Highway 2/Burlington Northern Santa Fe (BNSF) Railway transportation corridor abutting the southern boundary of Glacier National Park in the United States; (2) the Trans-Canada Highway (TCH)/Canadian Pacific Railway corridor transecting Banff and Yoho National Parks in Canada; and (3) the Dinaric region of Slovenia and Croatia in the Balkans.

The physical conditions and contexts of all three regions are strikingly similar: parallel closely-adjacent and heavily-trafficked highways and railways, confined to valley bottoms and passes, bounded by often rugged mountains. The physical nearness of and similarities between the Highway 2/BNSF and TCH/Canadian Pacific corridors makes research results from these two areas freely interchangeable. The TCH/Canadian Pacific corridor is roughly 200 miles (340 km) north-northwest of the Highway 2/BNSF corridor. Both are within cold-temperate to subalpine environs of the Rocky Mountains, in valleys bounded by rugged glaciated terrain (Figure 2). Train traffic on the Canadian Pacific Railway is heavier than on the BNSF railway (roughly 4 trains/hr [Dorsey 2011] versus 1.2-1.5 trains/hr [Waller & Servheen 2005]), although both qualify as being heavily used. Perhaps more germane, results from the Canadian study area foreshadow consequences for grizzly bears using the Highway 2/BNSF corridor arising from substantial increases in train traffic in this region.

This report is structured around the various ways that trains and railways affect grizzly and brown bears, premised on fundamental differences between the trains, as such, and the proximal environments associated with railways (Borda-de-Água et al. 2017, Barrientos et al. 2019). First and foremost, trains are potentially lethal projectiles that kill wildlife of all sorts. Trains also create sights, sounds, and smells that potentially disturb, displace, and alienate bears. On the other hand, environmental changes associated with the construction, maintenance, and use of railways can attract and feed bears through increased availability of carrion as well as favorable effects on vegetation. Less obviously, nearby highways can induce changes in bear behavior that can substantially modify what would otherwise be the direct and indirect effects of trains and railways in isolation.

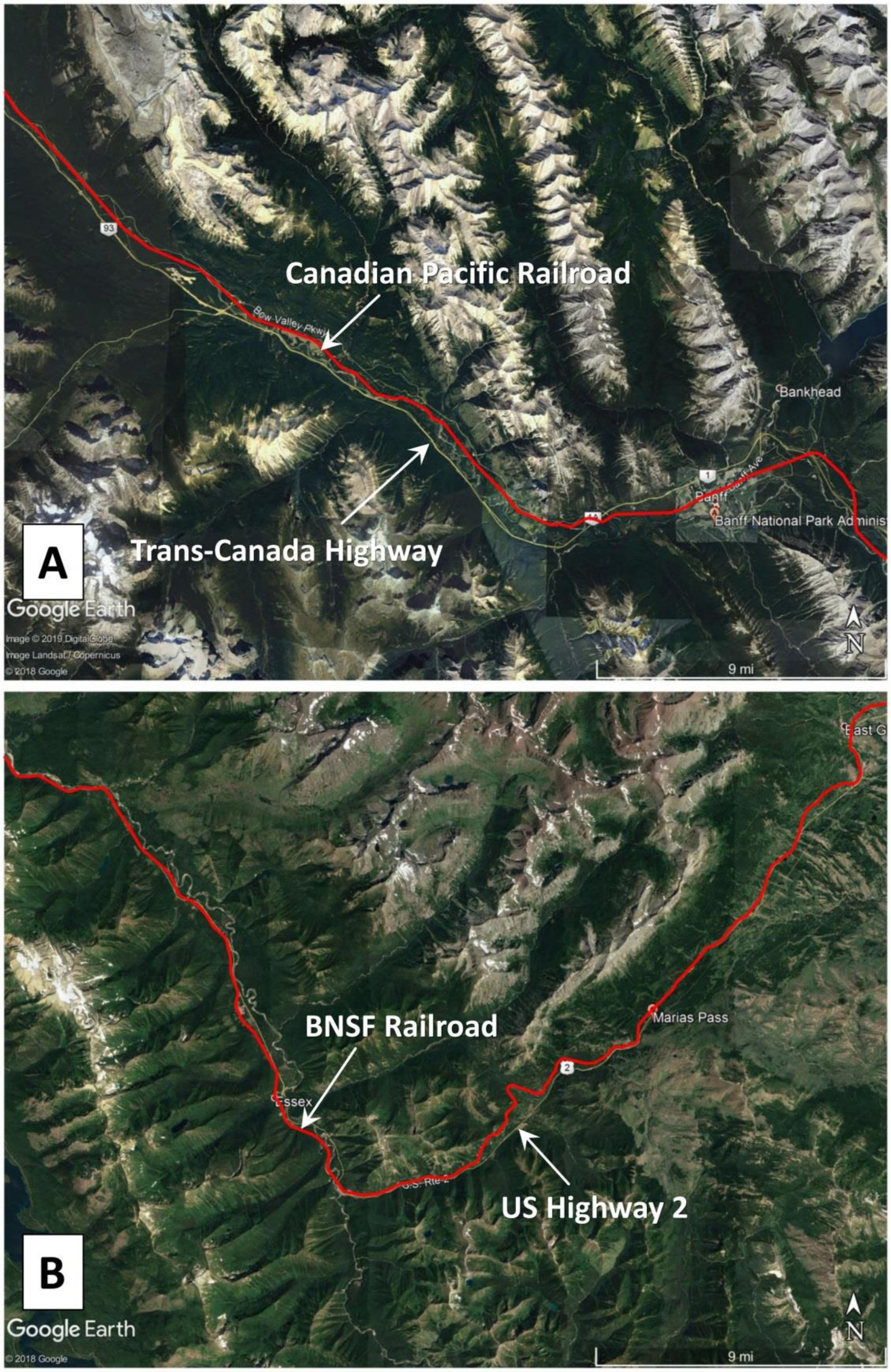

Figure 2. Satellite views of (A) the Trans-Canada Highway/Canadian Pacific Railway transportation corridor in Banff National Park in Canada, and (B) the US Highway 2/BNSF Railway corridor along the southern boundary of Glacier National Park in the USA (Google Earth). The railways in each are delineated red.

