Canadian Journal of Zoology

OPEN ACCESS | Research Article

Grizzly bears detected at ecotourism sites are less likely than predicted by chance to encounter conflict

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Abstract

Whether ecotourism can lead to human–wildlife conflict is not well understood. In Nuxalk Territory, grizzly bear (*Ursus arctos horribilis* Ord, 1815) conflict occurred ∼41–58 km downstream from ecotourism. We screened for genetic matches between individuals that encountered conflict ($n = 30$) and 118 individuals detected upstream via hair snags (including 34 at ecotour sites). Of these 34, one encountered conflict. In analysis Scenario 1, we considered all detected and undetected bears in the region as freely mixing, and used Bayes' theorem to account for imperfect detection of ecotour bears among conflict samples, deriving an estimate of 1.47 (rounded to 2). Accounting for this uncertainty, we used a probability approach to ask how large the unknown non-ecotour bear population would have to be to observe this frequency of conflict among ecotour bears (2/34) by chance. The resulting population level exceeded available estimates, suggesting ecotour bears are less likely to encounter conflict. In Scenario 2, we assumed that downstream bears are not necessarily from the same population as those sampled upstream; we compared the proportions of known ecotour and non-ecotour bears among conflict samples and found no evidence of a significant difference. Collectively, these analyses suggest other human-caused drivers of conflict.

Key words: Bayes' theorem, conflict, ecotourism, grizzly bears, probability, wildlife

1 Introduction

Multiple ecological and social processes can predispose wildlife to conflict with humans. Among them, temporal and spatial dynamics of wild and human-associated food availability are important across a range of taxa and geographic contexts (Nyhus 2016). For example, high proportions of pasture combined with low proportions of cropland largely explained spatial patterns in wolf (*Canis lupus* Linnaeus, 1758) depredation on livestock across wildland-farm landscapes in Wisconsin (Treves et al. 2004). Moreover, human–wildlife conflict in the form of crop raiding by mountain gorillas (*Gorilla beringei beringei* Matschie, 1903) in Uganda was influenced by human-associated food availability outside a protected area (Seiler and Robbins 2016). In Alberta, Canada, anthropogenic food sources such as bird feeders, compost, and cultivated fruit trees may contribute disproportionately to encounters between people and coyotes (*Canis latrans* Say, 1823) (Murray et al. 2015). Food provisioning of great white sharks (*Carcharodon carcharias* (Linnaeus, 1758)) during cage dives has been associated with increased chance of divers, beachgoers, and swimmers being attacked (Shannon et al. 2017). Lion (*Panthera leo* (Linnaeus, 1758)) attacks on people and livestock in Africa were higher in areas of lower prey abundance or when native prey populations were more difficult to find (Patterson et al. 2004; Inskip and Zimmermann 2009). Moreover, among grizzly bears (*Ursus arctos horribilis* Ord, 1815) that feed on salmon (*Oncorhynchus* spp. Suckley, 1861) in British Columbia, Canada, conflict kills of grizzlies were 20% higher for each 50% decrease in annual salmon biomass (Artelle et al. 2016).

In addition to association with foods, wildlife ecotourism could theoretically be associated with conflict if it increases tolerance of humans by wildlife. Although wildlife can avoid people in space or time as a risk reduction strategy (Tucker et al. 2018; Gaynor et al. 2019), thereby also likely minimizing conflict, some populations or individuals that comprise them can tolerate benign human activity like wildlife viewing. Some species or reproductive classes within species might in fact use humans as protective associates ("human shields"; Nevin and Gilbert 2005; Berger 2007; Field et al. 2024). Any associated tolerance of humans among these individuals might thus predispose them to engage in risky behaviour and subsequently encounter conflict with humans. Indeed, behavioural changes associated with habituation to tourists have been linked with increased boldness (Geffroy et al. 2015), suggesting that increased tolerance to benign human activity makes wildlife more vulnerable to negative interactions with people. In considering a global review of animals subject to ecotourism, Kc et al. (2022) suggested that communities adjacent to ecotourism in protected areas may face frequent, novel, and severe conflict in the form of livestock predation or attacks on people, a proposition not widely subject to empirical testing.

Here, we examine a case study in which the distribution and abundance of foods, as well as tolerance of humans, might underlie a pattern of conflict. In the unceded Territory of Nuxalk First Nation, located in what is now also known as the central coast of British Columbia, Canada, well-established and popular grizzly bear ecotourism occurs along the salmon-bearing Atnarko river in Tweedsmuir Provincial Park; approximately 41–58 km downstream, conflict occurs in the lower Bella Coola Valley (i.e., in or between the communities of Bella Coola and Hagensborg), an area with human-associated food attractants and a hotspot for grizzly–human conflict within British Columbia (Artelle et al. 2016). Given the high mobility of grizzlies, and responding to questions within communities as to whether bears subject to ecotourism might be commonly involved in conflict, local managers sought an assessment of the available evidence. We thus addressed the hypothesis that grizzly bear presence at ecotourism sites increases the probability it subsequently encounters conflict with humans at downstream sites due to higher tolerance of humans. Specifically, we screened data sets composed of bears genetically identified via non-invasive hair-snagging at ecotour sites (and beyond) and those that were captured after encountering conflict with humans in adjacent areas within the Bella Coola Valley (Fig. 1). We then considered two alternative scenarios, which relied on mutually-exclusive assumptions, to assess the evidence, each with associated analyses. Our first assumption ("Scenario 1", below) considered that all bears in the area are free to mix; that is, ecotour bears and non-ecotour bears comprise part of a larger, mobile population capable of occurring at ecotour sites, in and around sites of human occupation and activity (i.e., "downstream sites" of conflict on rural properties or townships) and the larger surrounding areas (Fig. 1). Our associated probability approach likewise considered individual bears as freely-mixing constituents of the entire population. The second scenario ("Scenario 2", below) considered the "upstream" and "downstream" populations as spatially-segregated. That is, ecotour and non-ecotour bears comprise an "upstream" population in a region approximately 41–58 km upstream from the downstream area where conflict occurs (Fig. 1). This assumption enabled us to use a Fisher's exact test to examine whether there was a relationship between conflict occurrence and whether individual bears were detected in the "ecotour" area or the "upstream" area prior to conflict.

