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Running header: Aural detection methods to survey pikas
Efficacy of aural detection methods for detecting Northern Pika (Ochotona hyperborea)
occupancy in rocky and densely vegetated habitats
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19 Teaser text: Pikas are considered vulnerable to warming climates, but detecting their
20 presence in rocky patches covered by dense vegetation is challenging. Here, we assessed the
21 efficacy of aural detection methods, namely auditory observation and playback, to survey
22 Northern Pikas in Japan.

23

24 Wildlife monitoring plays a key role in species conservation, with growing importance under 25 the threat of climate change. The Northern Pika (Ochotona hyperborea) is a cold-adapted 26 species found in Hokkaido, Japan, presumably vulnerable to such threats. However, its high 27 elusiveness hinders detailed population surveys, and visual detection methods-often used for 28 other pika species—are not applicable to its densely vegetated habitats. In this study, we 29 assessed the efficacy of aural detection methods to survey the occupancy of Northern Pika 30 through their distinct vocalizations. We conducted two types of point-count surveys-31 auditory observation and playback—during 2021 at 18 sites in and around Daisetsuzan 32 National Park. We then assessed the efficacy of these methods in detecting presence and 33 compared time until first detection of the animal. The Northern Pika was present at 11 of all 34 surveyed sites, with a predominance at higher elevations. Our results suggest that both 35 auditory observation and playback are effective at detecting presence, but playback is more 36 time-efficient. We discuss the advantages and disadvantages of each method given these 37 results. In conclusion, our results demonstrate that both survey methods are applicable for 38 Northern Pika population surveys-even in densely vegetated habitats-representing valid 39 and affordable survey methods that can help to improve current monitoring and conservation 40 efforts, and will be of increasing value given potentially negative effects of climate change on 41 persistence of the species.

42

- 43 Key words: aural detection, auditory observation, Northern Pika, playback, wildlife
- 44 monitoring
- 45

46 Cumulative evidence suggests that wildlife populations are declining globally, and monitoring 47 has been critical in detecting such changes (Collen et al. 2009; Almond et al. 2020). 48 Understanding the drivers of these declines poses a significant challenge informing 49 conservation policy and managing wildlife populations adaptively under global environmental 50 changes (Yoccoz et al. 2001; Di Fonzo et al. 2016). However, some species are more elusive 51 to detect than others (Thompson 2004), making monitoring surveys of rare and elusive 52 species prone to inaccurate detections and hindering our ability to obtain unbiased estimates 53 of occupancy and abundance.

54 Pikas are small lagomorphs found at high latitudes or altitudes in Asia and North 55 America. Because of their adaptation to cold environments (Yang et al. 2008; Wang et al. 56 2020), they are considered to be vulnerable to warming climates (Beever et al. 2011; Billman 57 et al. 2021). Therefore, efforts to monitor the status of pika populations are needed to better 58 understand how climate change affects population distribution and abundance. However, 59 some pika species are highly elusive given their preference to live in rocky patches (Henry 60 and Russello 2011), and while research exists for the American Pika (Ochotona princeps), it 61 is lacking for many of other rock-dwelling species. This is true for the Northern Pika 62 (Ochotona hyperborea), a species found in northeastern Eurasia that has the widest 63 distribution among all pika species (Smith et al. 2018). Although a recent study in the eastern 64 subspecies O. h. vesoensis in Hokkaido, Japan suggested its vulnerability to climate change 65 due to thermal constraints (Sakiyama et al. 2021), the effects of climate change on local 66 populations remain largely unknown. An absence of population studies on the Northern Pika 67 in Hokkaido is not only due to its habitat preference for rocky patches, but also to the dense 68 vegetation that covers their rocky habitats. Moreover, most habitats are located on steep 69 slopes, making accessibility and site navigation extremely difficult and time-consuming.

70 Therefore, establishing robust yet affordable methods to assess the occupancy of Northern 71 Pikas in Hokkaido and localities with similar habitat characteristics are needed. 72 Previous studies have surveyed the occurrence of rock-dwelling pikas either by 73 detecting sign of animal presence visually or aurally, or indirectly through presence of feces 74 and haypiles (Beever et al. 2010; Erb et al. 2011; Stewart et al. 2015; Hall et al. 2016; 75 Korolev 2017). Such multiple-evidence approaches likely aid in detecting the presence of this 76 elusive animal, but the major assumption of the survey (although not mentioned) is that the 77 visibility and navigability of the study sites allow for detection of these signs. This 78 assumption, however, does not apply to the environments found in Hokkaido because of the 79 aforementioned difficulties. 80 Here, we advocate instead for the use of survey methods based solely on aural detection 81 as an affordable and reliable alternative, and test their utility in the Hokkaido locality. 82 Northern Pikas are highly vocal, and their vocalizations are detectable from distant locations 83 (up to 200 m; Kawamichi 1969) even when the vocalizing individual is not visible 84 (Kawamichi 1970). Moreover, vocalizations are heard frequently during and after the 85 reproductive season (Kawamichi 1971), permitting population surveys in the snow-free 86 season (i.e., summer) even though their habitats-typically located in remote settings such as 87 deep forests and alpines-are inaccessible at other times of the year. Previous efforts have 88 been made to survey a Northern Pika population based on their vocalizations (Korolev 2017), 89 but that survey was conducted only at sites of known presence since the study focused on 90 abundance estimation. Occupancy surveys, in contrast, aim to establish whether the Northern 91 Pika is present or absent at a given site. 92 We conducted field experiments to evaluate the efficacy of two aural detection 93 methods-auditory observation and playback-for establishing occupancy of Northern Pikas