2. Trains Are a Significant Direct Cause of Bear Mortality

2.a. Trains kill numerous grizzly bears in the USA

Train strikes have killed a minimum of 56 grizzly bears in the Northern Continental Divide (NCDE), Cabinet-Yaak (CYE), and Selkirk Ecosystems (Recovery Areas) of Montana and Idaho during 1980-2018. Fifty-two of these known deaths occurred along the BNSF railway between Browning, Kalispell, and beyond (Figure 3). Three deaths occurred along a railway used by Montana Rail-Link along the southern boundary of the CY Ecosystem west of Thompson Falls. Train strikes accounted for 9% of total known and probable grizzly bear deaths during 1997-2013 in each of the NCDE and CYE—nearly every 1 in 10 bears that died.

Locations and some details of 38 train-caused deaths were recorded in databases obtained through a Freedom-of-Information-Act request and maintained by Montana Department of Fish, Wildlife, & Parks, and US Fish & Wildlife Service for the period 1997-2013. Waller & Servheen (2005) noted that 29 grizzly bears had been killed by trains during 1980-2002, which overlaps with the time span of the 1997-2013 database. A total of 56 deaths was obtained after accounting for this overlap and adding known deaths caused by train strikes reported in Montana Fish, Wildlife, & Parks Annual Monitoring Reports for 2014-2018 (Mace & Roberts 2015; Costello & Roberts 2016, 2017, 2018, 2019).

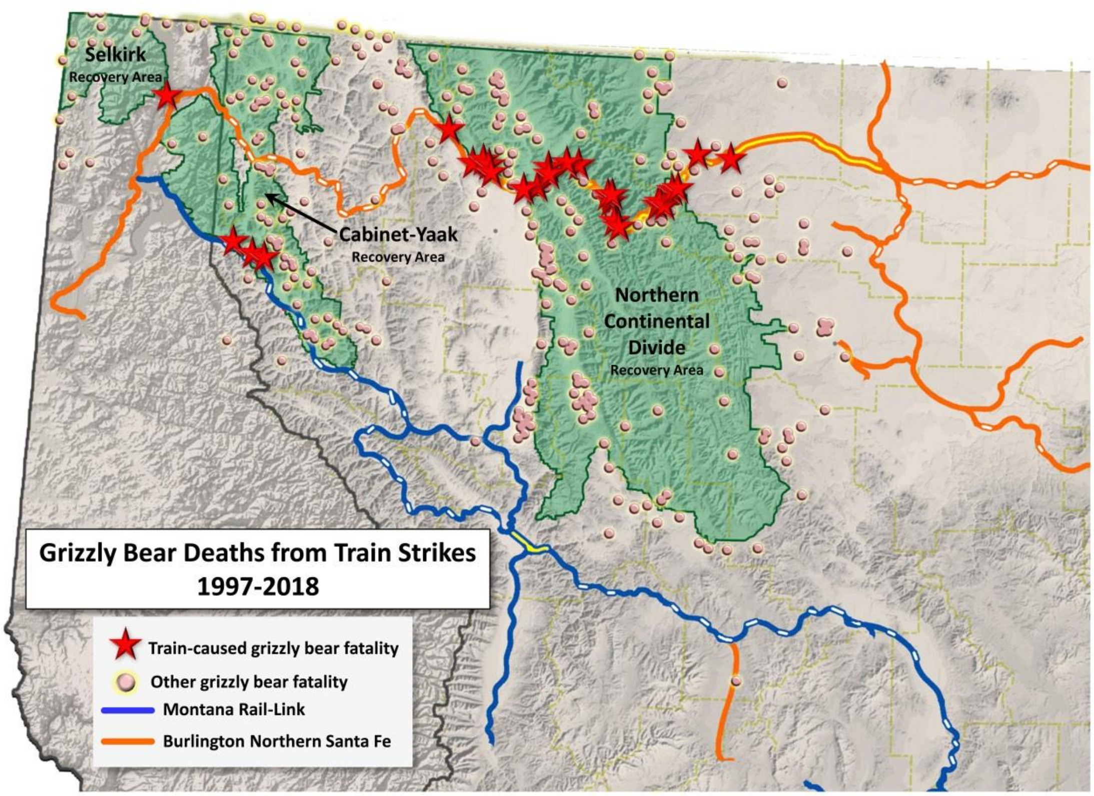

Figure 3. Locations of grizzly bear deaths caused by train strikes during 1997-2018 (red stars) relative to the Northern Continental Divide (NCDE) and Cabinet-Yaak (CYE) Grizzly Bear Recovery Areas (shaded green) and BNSF and Montana Rail-Link railways. Yellow-highlighted reaches denote twin tracks.

2.b. Trains kill numerous grizzly and brown bears In Canada and Europe

Train strikes kill numerous grizzly and brown bears in Canada, Eastern Europe, and elsewhere. The terms vary for how these deaths are reported (e.g., as a percent of total known mortality; as a percent of human-caused mortality; as a percent of total mortality related to collisions on highways and railways; as a per year rate), but the central theme is unambiguous. At a minimum, train strikes are a leading cause of grizzly bear mortality in Canada's Rocky Mountain National Parks (Bertch & Gibeau 2010, Burley 2015, Dorsey et al. 2017), as well as a major cause of brown bear mortality in Croatia (Huber et al. 1998, Kosak et al. 2000,), Slovenia (Kaczensky et al. 2003, Krofel et al. 2012), Slovakia (Rigg & Adamec 2007), the Abuzzo area of Italy (Boscagli 1987), and Savadkuh County in Iran (Marashi et al. 2017). In Slovenia, 5-6 bears are killed by trains each year (Krofel et al. 2012), including in excess of 1 per year along the Ljabljana-Trieste railway alone (Kaczensky et al. 2003). In Italy, train strikes were responsible during the 1980s for over 50% of all bear deaths in a management unit containing part of the endangered Abruzzo bear population (Boscagli 1987).

Most notably, trains traveling the Canadian-Pacific railway are the single greatest cause of grizzly bear deaths for the protected bear population occupying Banff and Jasper National Parks (Bertch & Gibeau 2009), which has catalyzed a major research program investigating details of how grizzly bears orient to and are affected by trains and railway environments. Roughly 25% of known and probable grizzly bear deaths in these Parks are attributable to train strikes, nearly 3-times greater than the fraction killed among protected grizzly bears in the NCDE and CYE, but remarkably consistent with the fact that train traffic is also roughly 3-times greater along the Canadian Pacific railway compared to the BNSF railway.