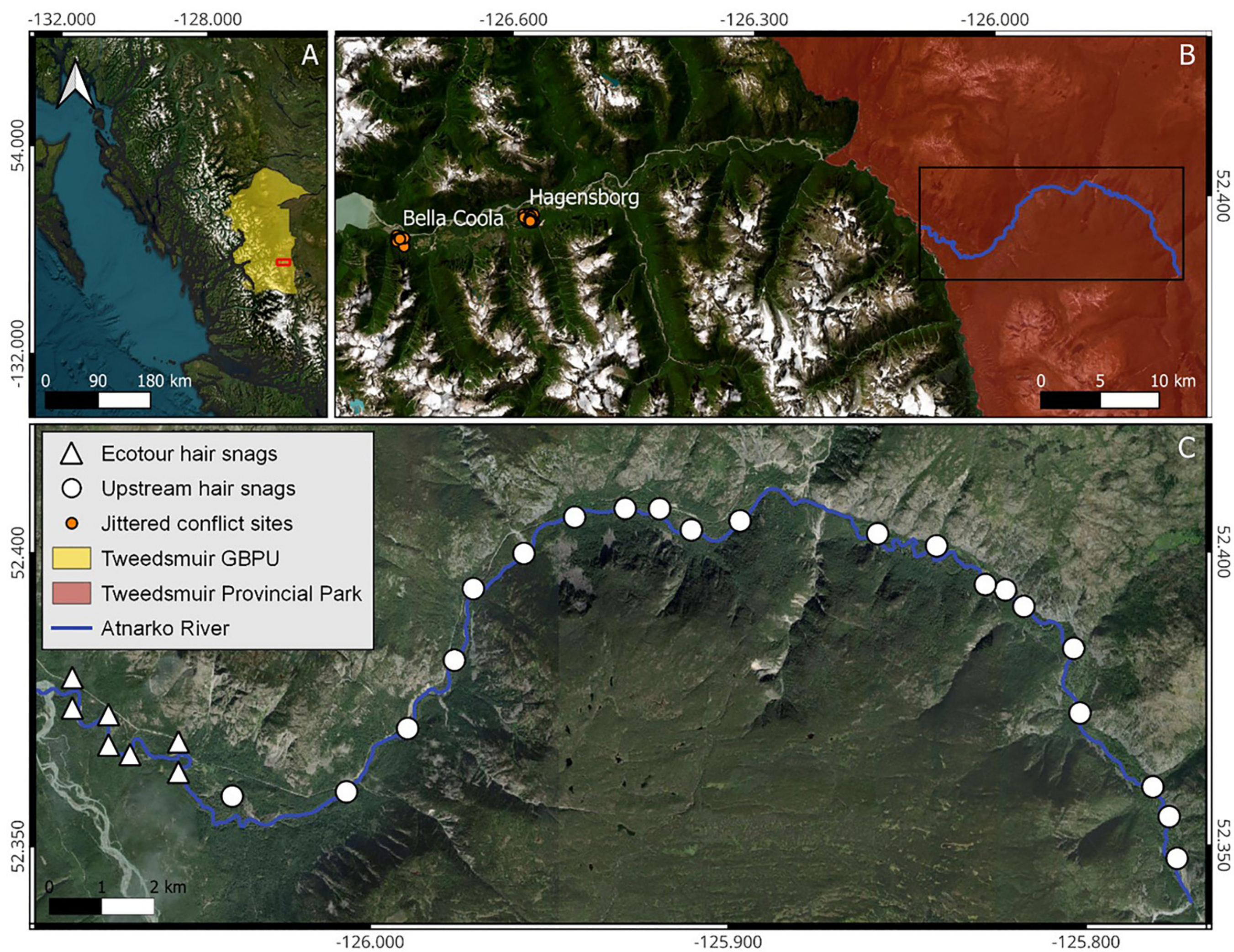
2 Materials and methods

2.1 Field methods

Our hair snag sampling was originally designed to test hypotheses related to the potential effects of ecotourism on grizzly bear activity (see Field et al. 2024), and before community-driven questions about conflict catalyzed this research. Specifically, we had deployed passive, non-baited hair snags (Woods et al. 1999; Proctor et al. 2010) to genetically identify individuals as approved by University of Victoria Animal Use Permit 2019-004 and following guidance from the "Canadian Council of Animal Care: Wildlife" (https://ccac.ca/Documents/Standards/Guidelines/CCAC_Guidelines-Wildlife.pdf). Areas hosting abundant natural attractant such as salmon provide an appropriate and efficacious context for non-baited, non-invasive hair collection because the snags likely do not affect the distribution and movement of bears (Wold et al. 2020). Snags (n = 28 in 2019; n = 29 in 2020; and n = 28 in 2021) were set of barbed wire at ~0.5 m height (Quinn et al. 2022) every ~0.5–2 km along the Atnarko river across well-worn bear trails or riverside banks where bears or their sign (i.e., tracks, scat) were commonly observed by local wildlife managers and technicians from the Nuxalk Fisheries and Wildlife Department, who survey the river and its banks each week or more, over many years prior to this work. The distance along the river from the most downstream hair snag to the most upstream hair snag was ~36 km. Sites occurred in riparian habitat where bears commonly travel, which is bounded to the east by the Interior Douglas-Fir biogeoclimatic zone of the Fraser Plateau–Western Chilcotin Ranges and to the west by the Coastal Western Hemlock biogeoclimatic zone of the Northern Pacific Ranges. The valley is steep-sided, bounded by cliffs and talus slopes with a pronounced floodplain along the Atnarko River. We actively monitored "ecotour" and "upstream" hair snag sites (Fig. 1) over 3 years during the late summer and autumn salmon runs (113 days in 2019 from 15 July to 5 November; 101 days in 2020 from 25 July 25 to 3 November; and 103 days in 2021 from 21 July to 1 November). Across years, crews sampled hair on average every 9 days ($\bar{x}$ = 8.6 days in 2019, $\bar{x}$ = 9.0 days in 2020, and $\bar{x}$ = 8.8 days in 2021), collecting 1806 samples. We subsampled high-quality samples (with abundant guard hair; n = 713) to identify individuals using genetic data (see below). Our sampling window (~14 weeks each year) represented a considerable portion (approximately two thirds) of the estimated active, non-denning period of grizzlies in this area (Blood 2003), and conflict samples were collected during the same summer and autumn months during which we conducted field sampling.