94 in Hokkaido. Auditory observation refers to a passive survey that involves listening to

95	naturally occurring vocalizations and is the most commonly used aural detection method for
96	pikas (Billman et al. 2021). Playback uses acoustic cues to trigger vocalizations from the
97	target animal, enabling detection of their presence. The playback method has been often used
98	in avian studies (Conway and Gibbs 2005; Kawamura et al. 2016); however, recent studies
99	have applied it to survey mammals including ungulates (Enari et al. 2017) and primates
100	(Dacier et al. 2011; Gestich et al. 2017). Several studies have used playback with pikas
101	(Somers 1973; Conner 1983, 1985a; b; Trefry and Hik 2009), but for purposes related to the
102	communicative nature of vocalizations rather than for conducting population surveys. Studies
103	applying the playback method to survey pika populations are scarce, with only two small-
104	scale studies using it to assess the occupancy of the Northern Pika in Hokkaido (Ieiri and
105	Yanagawa 2009; Sato et al. 2009), although they did not detail their description of method
106	and efficacy, and did not objectively contrast results with the auditory observation approach.
107	To fill this research gap, we: (1) compare the efficacy of auditory observation and
108	playback to survey the occupancy of the Northern Pika; and (2) further investigate how
109	acoustic cues in playback promote species detection.
110	
111	MATERIALS AND METHODS
112	Study area.— We conducted our study in Daisetsuzan National Park and the
113	surrounding forests in the Tokachi region of Hokkaido, the northernmost island of Japan. We
114	selected 18 rocky patches on talus slopes as study sites in June 2021 because rock interstices
115	found within this landform are the primary microhabitats for Northern Pikas (Fig. 1). The
116	study sites (elevation range 350-2200 m) were selected to cover to the greatest possible extent
117	the known elevational distribution, ranging from 50 m (Kawabe 1990) to 2200 m (Onoyama
118	and Miyazaki 1991). Vegetation changes across this wide elevational gradient, ranging from
119	primarily forest vegetation at lower elevations to alpine vegetation at higher elevations. Based

120 on differences in the structure and amount of vegetation types, we classified the study sites 121 into higher (n = 9) and lower (n = 9) elevation sites (Fig. 1; Sakiyama et al. 2021). 122 All procedures in this study were conducted with the permission of the Hokkaido 123 Regional Forest Office and Daisetsuzan National Park (Permit numbers 2106071 and 124 2106072) and followed the American Society of Mammalogists guidelines (Sikes et al. 2016). 125 Occupancy survey.—Surveys were conducted at each site every month between July 126 and September 2021 because Northern Pikas in Hokkaido emit vocalizations frequently 127 during these months and the sites are not covered with snow. Surveys were conducted on both 128 clear and cloudy days, in the morning between 05:00 and 10:30 when pika activity is 129 reportedly highest (Kawamichi 1971). 130 To detect the presence of Northern Pikas, we conducted two point-count aural detection surveys using both auditory observation and playback approaches. Auditory observation 131 132 consisted of listening to the natural vocalizations of the Northern Pika without intervention. 133 By contrast, playback involved the broadcast of a prerecorded pika vocalization as a cue to 134 elicit responding vocalizations. Upon arrival at each site, we remained silent and inactive for 135 10 min to reduce the possibility of human arrival stimulating pikas to vocalize. After this 136 initial waiting period, we conducted auditory observation first, followed by playback. 137 Nonetheless, pika vocalizations detected prior to the survey upon arrival at the site were also 138 recorded as a baseline to assess the efficacy of auditory observation and playback. For both 139 methods, we listened to vocalizations in a fixed facing direction (upslope or downslope) and 140 recorded the following information for each detected vocalization activity: (i) time from start 141 of the survey (time after the broadcast ended in the playback); (ii) vocalization type (see next 142 section); and (iii) direction at 10-degree intervals (all surveys were conducted by T. 143 Sakiyama). The survey timeframes were 50 min for auditory observation and 5 min for 144 playback. Auditory observation was longer because lack of intervention could delay the first

detection, whereas we expected a much quicker detection for playback. After the survey, site
occupancy was marked as present if any type of Northern Pika vocalization was detected and
absent if not.