Given the comparability of protections, topography, and proximal environs between the NCDE and Banff-Jasper regions, the proportionally higher lethality of train traffic in Banff-Jasper serves as a reasonable proxy for what might be expected with an increase in train traffic along the BNSF and Montana Rail-Link railways in the USA. This interpretation is rendered more reasonable yet by the comparability of documented train speeds between focal reaches of the BNSF railway (average of 25-35 mph [40-56 kph]; maximum of 37 mph [60 kph] [Waller & Servheen 2005]) and focal reaches of the Canadian Pacific railway (median of 19 mph [30 kph]; maximum of 37-50 mph [60-80 kph] [Burley 2015, Dorsey et al. 2017]).

2.c. Bears killed by train strikes are typically not clustered spatially

Grizzly and brown bears killed by train strikes are often not spatially clustered. This phenomenon is evident in Figure 3 for grizzly bears killed by train strikes along the BNSF corridor, consistent with research reported by Dorsey et al. (2017) from the Canadian Pacific corridor in Banff National Park (page 146: "…no segment was identified as a hotspot") and by Huber et al. (1998) from Croatia. Similar near-random distributions of grizzly bear mortalities from vehicle strikes have likewise been documented along US Highway 93 in western Montana (Huijser et al. 2016). The upshot is that identification of corridors amenable to mitigation (e.g., over- and under-passes) can be problematic.

3. Railways Attract Bears Because of Enhanced Food Availability

Several researchers have either anecdotally noted or definitively documented the attractiveness of railways to bears, evident either in sign of feeding along or near tracks (Dorsey 2011, Murray et al. 2017, Put et al. 2017) and/or selection for areas near railways (Friesen 2016, Murray et al. 2017). This attractiveness has been attributed to enhanced food availability caused by modifications of the physical environment, spillage of transported grains, and/or carrion from ungulates struck by trains (Waller 2005, Waller & Servheen 2005, Dorsey 2011, Burley 2015, Hopkins et al. 2014, Friesen 2016, Gangadharan et al. 2017, Murray et al. 2017, Pollock et al. 2017, Put et al. 2017).

3.a. Spilled grain along railways is a major attractant for bears

Grain spilled from hopper cars has been flagged in both the USA and Canada as a major attractant for grizzly bears and probable ultimate cause for a certain (although unspecified) amount of related bear mortality from strikes by trains (Gibeau & Herrero 1998, Waller 2005, Waller & Servheen 2005, Dorsey 2011, Burley 2015, Hopkins et al. 2014, Friesen 2016, Gangadharan et al. 2017, Murray et al. 2017). Although there have not yet been any investigations specific to grain spillage and consumption by bears in the USA, recent research from Canada has focused on this issue. Gangadharan et al. (2017) estimated that near 110 tons of grain is deposited annually along the Canadian Pacific railway as a result of leakage from hopper cars alone—enough to cover the energetic requirements of >40 grizzly bears. However, a single major derailment can spill far more grain than is deposited by leakage (Pissot 2007; e.g., Pearson 2019).

Gibeau & Herrero (1998) were the first researchers to provide evidence that grizzly bears feed on spilled grain, noting that 6 of 7 radio-marked bears coming into contact with the Canadian Pacific Railway were known to feed on spillage. Murray et al (2017) confirmed the importance of spilled grain as a bear food through analysis of bear feces, finding that roughly 40% of scats collected within 150 m of the Canadian Pacific Railway contained grain, with that percentage increasing by near 6-fold during fall compared to spring and summer, coincident with peak east to west shipment of recently-harvested grain. Related, Put et al. (2017) found evidence that grizzly bears foraged on spilled grain cached by red squirrels (*Tamiasciurus hudsonicus*) in middens near railways. Dorsey (2011) also found a correlation between time spent by bears foraging along the CP Railway and densities of spilled grain, although without finding a correlation between locations where bears were struck by trains and either amount of available grain or local levels of bear foraging. This last result suggests that either grain was not a highly preferred food (Dorsey 2011) or that bears tending to specialize in and survive use of railway environments were especially canny and attentive, even while foraging (Burley 2015).

Owners of the railways have collaborated with wildlife and National Park managers in both the USA and Canada to remedy the problems created by grain spilled from hopper cars. In the USA, much of the resulting remedial action has been conducted under auspices of the Great Northern Environmental Stewardship Area (GNESA), which originated during 1992 as the Burlington-Northern Environmental Stewardship Area (Waller 2017). Here, as well as more recently in Banff National Park, the involved railway companies implemented measures such as deployment of vacuum trucks to recover spilled grain, as well as reporting and removal of carrion resulting from train strikes (Pissot 2007, Waller 2017).

None of these measures have yet yielded demonstrable benefits along the Canadian Pacific railway corridor (Pissot 2007, Dorsey et al. 2017). On the other hand, Waller (2017:300) claimed that remediation along the BNSF railway corridor had demonstrable, even dramatic results: "…the numbers of bears hit and killed along the railroad tracks has dropped significantly; only four grizzly bears were killed between 2010 and 2015, compared to the six-year running average of 11."

As hopeful as this might sound, an examination of data in government-maintained databases shows that 19 grizzly bears were killed by train strikes along the BNSF corridor during 2000-2009 (1.9/yr) versus 9 during 2010-2018 (1.0/yr). This does represent a decline, although not nearly as dramatic as suggested by Waller (2017), and at substantial variance from the numbers he reported. Likewise, Waller (2005:157) parenthetically noted: "…we know that bears continue to obtain and consume grain along the tracks. The stomach of F 11, examined after she was killed along the tracks, contained corn." In short, the GNESA initiative has apparently not been as successful at mitigating mortality risk for grizzly bears as is commonly thought, nor are there any explicit performance-related data on the actual extent to which remedial measures have mitigated availability of either spilled grain or rail-side carrion.

3.b. Availability of carrion and vegetal foods is enhanced along railways

Train strikes kill numerous ungulates that end up as carrion along railways (Wells et al. 1999, Dorsey 2011, Dorsey et al. 2017, Santos et al. 2017), resulting in the probable attraction of scavenging grizzly and brown bears to this high-quality resource (Wells et al. 1999, Kaczensky et al. 2003, Krofel et al. 2012, Hopkins et al. 2014, Friesen 2016, Murray et al. 2017). Interestingly, even though this scenario is often invoked, there is little direct evidence other than offered by Wells et al. (1999), although elevated δ^{15} N levels among bears using areas near the railway in Banff National Park indicate greater consumption of terrestrial meat sources either by scavenging or predation (Hopkins et al. 2014). Nonetheless, there is ample evidence from elsewhere that bears are attracted to carrion (e.g., Green et al. 1997; Mattson 1997, 2017; Krofel et al. 2012; Lewis & Lafferty 2014; Krofel & Jerina 2016).