We defined conflict samples as those hair samples collected by British Columbia Conservation Officer Service (BCCOS) from captured (i.e., relocated or sent to rehabilitation) or euthanized bears. Specifically, BCCOS trapped or killed bears when there was perceived risk to safety and property, and often related to unsecured food attractants. We obtained these samples under a research agreement with the British Columbia Ministry of Forests, Lands and Natural Resource Operations Fish and Wildlife Branch, and genotyped them for potential matches with hair samples collected in upstream and ecotour areas. Specific spatial coordinates related to conflict samples from this "downstream" area were not available. Conflict samples were known to be attributed to (or in between) the communities of Bella Coola and Hagensborg, approximately 58 and 41 km downstream from the ecotour zone, respectively, and also occurring at the valley bottom (Fig. 1). We analyzed 15, 13, and 2 conflict samples that were collected from July to November in 2019, 2020, and 2021, respectively. These windows of conflict samples aligned with our hair-snagging deployment (above).

Fig. 1. Bella Coola and Atnarko valleys and surrounding areas, Nuxalk Territory. Map (A) displays the central coast of British Columbia, Canada, and the boundary encompassing the British Columbia Tweedsmuir Grizzly Bear Population Unit (GBPU), as well as the red rectangular "area of interest" denoting Map (B) (referred to in Results calculations). The black rectangle in Map B denotes the hair snag sampling array, which is displayed in Map (C). We genetically identified grizzly bears (*Ursus arctos horribilis*) that encountered conflict in the Bella Coola Valley ("downstream" conflict area; $n = 30$; orange circles denote jittered locations of sampling areas, all of which had unknown geographical coordinates but occurred in Hagensborg, Bella Coola, or in between) and via our hair snags upstream in the nearby Atnarko Valley ($n = 118$; white triangles and circles represent "ecotour" and "upstream" sites, respectively). Map attribution: ©Esri—Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community. Spatial Reference System EPSG:3005 - NAD83/BC Albers. Tweedsmuir GBPU and park shapefiles were retrieved from British Columbia Data Catalogue (British Columbia Ministry of Environment and Climate Change Strategy).

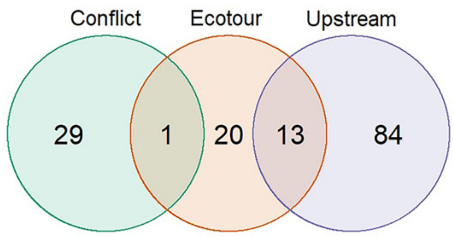


2.2 Genetic identification of bears detected via field sampling and conflict sampling

We screened for genetic matches between individual bears that encountered conflict in the Bella Coola Valley and grizzly bears we detected previously (in same or previous years) via hair snags further upriver. All samples from the field and among the conflict sampling set were sent to Wildlife Genetics International (Nelson, BC), where information from seven microsatellite loci plus a sex marker revealed individual identity, sex, and species from hair samples. The laboratory procedures and methods used to minimize genotyping errors are detailed in Paetkau (2003). Specimens collected via hair snags are vouchered at the Applied Conservation Science Lab, University of Victoria.

Among hair snag samples, we identified 118 grizzly bears (73 females and 45 males) along the Atnarko river. Of these 118 individuals, 34 (28%; 24 females, 10 males) were detected in the ecotour zone at least once. Thirteen ecotour bears (11%; 10 females, 3 males) were detected in the snags upstream of the ecotour sites, and another 84 (71%; 49 females, 35 males) exclusively upstream (Figs. 1 and 2). Of hair-snagged ecotour bears, 1 (female) of 34 (3%) encountered conflict in the Bella Coola Valley over our three-season sampling period. The other 29 individuals that encountered conflict (18

Fig. 2. Genetic matches between grizzly bears (*Ursus arctos horribilis*) detected via hair snags (at "ecotour" and "upstream" sites) and conflict sampling (from "downstream" areas composed of human communities downstream of ecotour area).



females, 11 males) had been detected at neither ecotour nor upstream hair snags in the Atnarko Valley (Fig. 2). Such a pattern suggests that ecotour bears are not commonly encountering conflict, but alone this approach does not consider the reality that the non-ecotour bear population is much larger, and that its relative size compared to the ecotour bear population could underlie the difference in proportions involved in conflict.

Given the distance between ecotour and downstream conflict areas, and to inform analytical considerations, we assessed the potential mobility of grizzlies in the region by drawing on our modest recapture data from genetically-tagged individuals ($n = 81$ recaptured individuals; Fig. S1). Specifically, we calculated the distance between the two furthest sites at which each recaptured individual was detected across years. To do this, we calculated the river network distance (i.e., distance along the linear river feature) to account for preferred travel routes by bears during the salmon spawning season. Our bear movement data suggest that the distances bears travel varies (Fig. S2), with some individuals detected across considerable distances (including the one individual that traveled the 47.8 km distance from the ecotour area to the downstream area of conflict), as well as individuals redetected within the "ecotour" and "upstream" areas (Figs. 1 and S2). Such a varied pattern among individuals supports our consideration of both assumptions: a freely-mixing population and a spatially-segregated population, composed of "upstream"/"ecotour" population and "downstream" sub-population.