148 For playback, we broadcast an audio file from a monophonic audio speaker (JBL 149 CHARGE4, JBL, California, USA; frequency response 60-20,000 Hz) as a cue to provoke 150 vocalizations from individuals. The audio file consisted of three repetitions of a Northern Pika 151 'song' (also known as 'long call'; Kawamichi 1981), each played with the speaker facing in 152 three directions perpendicularly (leftward, forward, and rightward relative to the facing 153 direction) to cover the entire study site. While the vocalization type used for playback was not 154 mentioned in previous studies (Ieiri and Yanagawa 2009; Sato et al. 2009), we used the song 155 as a cue because we successfully heard responding vocalizations in a preliminary trial when 156 using this type of call (T. Sakiyama, personal observation). We conducted surveys at a 157 monthly interval to prevent pika individuals from habituating to recorded vocalizations 158 (Trefry and Hik 2009). The song was prerecorded using a stereophonic audio recorder 159 (Olympus LS-P4 Linear PCM Recorder) located 5 m from a Northern Pika individual. After 160 successfully recording the song, we reduced external noise in the audio, modified the song 161 length from six elements (as defined in Kojima et al. 2006) to ten elements to enable longer 162 broadcast, and created an audio file comprising of three repeats of the song with an 163 approximate total duration of 30 s long. Both modification and creation procedures were 164 conducted using Audacity v. 3.0.0 (Audacity Team 2021). The spectrogram of a single song 165 and the audio file of the playback are available in Supplementary Data SD1 and SD2, 166 respectively.

In aural detection, including both auditory observation and playback, the auditory
capability of a surveyor may bias the quality of occupancy detection. Therefore, each
surveyor underwent preliminary training to locate pika vocalizations by ear, and we evaluated

170 the auditory capability of the surveyor in locating the sound source (distance and direction) in 171 a test experiment in order to confirm that a surveyor was efficient in detecting the Northern 172 Pika vocalizations at different directions and distances (see Supplementary Data SD3). 173 Moreover, Northern Pikas could have been more detectable from the front than from the back 174 during the actual surveys because the surveyor faced one fixed direction in the talus patch 175 during the surveys. To assess if such directional bias was introduced, we created histograms 176 of the direction from which vocalization activity was detected for both auditory observation 177 playback surveys. We counted the number of surveys that detected vocalization activities for 178 each direction over the three sessions across sites and used it as the frequency. 179 Vocalization type classification.—The Northern Pika is known to emit various types of 180 vocalizations (Kawamichi 1981; Lissovsky 2005), and therefore, we distinguished the 181 vocalization types by ear in the surveys. However, there has been high ambiguity in the 182 terminology of each vocalization type in previous literature. For example, Kojima et al. 183 (2006) followed terminologies in Kawamichi (1981), but Lissovsky et al. (2021) followed a 184 different terminological system (Lissovsky 2005; described in Russian). To minimize 185 potential ambiguities, we consider literature descriptions of qualitative and quantitative 186 characteristics of vocalization types as follows: the 'long call' described in Kawamichi (1981) 187 matches the 'song' described in Lissovsky (2005); the 'short call' in the former matches the 188 'alarm call' in the latter; the 'trill' in the former equals the 'chirring' in the latter. Although 189 we could not obtain detailed information on function and spectrogram for the 'submission 190 call' in Kawamichi (1981) and the 'trill' in Lissovsky (2005), we did not detect these types in 191 our surveys. Therefore, we only considered the three aforementioned vocalization types in our 192 study, all being detectable by human ear (further detail in Supplementary Data SD4). 193 The detectable range of vocalization activities varied depending on the type of vocalization-'long call/song' and 'short call/alarm call' were detectable from a distance of 194

195 100 m, whereas 'trill/chirring' was only detectable from a distance of 25 m or closer. Our 196 detection range is more conservative than that of Kawamichi (1969; i.e., 200 m) because those 197 ranges probably were attained under optimal ambient noise conditions. Given that our surveys 198 were occasionally conducted in windy conditions (≤ 6.0 m/s) and cicada singing background 199 noise (< 60 dB), we elected to use a conservative detection range of 100 m from the site 200 center in our surveys.