In addition to provisioning bears with carrion, railway environments can also enhance or modify availability of vegetal foods through effects on either abundance or phenology. Railways are highly modified environments typified by removal of overhead vegetation cover and resulting greater incident radiation; increased track-side soil moisture from displacement of snow by plows; and greater air movement resulting from both greater openness to wind and turbulence created by passing trains (Friesen 2016, Pollock et al. 2017). More specifically, Gibeau & Herrero (1998), Friesen (2016), and Pollock et al. (2017) all note that cover of vegetal bears foods is, on average, much higher in openings of all sorts compared to under forest canopy, which holds as well for railways. Along railways, the greatest abundance of palatable herbaceous foods occurs during spring—notably for horsetail (*Equisetum arvense*)—and the least during fall (Friesen 2016), although the quality and quantity of fruits on shrubs such as buffaloberry (*Shepherdia canadensis*) is much greater along railways during fall, especially in contrast to not only forests, but also other habitats.

3.c. Bears tend to select for, forage, and die along railways

The extent to which bears seasonally select for areas near railways, spend time foraging there, and then correspondingly die because of train strikes, provides evidence for judging the extent to which bear foods in track-side environments attract bears. This sort of evidence is also a basis for testing claims that mitigation programs adequately remove or neutralize attractants resulting from grain spillage, carrion, or modified railway environments (e.g., Waller 2017).

Of direct relevance, researchers from Canada found that radio-marked grizzly bears selected for areas near railways during spring and fall while at the same time avoiding roads year-round and power-line rights-of-way during fall (Friesen 2016; Figure 4a), suggesting that something was attracting bears to railways during spring, but even more so during fall. Monthly numbers of deaths from train strikes roughly track these seasonal changes in orientation by bears to railways, not only in the Mountain National Parks in Canada (Bertch & Gibeau 2009; Figure 4b), but also, interestingly, in the NCDE and CYE of the USA (Figure 4b) as well as Croatia and Slovenia (Kaczensky et al. 2003; Figure 4c). A pronounced peak during May is followed by a decline through the end of summer, after which mortalities rise to a second peak during September and October, especially in the USA.

In light of the information presented in 3.a. and 3.b., the May peak is logically explained by bears seeking out railways to exploit carrion from ungulates killed by train strikes during winter, herbaceous vegetation subject to accelerated phenology, and perhaps for ease of travel at a time when snow lingers elsewhere. The fall resurgence of mortality is likely explained by bears seeking out grain spilled from hopper cars transporting late-summer and fall harvests, as well as exploitation of enhanced fruit crops along railways. Put another way, the monthly and seasonal patterns of habitat selection and related train strikes are not readily explained by the seasonal cycle of grizzly and brown bear foraging. The period of peak feeding (hyperphagia) for grizzly bears generally begins throughout the Northern Hemisphere during mid-July and lasts until the onset of hibernation (Folk et al. 1976, Mattson et al. 1991), at variance with the May and September-October spikes in train strikes, especially in the USA.

Of particular relevance to the BNSF corridor and associated Great Northern Environmental Stewardship Area (GNESA), the monthly pattern of grizzly bear train strikes here is consistent with bears seeking out feeding opportunities along the railway, and inconsistent with a highly effective mitigation program. Notably, 8 of the 9 grizzly bear deaths since 2010 have occurred during September-October, coincident with the beginning of peak grain shipments (e.g., Murray et al. 2017). More certainly, the monthly pattern of train strikes has continued to feature a May and a September-October peak since 2000, which was when the GNESA mitigation program should have been amply evident.