3 Analysis

3.1 Accounting for uncertainty in raw detection data

3.1.1 Estimation of total "ecotour" population of grizzly bears

Recognizing that we might not have detected all individuals using the ecotour sites with hair snags, we used jackknife and bootstrap methods to estimate the total "population" of individuals using the ecotourism area. Specifically, whereas we assumed bears using ecotourism sites are well sampled by our hair-snagging approach and likely provide a representative account of individuals (see Wold et al. 2020), we nonetheless used the "vegan" Community Ecology R package version 2.6-4 to estimate the total extrapolated number of individuals using a species accumulation curve (applied to individuals, in our case). The curve illustrates how the number of unique individuals detected accumulates as additional sampling events are included. This method provides an estimate of the ecotour bear population by extrapolating the observed accumulation trend. Whereas this approach is commonly used to estimate the number of unobserved species and adding them to an observed species richness in a community (Palmer 1990), we applied this concept to resampling of individuals. Using this approach, the total number of ecotour bears as estimated by bootstrapping and jackknife ranged from 41.3 (SE = 1.9) to 49.8 (SE = 3.9), respectively, as estimated using the "specpool" function in the "vegan" Community Ecology R package. These estimation approaches suggested that the 34 ecotourism individuals identified comprised a large proportion (68%–82%) of the total number of bears subject to ecotourism, but there were likely individuals not detected for which we needed to account in subsequent analytical steps.

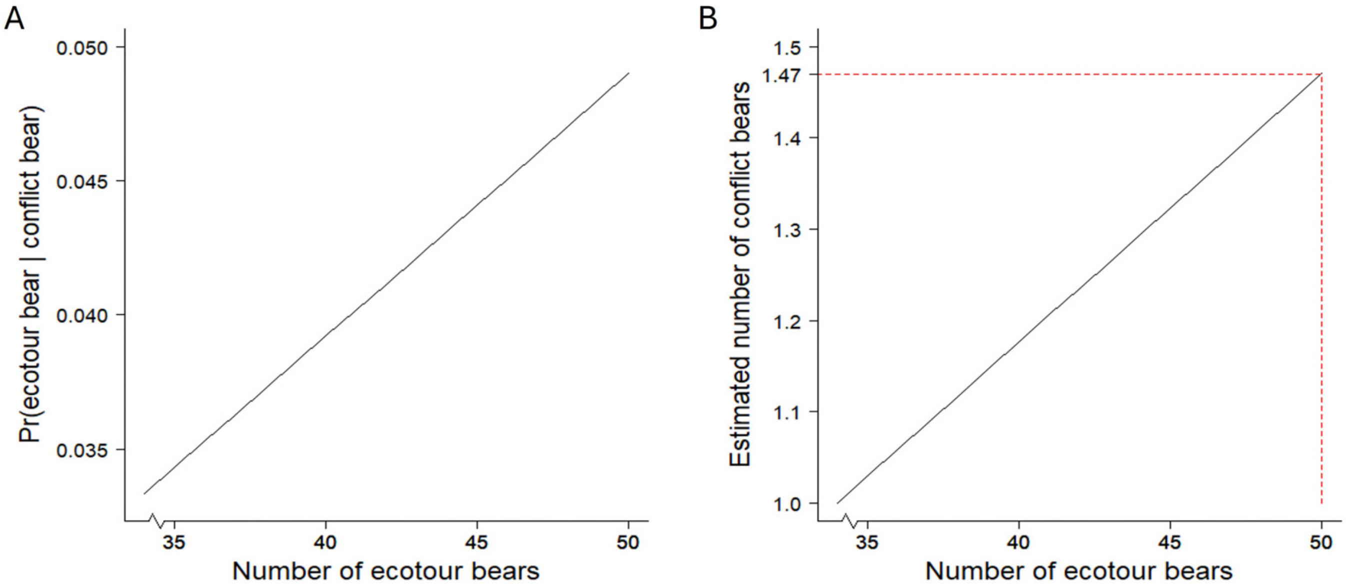
Some of the undetected individuals might arise from potential sources of biases in the form of possible differences in avoidance of hair snags among individuals. For example, Sawaya et al. (2012) reported that lure-scented hair traps under-sampled male brown bears but were unbiased for female brown bears and black bears (*Ursus americanus* Pallas, 1780) of both sexes. Beyond sex, detectability via non-invasive genetic sampling can also vary based on "trap-happy" and "trap-shy" responses following first capture (Zarnoch 1979), capture heterogeneity due to individual differences (Boulanger et al. 2008), and seasonal effects (Boulanger et al. 2004). In the absence of bait and with the use of a non-invasive sampling technique, however, we considered detection heterogeneity minimal, and unlikely that the detection of an individual would influence the likelihood of subsequent detections (Wirsing et al. 2018). Moreover, using paired camera and hair traps, Wold et al. (2020) found a high proportion of bear approaches to wires that led to contact with the wire, suggesting the hair sampling method is generally unbiased. Spatial effects may include samples that are biased to those individuals with home ranges that include or are centred on the river valley bottom, where probability of detection is a decreasing function of distance from home range centre (Efford and Mowat 2014). However, the Atnarko river features predictable patterns in salmon spawning timing during our sampling window (Connors and Atnarko Sockeye Recovery Planning Committee 2016) and we suspect few individuals of this highly mobile species would forgo this resource during hyperphagia.