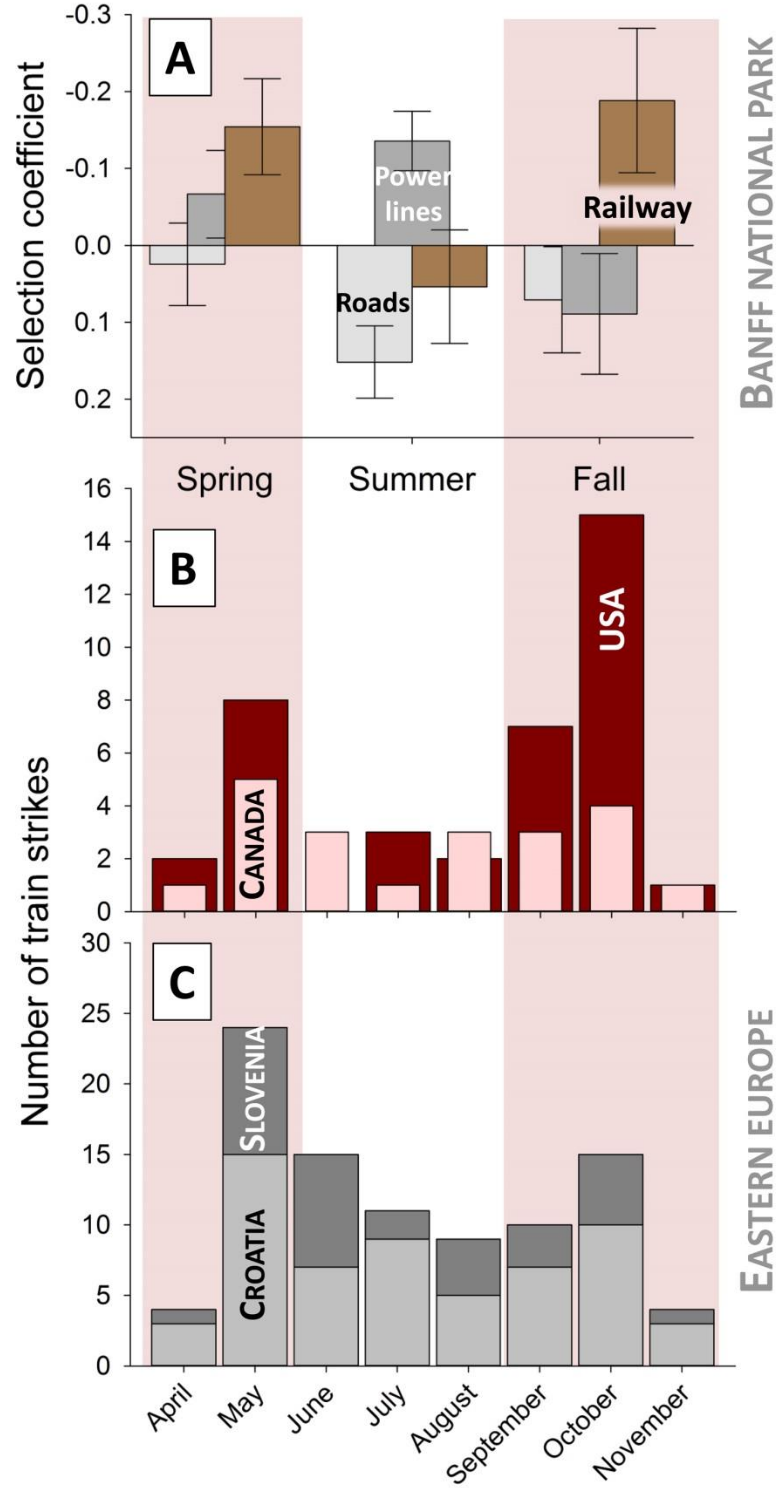

Figure 4. Monthly and seasonal patterns of (A) selection by radio-marked grizzly bears for linear features in Banff National Park, Canada (negative values denote greater attraction/selection); (B) grizzly bear mortality attributable to train strikes along the BNSF and Montana Rail-Link railways in the USA, 1997-2018, and along the Canadian Pacific and Canadian National railways in Canada, 1980-2008; and (c) brown bear mortality from train strikes in Croatia and Slovenia (additively combined).

4. Nearby Highways Compound the Lethality of Railways

Heavily-trafficked highways that parallel railways—as is typical in mountainous regions—introduce dynamics at different scales and in different dimensions that modify, and even increase, the lethality of trains. Heavily-trafficked highways alienate large swaths of nearby bear habitat, cause bears to change diel activity patterns, and fragment bear populations. These effects translate into changes in bear behavior that can, under certain circumstances, increase the likelihood that bears will be struck by trains.

4.a. Bears avoid heavily-trafficked highways and cross them more often at night

The majority of grizzly bears avoid highways with even modest levels of traffic (Mattson et al. 1987, Martin et al. 2010, Northrup et al. 2012, Kite et al. 2016). But, as might be expected, avoidance increases, both spatially and temporally, as traffic increases (Gibeau et al. 2002, Chruszcz et al. 2003, Northrup et al. 2012). The resulting under-use of areas near highways can extend out as much 1/3 to 2/3 of a mile (500-1000 m), alienating bears from substantial portions of otherwise productive habitat (Mattson et al. 1987, Kasworm & Manley 1990, Mace et al. 1996, Waller & Servheen 2005, Northrup et al. 2012, Bischof et al. 2017).

Crossings of highways by bears correspondingly decline (Gibeau 2000, Chruszcz et al. 2003, Graves et al. 2006, Graham et al. 2010, Lewis et al. 2011, Northrup et al. 2012, Skuban et al. 2017, Find'o et al. 2018), to the point where highways become an impenetrable barrier to bears during periods when traffic levels are approximately 100 or more vehicles per hour (Waller & Servheen 2005, Northrup et al. 2012) or 4000-5000 vehicles per day (i.e., a daily average of 167-208 vehicles per hour; Skuban et al. 2017, Findo et al. 2018). Grizzly and brown bears compensate for elevated traffic during daylight hours by crossing affected highways more often at night and crepuscular hours, but only as long as night-time traffic is below the approximate threshold of 100 vehicles per hour (Waller & Servheen 2005, Martin et al. 2010, Mueller et al. 2004, Northrup et al. 2012, Skuban et al. 2017).

All of these global patterns vis-à-vis heavily trafficked highways are evident along the US Highway 2 corridor (Waller & Servheen 2005). Grizzly bears tend to avoid and correspondingly underuse areas within roughly 350-m of the highway (Figure 5a), consistent with many fewer crossings of the road—and railway—than would be expected by chance for most bears (Figure 5b). More important, observed crossings occur at times of day when there is least vehicle traffic on the highway, and essentially none at all at times when traffic is >100 vehicles per hour (Figures 6a and 6b).

A notable proviso to these patterns arises from individual differences in responses of bears to humans, in concert with relations among bears related to risk of intra-specific aggression. Although the broad pattern is for bears to avoid highways, individual bears that have habituated to the presence of humans can actually select for areas of human activity—most notably adolescent bears and females with cubs seeking to avoid aggression by other adult bears, of which adult males are the most prominent aggressors (Mattson et al. 1987, 1992; McLellan & Shackleton 1988; Gibeau et al. 2002; Chruszcz et al.

2003; Mueller et al. 2004; Graham et al. 2010). These bears seeking refuge from aggressive adults thereby become the most vulnerable to human-caused mortality of all sorts (Mattson et al. 1992, Benn & Herrero 2002, Mueller et al. 2004, Boulanger & Stenhouse 2014).

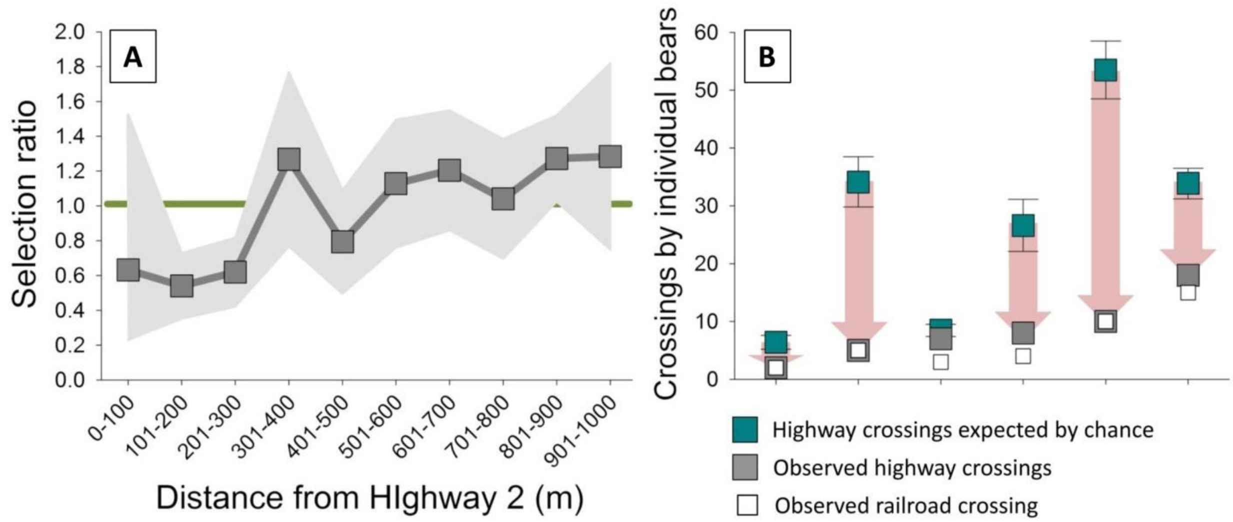

Figure 5. (A) Observed selection by radio-marked grizzly bears for habitat by distance from US Highway 2 (values <1 denote avoidance); and (B) observed crossings of the highway (gray squares) and the BNSF railway (white squares) relative to crossings expected if these linear features were not an impediment (turquoise squares): each of the 6 results are for individual bears ordinated by observed frequency of crossings (adapted from Waller & Servheen [2005]).

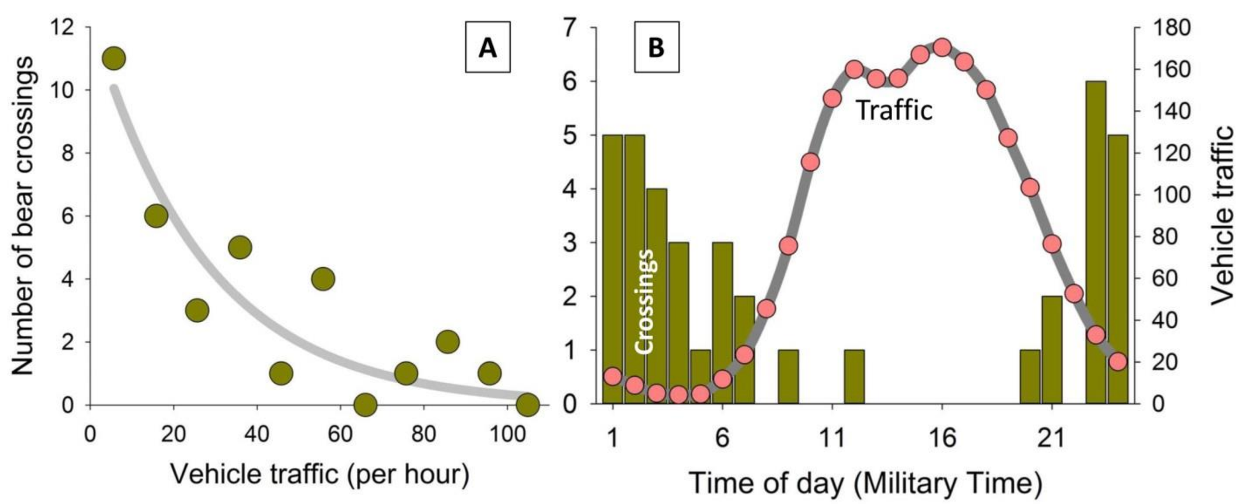

Figure 6. (A) Relation between observed crossings of US Highway 2 by radio-marked grizzly bears and average hourly vehicle traffic, and (B) these same data arranged by hour of day, from 1 am at left to 12 am at right (adapted from Waller & Servheen [2005]).

4.b. Crossing and foraging during crepuscular/night-time hours increases exposure of bears to trains

Unlike vehicle traffic on most highways—including US Highway 2 and the Trans-Canada Highway—train traffic on railways does not lessen at night. In fact, along the BNSF and Canadian Pacific railways, train traffic tends to increase during both night-time and crepuscular hours (Figures 7a and 7d; Waller & Servheen 2005, Dorsey 2011). Diel avoidance of vehicle traffic on Highway 2 and the TCH by grizzly bears and resulting displacement of crossings to crepuscular and night-time hours paradoxically does not reduce but rather increases exposure to trains.

All else equal, this perverse heightening of risk resulting from avoidance of traffic on nearby highways is likely compounded by the tendency for grizzly bears to forage more intensively during crepuscular hours. This tendency is evident in hourly data derived from video recordings of grizzly bears foraging along the Canadian Pacific Railway in Banff National Park (Dorsey 2011, Figure 7c). Both total observed foraging time as well as duration of individual foraging bouts peaked between 5-10 am and 7-9 pm—times typified by lower light levels.