3.1.2 Using Bayes' theorem to account for imperfect detection of ecotour bears

Whereas only one detected ecotour bear encountered conflict, our ability to identify bears that encountered conflict as ecotour bears is limited by our imperfect ability to detect all

Can. J. Zool. **103:** 1–11 (2025) | dx.doi.org/10.1139/cjz-2024-0102

Fig. 3. Output from Bayes' theorem calculations to account for up to 16 undetected ecotour grizzly bears (*Ursus arctos horribilis*) to estimate the probability that a grizzly bear is an ecotour grizzly bear, given that it engaged in conflict (Panel A); and the outcome of eq. 1 (see Materials and methods) over the 34 to 50 range of possible undetected ecotour grizzly bears required to estimate the expected number of grizzly bears that encountered conflict are also ecotour grizzly bears. At value of 50, we estimated that 1.47 ecotour grizzly bears were involved in conflict (Panel B), which we rounded to 2 in the subsequent probability analysis (below).



bears that used the ecotour zone (*Estimation of total "ecotour" population of grizzly bears*; above). To estimate how many of the 30 bears that encountered conflict could have used the ecotour zone, and reflecting our uncertainty in the true number of bears that used the zone, we used Bayes' theorem to estimate the probability that a bear is an ecotour bear, *given that it engaged in conflict*:

$$\mathrm{Pr(ecotour\ bear\ |conflict\ bear)} = \frac{\mathrm{Pr(conflict\ bear\ |ecotour\ bear)} \cdot \mathrm{Pr(ecotour\ bear)}}{\mathrm{Pr(conflict\ bear)}}$$

The probability of conflict given that a bear engaged in ecotourism, Pr(conflict bear | ecotour bear), is 1/34. This statement is based on our observation that 1 out of 34 detected ecotourism bears engaged in conflict. Pr (ecotour bear) is approximated by the number of bears that visited ecotourism relative to the unknown total population of bears. We detected 34 bears using ecotourism, but we drew upon the observation that there may have been up to 16 undetected ecotour bears (i.e., the difference between ∼50 individuals, as estimated by the higher jackknife estimation, minus the 34 individuals detected at ecotour sites). Finally, we estimated P (conflict bear) as the number of bears that engaged in conflict (i.e., 30), relative to the total number of bears in the population. If E is the number of ecotour bears from 34 (observed value of detected bears at ecotour sites) to 50 (highest estimate calculated via resampling) and N is the total number of bears in the population, the calculation becomes eq. 1:

$$(1) \qquad P\,(\mathrm{ecotour\ bear|conflict\ bear}) = \frac{\frac{1}{34} \cdot \frac{E}{N}}{\frac{30}{N}} = \frac{E}{34{\cdot}30} = \frac{E}{1020}$$

If the true number of ecotour bears (E) was 34, as observed, the probability that a bear had used the ecotourism site given that it engaged in conflict is 3.3%. At the upper level of the jackknife estimate of ecotour bears (E; i.e, 50), this probability increases to 5%. We repeated this calculation for all potential round numbers of ecotour bears between 34 and 50 (Fig. 3A).

At a value of $E = 50$, we estimated that 1.47 of the 30 bears involved in conflict were ecotour bears (Fig. 3B). Thus, even if 16 bears went undetected by our snags in the ecotour zone, the best estimate is that between 1 and 2 bears that encountered conflict were ecotourism bears. To correct for the possibility of falsely attributing all 29 non-ecotour conflict bears to the non-ecotour group, we repeated the probability approach based on the possibility that two (rounded from 1.47) of the 30 bears that encountered conflict could have been bears that used the ecotour zone but were not detected doing so (see Results).

3.2 Probability approach to estimate whether ecotour individuals occurred more by chance among conflict samples (Scenario 1)

We used a probability approach to ask whether ecotour bears were more or less represented among conflict samples than predicted by chance. We define "by chance" as the probability of ecotour bears encountering conflict being the same as the probability of those bears not detected in the ecotour area. Although our spatial data are limited, this approach assumes that ecotour bears and non-ecotour bears (detected genetically or not) collectively comprise a much larger, mobile population capable of occurring in towns, at ecotour sites, and the surrounding areas. We constructed a probabilistic argument by asking how large the unknown non-ecotour bear population would have to be to have observed at least 28 conflicts (the difference between 30 conflict samples minus an estimate of 2 ecotour individuals among these conflict samples) if the probability of conflict were equal to that observed with ecotourism bears (1 of 34).

To assess whether 28 non-ecotour bears could have been observed in conflict by chance given the observed rate of conflict among ecotour bears (1/34), we modelled the number of non-ecotour bears that encountered conflict, X, as a binomial random variable. The probability of conflict is given by the observed proportion of conflict among ecotour bears (1/34), and the true non-ecotour bear abundance, N, which is unknown.

$$X \sim \text{Binomial}\,(N,\,1/34)$$

The cumulative distribution function (CDF) of X, $F_x(x)$, describes the probability that random variable X takes a value less than or equal to x:

$$F_x\,(x)\;=P\,(X\leq x)$$

Accordingly, we computed $1 - F_x$ (27) to determine the probability that at least 28 non-ecotour bears engaged in conflict while varying the unknown non-ecotour bear abundance, N.

3.2.1 Drawing on population density estimates for reference points

To provide reference points for comparing bear abundance along the CDF, we drew on available density estimates for grizzly bears in the region. How many additional and unsampled individuals occurred in sampled and unsampled regions in the "area of interest" and the much larger Tweedsmuir Grizzly Bear Population Unit (GBPU) was key to interpretation. Specifically, we considered the possibility that so few ecotour individuals encountered conflict because the total population of bears, composed of individuals equally likely to encounter conflict, was sufficiently large so that the relatively small number of ecotour bears could have occurred by chance given the potentially larger number of bears not detected at ecotour sites. That is, with high bear abundance beyond the ecotour sites, more conflicts would be expected in this group, but this does not necessarily indicate a higher frequency of conflict among non-ecotour bears.

We drew on density estimates from the grey literature and in a manuscript undergoing peer review. The former reported a point estimate, based on provincial government expert model (22 bears/1000 km^2; Environmental Reporting British Columbia). We applied this density estimate to an area within the Tweedsmuir GBPU that is attributed by the province as "area of usable habitat" (Environmental Reporting British Columbia; ∼16 663 km^2), which excludes "fresh water", "salt water", "glaciers and snow" as delineated by the province's *Baseline Thematic Mapping Present Land Use Version 1 Spatial Layer*. We also applied this density estimate to a smaller region (∼2460 km^2), which we refer to as our immediate "area of interest" (rectangle in Fig. 1), which roughly centred our samples and was bounded by topographic features that define the greater Bella Coola and Atnarko river valleys and some of their tributaries. Across these same two scales, we also considered a lower but empirically-derived mean estimate of density (10.2/1000 km^2; 95% CI: 9.6–11.1) from an 28 500 km^2 area of the central coast of British Columbia, which included our area of interest, some of the Tweedsmuir GBPU, and adjacent areas to the northwest (Artelle et al.[1]).