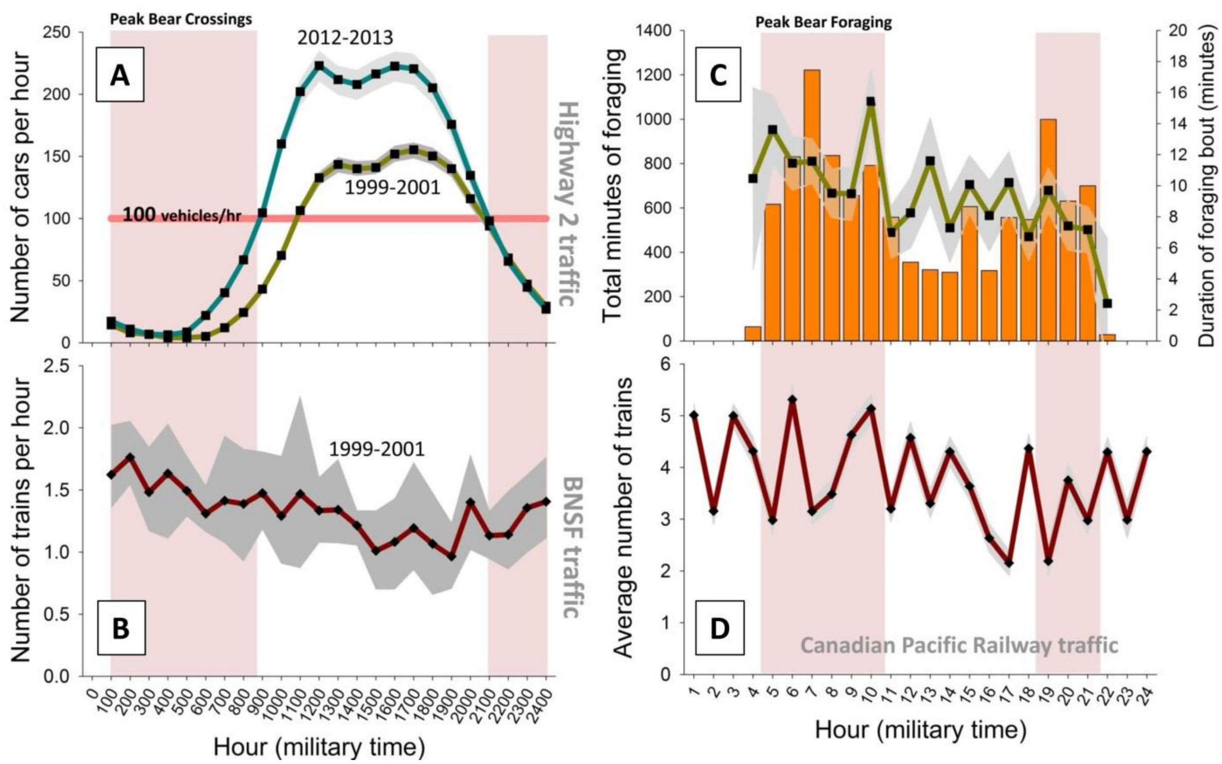

Figure 7. (A) Mean hourly traffic on US Highway 2 during 1999-2001 (Waller & Servheen 2005) and 2012-2013 (Waller & Miller 2015), showing increases in traffic during this period and corresponding reduction in the window within which bears will likely cross; (B) hourly number of trains on the BNSF Railway (adapted from Waller & Servheen 2005) and (D) on the Canadian Pacific Railway (Dorsey 2011); and (C) total observed minutes of foraging and mean duration of observed bouts for grizzly bears along the Canadian Pacific Railway in Banff National Park (adapted from Dorsey 2011).

4.c. Proximal bear behaviors only partially mitigate risk

Grizzly bears are highly reactive to approaching entities that they perceive to be a threat. As such, they are classed as 'avoiders' (Jacobson et al. 2016). This reactivity is evident in the uniform tendency of bears to flee approaching trains, although initiated at greater distances when the train is approaching rapidly in a location with locally concave topography (Burley 2015).

Even so, individual trains transect any given locale at frequencies >100-times less than that of vehicles on typical heavily-trafficked highways such as US Highway 2 and the TCH. Even though an individual train can be comprised of 20-100 cars attached to one or more locomotives, an encounter by a bear with a train almost certainly registers as only a single event for the involved animal. This difference no doubt explains why grizzly bears exhibit often strong avoidance of heavy vehicle traffic on highways (Figure 5), but not the comparatively much less frequent train traffic on railways (Figure 4a). Insofar as a sensory experience is concerned, heavy traffic on a highway no doubt translates into a constant perceived threat to all but the most habituated of bears, whereas even the most heavily used railways likely entail gaps in perceived threat that allow the involved bear to commit itself to either crossing or foraging nearby. The result is predictable and evident in the large number of grizzly bear deaths from train strikes along both the Highway 2-BNSF and TCH-Canadian Pacific travel corridors (see Section 2).

5. Heavily-Trafficked Railways & Highways Fracture Bear Range

Parallel heavily-trafficked highways and railways impede, if not altogether prevent, connectivity among and within brown and grizzly bear populations. Scaling up from the movements and habitat selection patterns of individual bears, there is ample evidence from the Rocky Mountains of Canada and the USA, as well as from Europe (e.g., Kaczensky et al. 2003, Molinari & Molinari-Jobin 2001), that major transportation corridors not only limit movements and associated demographic connectivity, but also gene flow.

Proctor et al. (2002, 2005, 2012) comprehensively documented subpopulations of grizzly bears in southeast British Columbia, southwestern Alberta, and northwestern Montana differentiated by fracture zones entailing limited connectivity. These fracture zones were invariably associated with major transportation corridors and/or lowlands comparatively heavily settled by humans. Notably, there was very limited or, in places, no gene flow attributable to female movements across the TCH/Canadian Pacific Railway corridor and no gene flow of any sort across the Highway 2/BNSF corridor in the Cabinet-Yaak Ecosystem (CYE). Corroborating this result, Proctor et al. (2015, 2018) noted that "highway crossings were relatively rare" in this ecosystem, despite the theoretical existence of numerous modeled corridors (i.e., linkage zones), and with no evidence of genetic connectivity between the Yaak and Cabinet Mountains portions of the CYE (Proctor et al. 2018).

Proctor et al. (2012:33) also noted “minor fragmentation of historic and unknown origin” along the Highway 2/BNSF corridor in the Northern Continental Divide Ecosystem (NCDE), deriving from very limited cross-corridor movements by bears, especially along western portions of this corridor where highway traffic is much heavier than along eastern portions nearer Marias Pass. Mikle et al. (2016) similarly found the signature of past population decline, limited influx of immigrants, and related diminishment of genetic heterozygosity south of Glacier National Park and the Highway 2/BNSF corridor (Figure 8a), that has since 2004 been alleviated by the influx of migrant bears from source areas primarily to the north. Even so, this recent increase in demographic and genetic connectivity between northern and southern portions of the NCDE is superimposed on a pronounced source-sink structure centered on source areas in Glacier National Park and the adjacent Middle Fork of the Flathead, with sinks of varying degrees essentially everywhere else (Figure 8b; based on data from Costello et al. 2016).