3.3 Fisher's exact test (Scenario 2)

We used Fisher's exact test to examine whether there was an association between conflict occurrence and bear type (i.e., ecotour and non-ecotour bears). This approach relied on the assumption that ecotour and non-ecotour bears comprised a population in a region distinct from the area where conflict occurs. This test was appropriate for our data given small sample size and low occurrences of conflict events among ecotour (1 of 34) and non-ecotour bears (0 of 84). We created a 2 × 2 contingency table to categorize the data according to bear type and conflict occurrence, and tested the null hypothesis that there was no association between bear type and conflict occurrence.

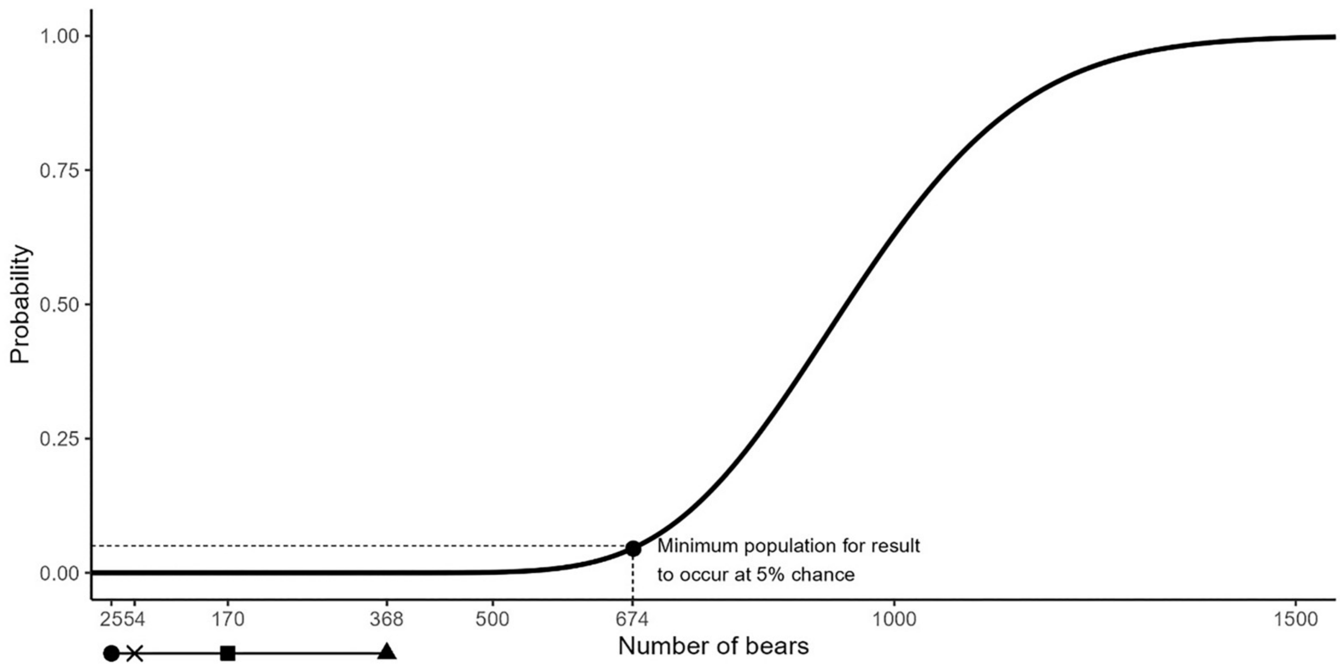
4 Results

Our approach considered the premise that so few ecotour individuals occurred as conflict bears because the total population, composed of individuals equally likely to encounter conflict, was sufficiently large so that the relatively small number of ecotour bears could have occurred randomly and at no greater proportion than among bears not detected at ecotour sites. If non-ecotour bears encounter conflict at the observed rate of 1/34 for ecotour bears, our results suggested that the probability of observing at least 28 non-ecotour bears that engaged in conflict is nearly zero when true bear abundance is low; the probability increases to 5% as bear abundance reaches 674 bears (Fig. 4). That is, the unknown non-ecotour bear population would have to be 674 to have observed at least 28 conflicts if the probability of conflict were equal to that observed with ecotourism bears (1 of 34).

We assessed how this 674 bear scenario (the estimate under which we would expect the pattern we observed to have occurred by chance) compared to a range of plausible estimates for population size calculated at two scales and using two information sources on density (Materials and methods). Drawing on these estimates, the number of bears in a total population across this variation in density and scale poten-

[1] Artelle K., Sun, C., Bourbonnais, M., Reynolds, J., Darimont, C. Unpublished manuscript. Combining Spatial Capture-Recapture and Network Analyses to inform land-use planning: insights from grizzly bears in the Great Bear Rainforest.

Fig. 4. Cumulative distribution function used to compute the hypothetical number of non-ecotour grizzly bears (*Ursus arctos horribilis*) that would need to comprise the population in order for 28 of 30 conflict grizzly bears to have not been associated with ecotourism, given the observed proportion of 1 of 34 ecotourism grizzly bears engaged in conflict (i.e., the "Results" annotated above). For this probability to exceed 5% (dashed reference line), the non-ecotour grizzly bear population would have to be greater than 674, which greatly exceeds the plausible range of grizzly bear abundance. Solid reference line below the *X*-axis represents a range of population estimates among grizzly bears potentially encountering conflict: circle and square = derived from empirical density estimate from the central coast of British Columbia (Artelle et al.), applied to our area of interest (~2460 km^2) and Tweedsmuir Grizzly Bear Population Unit (GBPU) (16 663 km^2) (Province of British Columbia Data Catalogue); x and triangle = derived from point density estimates by provincial government (Environmental Reporting BC), applied to our area of interest and Tweedsmuir GBPU.



tially subject to conflict varied from 25 to 368 bears. Even the highest estimate, derived from calculating over an enormous area over 16 000 km^2 (far beyond the spatial capability of lifetime movements by males), was only approximately half the 674 bear scenario under which we would expect the pattern of ecotour bears involved in conflict to have occurred by chance (Fig. 4).

In analysis Scenario 2, we used Fisher's exact test to determine whether the observed differences in conflict rates between ecotour and upstream bears were statistically significant. This complementary approach, which considered the sampled bears only and simply assessed the relationship between bear type (ecotour and non-ecotour) and the occurrence of conflict revealed no evidence of association (Fisher's exact test; $p = 0.288$). The 95% confidence interval for the odds ratio ranged from 0 to 15.79 with an estimated odds ratio of 0. Simply put, this tells us that there are similar conflict rates across both ecotour and upstream groups of bears.

5 Discussion

Our findings revealed no support for the hypothesis that bears that experienced ecotourism were later likely to encounter conflict. Our genetic screening approach identified only a single bear that encountered conflict among the 34 samples that were associated with ecotourism. Likewise, our probability approach, which considered the larger area's population (Scenario 1) as well as the uncertainty in the number of total bears exposed to ecotourism, offered no evidence of ecotourism predisposing bears to subsequent conflict. In fact, owing to the large difference between the range of population estimates and a calculated population at which it is possible that the pattern we observed arose by chance, ecotourism bears in fact appear as conflict individuals less than that predicted by chance. Finally, the Fisher's exact test applied to Scenario 2 suggested no association between bears exposed to ecotourism and those later detected among conflict samples.

There are several explanations for these results. First, those individuals involved in conflict might simply have home ranges that include a higher proportion of human-dominated areas (and far downstream of ecotourism areas). In other words, its unsurprising that individuals present at ecotourism sites in the Atnarko Valley did not frequent areas in the downstream Bella Coola Valley, and thus be subject to conflict. We recognize, however, the large movement ability of grizzlies, especially of males, and that rural properties and townships (sites of conflict) exist in, and all along, the valley bottoms, making long-distance travel less energetically-expensive. Moreover, the distance from the ecotour area to Hagensborg and Bella Coola (~41 and 58 km, respectively) falls well within potential travel distances inside the home range of both male and female grizzly bears in coastal temperate rainforests (MacHutchon et al. 1993), especially considering the relatively easy movement along riparian routes. Accordingly, we find this simple spatial explanation plausible but not entirely comprehensive in that by itself it cannot exhaustively discount the hypothesis that ecotour bears are more likely to encounter conflict. Accordingly, we also took a conservative approach, which incorporated uncertainty, by rounding up the number of ecotour bears potentially involved in conflict, and considered even the very highest estimates of the entire bear population in our probability framework. Despite these steps, which increase the likelihood of detecting evidence for an association between ecotourism and conflict, no such evidence emerged. In fact, our results suggested bears that used the ecotour zone were in fact less likely to encounter subsequent conflict.

Although our data can neither support nor refute the following interpretation, we also consider an explanation related to the relationship between food acquisition and risk-taking. Specifically, ecotourism and upstream sites occur at particularly dense aggregations of spawning salmon in the Atnarko River (Atlas et al. 2021). Accordingly, we speculate that bears that access the area can acquire the foods they require during the energetically-demanding season, and need not search for human-associated resources in the downstream communities, which are a considerable distance away. We speculate that this may provide an explanation for not detecting upstream bears in conflict. Such an explanation aligns with theory in that conflict patterns are driven by regional food supply (Gunther et al. 2004; Baruch-Mordo et al. 2014; Artelle et al. 2016).

There are several limitations to our approach. One, it is possible that those individuals more likely to be detected via hair snags might be somehow less likely to engage in conflict. We find this unlikely, given that hair snags themselves might be perceived by bears as human-associated items. On the other hand, hair-snagging can miss cubs with heights less than their 0.5 m arrangement, and these cubs—which mature around ecotourists—might be later prone to encounter conflict. We also find this explanation unlikely, given the typical 3-year association between mothers and cubs combined with the 3-year duration of this study. An additional limitation is the possibility that not all bears that encountered conflict were reported to BCCOS. We acknowledge that the conflict samples originated from a subset of all bears that encountered conflict with humans. We have no reason to believe, however, that this subset could have been skewed to include disproportionately more or less individuals subject to ecotourism. Future studies may consider conducting interviews to estimate the proportion of individuals that are reported within the total population of bears that encounter conflict. We also acknowledge the possibility that we did not detect all ecotour bears, and that an underestimate of ecotour bears could reflect an underestimate of the number of ecotour bears involved in conflict. To account for this uncertainty, our probability approach was based on the possibility that two (rounded from 1.47; see *Using Bayes' theorem to account for imperfect detection of ecotour bears*) of the bears that encountered conflict could have been unobserved ecotour bears. Finally, heterogenous distributions of wild and human-associated foods across the landscape may drive movement and thus differentially predispose grizzly bears to conflict. Although we recognize that movement patterns by individual bears may predispose some individuals to encountering conflict, our presence-only data, gathered from hair snags exclusively deployed in the ecotour areas and those further upstream (i.e, further from downstream conflict areas; Fig. 1), provide only limited inference into bear movement. Future studies may therefore consider incorporating resource availability data in analyses, and sample bears across a broader extent of the landscape (i.e., including in areas immediately adjacent to areas of conflict, as well as in ecotour and upstream areas). Such a study design, which would aim to yield insight into the spatial origin of bears that encounter conflict, might use a grid hair snag array throughout the area of interest, rather than a linear hair snag array along the valley bottom.