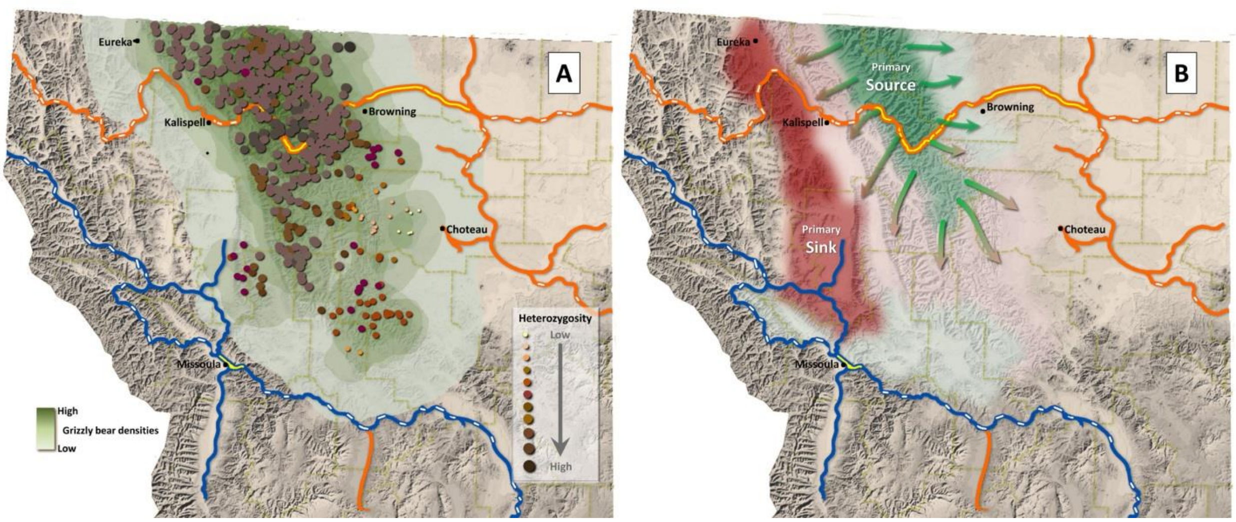

Figure 8. (A) Levels of heterozygosity of individual grizzly bears sampled circa 2004 in the NCDE (adapted from Mikle et al. 2016), superimposed on isopleths of grizzly bear density, in shades of green (adapted from Costello et al. 2016); and (B) approximate sink and source areas in the NCDE based on the ratio between observed mortality and estimated density in different management units from Costello et al. (2016). Areas shaded darker red are more likely to be population sink areas; areas shaded darker green are more likely to be source areas. Railways are shown in both A and B in orange (BNSF) and blue (Montana Rail-Link).

As a result of this history and structure, recovery and resilience of the NCDE grizzly bear population is contingent on sufficient connectivity between source and sink areas, across the currently problematic Highway 2/BNSF travel corridor. Servheen & Sandstrom (1993), Servheen (1998), Servheen et al. (1998, 2001), Waller & Servheen (2005), and Waller & Miller (2015) all either flagged this issue, articulated the argument for healthy intra- and inter-population linkages, and/or voiced concerns about the emergence of greater fracturing along the Highway 2/BNSF corridor with increasing traffic on the highway and continued or increased bear mortality from train strikes.

6. Summary, Conclusions & Implications

- Brown and grizzly bears are killed by train strikes in Europe and North America every year. In the contiguous USA alone, 55 grizzly bears have been killed by trains since 1980, accounting for 9% of total known or probable deaths in the Cabinet-Yaak (CYE) and Northern Continental Divide (NCDE) Ecosystems since 1997. In the similar physical environment of Banff National Park (NP), Canada—but with roughly twice the railway traffic as in the USA—train strikes currently account for nearly ¼ of all grizzly bear deaths.

- Grain that either leaked or spilled from hopper cars has been and continues to be a major attractant for grizzly bears along the Canadian Pacific and BNSF Railways. Feeding by bears on grain along railways has been well-documented in Canada, although there is no comparable data from the USA to determine whether purported mitigation measures have reduced consumption of grain by bears along the BNSF Railway.

- Grizzly bears are also likely attracted to railways by carrion from train strikes and by increased abundance of certain vegetal foods during spring and fall attributable to a modified proximal physical environment. Increased abundance of horsetail, buffaloberry, and certain weedy forbs such as dandelion has been documented along the Canadian Pacific Railway in Banff NP.

- Seasonal patterns of habitat selection and mortality from train strikes support the conclusion that significant numbers of grizzly bears are attracted to railway environments during spring and fall. Train-caused deaths exhibit pronounced spikes during May and September-October along the BNSF Railway in the NCDE; similar monthly patterns occur in Eastern Europe and along the Canadian Pacific and Canadian National Railways. The fall increase in train strikes in both Canada and the USA is consistent with bears continuing to seek out grain spilled from hopper cars transporting fall harvests west from the Great Plains.

- Heavy vehicle traffic on highways paralleling railways displaces grizzly and brown bears spatially as well as temporally—albeit contingent on the richness of nearby natural habitats. Such patterns have been documented along both US Highway 2 in the NCDE and along the Trans-Canada Highway (TCH) in Banff NP.

- Highway crossings by grizzly and brown bears are nil when traffic is greater than roughly 100 vehicles/hour, although this level of traffic is restricted largely to day-time hours on Highway 2 and the TCH. As a result, highway crossings are displaced to night-time and crepuscular hours, coincident with low light levels and times when bears naturally feed most heavily.

- In contrast to highways, bears tend to not avoid railways, as such, perhaps because of much lower levels of individuated traffic on railways compared to highways, as well as the presence of anthropogenic attractants.

- Bears avoiding heavy day-time traffic on nearby highways; peak railway traffic during night-time and crepuscular hours; and the attractiveness of railway environments combine to produce a potentially lethal situation for grizzly bears active near or trying to cross major transportation corridors such as US Highway 2 and the BNSF Railway.

- The abbreviation of daytime crossing opportunities that predictably comes with increasing vehicular traffic, when combined with increased levels of night-time and crepuscular train traffic, will almost certainly increase the lethality of the Highway 2/BNSF corridor in the NCDE and CYE—as well as the Highway 200/Montana Rail-Link corridor southwest of the Cabinet Mountains.

- The TCH/Canadian Pacific Railway corridor foreshadows the consequences of increased vehicular and train traffic along the Highway 2/BNSF corridor. The physical environments of both corridors are quite similar, both transect protected grizzly bear populations, and the TCH/Canadian Pacific corridor is transected by levels of both vehicular and train traffic that will, in the future, likely typify the Highway 2/BNSF corridor. Train strikes promise to be a major cause of bear deaths, comprising an even larger fraction of the total in both the NCDE and CYE.

- Regardless of whether or not grizzly bears are attracted to railways by spilled grain or rail-side vegetation, bears die from being struck by trains of all sorts. Self-evidently, grizzly bears do not preferentially seek out locomotives pulling one assortment of cars versus another. A coal train can be as lethal to a bear as a freight or grain train.

- The Highway 2/BNSF corridor bounds and transects the main source area for the NCDE grizzly bear population centered on Glacier National Park and the Middle Fork of the Flathead River. Several researchers have flagged incipient or full-blown fracturing along this corridor as a potential threat to long-term viability of the NCDE population. Fracturing is almost certain to be accentuated by increased vehicular and train traffic along the corridor, thereby posing a significant threat to this grizzly bear population.

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