Our probability approach relied on a central assumption. Namely, we assumed that all individuals within the "area of interest" (Fig. 1) could encounter both areas with ecotourism and where conflict occurred. Our result was conservative in that we considered an area as large as the Tweedsmuir GBPU (16 663 km^2, compared with our area of interest of 2460 km^2), which estimates about half the grizzly bear abundance as the minimum population required in order for our result to have occurred by chance, as derived from our probabilistic approach. We acknowledge that our approach is constrained by a lack of behavioural data on genetically-identified individuals. For example, we do not have information on the personality traits, measures of potential tolerance, or past experiences of the bears in our study. This limitation means that we cannot directly assess the extent to which individual behavioural tendencies contributed to the likelihood of conflict.

Our finding that ecotourism does not appear to contribute to conflict in this region might not be the case in other contexts. Human behaviour and characteristics of ecotourism management, for example, could influence outcomes. For example, ecotourism that provisions food to wildlife has been shown to increase habituation and aggression, exacerbating human–wildlife conflict in communities (Cui et al. 2021). Although food provisioning is prohibited by law in our study area, supplemental feeding of bears at ecotourism sites occurs in Europe with unclear implications for "nuisance-bear" behaviour (Penteriani et al. 2017). Broadly, climate's role in habitat suitability, as well as resource abundance, distribution, and phenology can propagate climate change as a contributing factor in human–wildlife conflict. Examples include severe drought eliciting crop raiding by elephants (*Loxodonta africana* (Blumenbach, 1797)), and delayed sea ice freeze-up driving human–polar bear (*Ursus maritimus* Phipps, 1774) conflict (see review in Abrahms et al. 2023).

We speculate that social dimensions beyond our data underlie conflict dynamics in our case study. Specifically, the abundance and dispersion of human-associated food attrac-

 Can. J. Zool. **103:** 1–11 (2025) | dx.doi.org/10.1139/cjz-2024-0102

tants is likely important in the Bella Coola Valley bottom. Indeed, grizzly–human conflict in other areas is associated with persistent anthropogenic attractants (Wilson et al. 2006). Responding to this challenge, the Nuxalk Nation Bear Safe Program and other community organizations (for example, WildSafe BC, Bella Coola Valley Tourism) have delivered education as well as non-lethal and preventative approaches, for example installing electric fences around high-reward attractants like salmon-cleaning stations and fruit trees (Artelle et al. 2021). More broadly, sociopolitical context is also likely influential. Conflict between humans and wildlife often involves human–human conflicts among different groups and includes dynamics related to perceived threats to lifestyles, values, and world views (Nyhus 2016). Moreover, wildlife ecotourism has been shown to mitigate human–wildlife conflict through improved attitudes towards wildlife, particularly if the benefits it accrues are equitably distributed in communities adjacent to the protected areas within which ecotourism occurs (Maheshwari and Sathyakumar 2019). Mitigation of conflict may thus be more complex in regions like the Bella Coola Valley where historical or cultural complexities related to settler colonization, dispossession, and commercialization predispose communities to conflict in varying ways.

More broadly, the methodological and conceptual approaches we used engaged multiple aspects of previous human–wildlife conflict research. Specifically, whereas much of the previous human–wildlife conflict work has used genetic analyses to identify which species were involved in conflict (e.g., Caniglia et al. 2013; Plumer et al. 2018, though see Morehouse et al. 2016), our analysis genetically identified individuals to focus on within-species, individual variation in conflict and ecotourism encounters. An examination of individual body condition, age, and life experiences of individuals would further enrich our understanding of conflict drivers. Conceptually, human–wildlife conflict research conducted in or adjacent to protected areas sometimes reflects human–human conflict (human disagreements over wildlife management decisions) (Peterson et al. 2010). This work may thus be informative during community dialogue about conflict drivers and mitigation. Specifically, our results suggest wildlife ecotourism does not appear to contribute to conflict in this area.

Acknowledgements

This work was conducted in the unceded Territory of the Nuxalk First Nation. Thank you to the director and managers from Nuxalk Stewardship Office at the time of the project (Sam Pascoe and Rhonda Morton) and BC Parks (Steve Hodgson, Lori Homstol, and Rae Busse) for continuous support throughout the years. Special thank you to Steve Hodgson for thoughtful review and feedback on the manuscript. A special acknowledgement to the Nuxalk Stataltmc (Hereditary Chiefs) supporting ongoing bear work following the signing of the Grizzly Bear Protocol on 12 November 2011 at Snuxyaltwa's (Deric Snow's) Potlatch. The work would not have been possible if it were not for contributions from Nuxalk Fisheries and Wildlife staff (Kelly Milton, Shanti Tallio-Milton, Ron Schooner, and Quentin Hans), including sharing of in-depth knowledge of the river to guide our study design. Thank you to Nuxalk Coastal Guardian Watchmen for in-field assistance collecting hair. The field research assistants (Andrew Sheriff, Emina Ida, Sean Murray, and Nina Sylvester) and volunteers of the Raincoast Applied Conservation Science Lab were integral to the success of the project. Thank you to ecotour operators, Snootli Hatchery crews, and Department of Fisheries and Oceans crews for working alongside us during the data collection stages of the project. Thank you to Shelley Marshall and British Columbia Ministry of Forests, Lands and Natural Resource Operations Fish and Wildlife Branch for coordinating sample sharing from bears that encountered conflict. Thank you to Belarko Wildlife Viewing Platform staff, BC Parks Rangers, and many community members who housed and worked with us throughout the project.

Article information

History dates

Received: 17 June 2024
Accepted: 12 September 2024
Version of record online: 14 January 2025

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Data availability

Code and data to reproduce this study's results are available in the following GitHub repository: https://github.com/ACSLabUVic/conflict-analysis. Raw data generated during this study are not publicly available due to research agreement with the Nuxalk Nation and British Columbia Ministry of Forests, Lands and Natural Resource Operations.

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Competing interests

The authors declare there are no competing interests.

Funding information

This project received funding from The Natural Sciences and Engineering Research Council of Canada (PGS-A Fellowship to KAF and Discovery Grant to CTD), Raincoast Conservation Foundation, the SkyeMikko Foundation, BC Parks License Plate Program, with in-kind support from the Nuxalk Stewardship Office.

Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/cjz-2024-0102.

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