201 Statistical analysis.—To compare the efficacy of aural detection methods, we analyzed 202 the accuracy of each method with respect to time spent on the survey by creating confusion 203 matrices and computing the true positive rate and accuracy. True positive rate (also referred to 204 as sensitivity) indicates the probability of a method detecting presence at sites that are truly 205 occupied by the pika. Accuracy indicates the probability of a method detecting the true status 206 of occupancy (i.e., present or absent) at each site. The true status of occupancy at a site was 207 based on the overall combined results from all surveys over the season. Here, we assumed that 208 our overall surveys could detect the true status of occupancy at each site and that it did not 209 change during survey season (i.e., closed population setting). However, this assumption might 210 not hold true because, according to one study, the Northern Pika disperses from late July 211 through August (Kawamichi 1971), which overlaps with our survey season. Therefore, we 212 also examined how the number of sites detected changed over time. Since the timeframe 213 differed between auditory observation and playback (50 and 5 min, respectively), we divided 214 each auditory observation survey record into 10 survey periods of 5 min each and computed 215 true positive rate and accuracy of detection for each.

We compared the time until first detection between auditory observation and playback methods to understand how intervention of the playback broadcast promoted their response. We used the detection result from the first survey period for auditory observation to match the timeframe of the playback survey, and used only those cases where both methods succeeded

220 in detecting the animal. We compared time until first detection using a generalized linear 221 mixed model with a negative binomial distribution. We selected this distribution because our 222 data included zero values (i.e., 0 s when detected) and because overdispersion was detected 223 when data were first analyzed using the Poisson distribution. We fitted time of first detection 224 as the response variable and methods (i.e., auditory observation and playback) as categorical 225 explanatory variables. The intercept in the linear predictor was omitted from the model and 226 site was included as a random intercept. We interpreted the difference between methods as 227 significant if the 95% confidence interval of the prediction did not overlap.

All statistical analyses were conducted using R 4.1.2 (R Core Team 2021). Confusion matrix analysis was conducted using the *caret* package (Kuhn 2008) and mixed model analyses were conducted using the *lme4* package (Bates et al. 2015).

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- 232

RESULTS

233 We detected Northern Pika at 11 of the 18 sites from the occupancy surveys, with eight sites 234 corresponding to higher-elevation and three to lower-elevation sites (Fig. 1). The highest 235 elevation among the present sites was 2220 m at Mt. Hakuun, which corresponds with 236 previous reports (Onoyama and Miyazaki 1991). On the other hand, the lowest was 470 m 237 along the Horoka-Piribetsu river, which to our knowledge has previously not been reported as 238 Northern Pika habitat. The occurrence of Northern Pikas indicated a positive spatial 239 autocorrelation pattern, where present and absent sites were found relatively close to other 240 present and absent sites. We often detected presence upon arrival at the site in higher 241 elevations in early summer. In contrast, such cases were uncommon at lower elevations, with 242 lower-elevation sites necessitating the use of auditory observation or playback surveys to 243 detect presence most of the season (Supplementary Data SD5). Among the different 244 vocalization types, 'long call/song' and 'short call/alarm call' were more frequently heard

than 'trill/chirring' for all months at both higher and lower elevations (Supplementary DataSD6).

247 Confusion matrix indices revealed that detection accuracy changed according to survey 248 duration for the auditory observation method. When duration increased from the shortest (5 249 min) to the longest (50 min) setting, the true positive rate increased from 0.606 to 0.909 and 250 accuracy increased from 0.759 to 0.944 (Fig. 2). Both indices initially changed drastically 251 over shorter survey durations, reaching a plateau around the sixth survey period, 252 approximately 30 min after the survey was started. For playback, which was conducted for 253 only 5 min, the true positive rate and accuracy were 0.879 and 0.926, respectively. We found 254 that values from playback are comparable to those of the longest duration setting of the 255 auditory observation method (Fig. 2).

The time at first detection of Northern Pika vocalizations was statistically significantly shorter for playback than auditory observation (Table 1, Fig. 3). First vocalizations—recorded using playback—were detected 23.8 s after the audio was played on average, whereas they were detected after 127.6 s with auditory observation.

During auditory observation surveys, Northern Pika vocalizations were detected more frequently from the front side than the back side for 'short calls/alarm calls'. However, in other cases, detections were oriented sideward (i.e., left and right sides), which differed from our initial expectations. Detection of 'trill/chirring' was rare during our surveys (Fig. 4, Supplementary Data SD6).

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DISCUSSION

In this study, we compared the performance of two aural methods for detecting presence of the Northern Pika by listening for their vocalizations. Our results showed that both auditory observation and playback are highly and comparably effective in detecting presence. And while presence was more frequently represented at higher-elevation than lower-elevation sites

(Fig. 1), this agrees with previous reports describing their distribution in Hokkaido (Onoyama and Miyazaki 1991; Kawabe 2008), and modelled distribution of the species that reflects their
adaptation to cold environments (Sakiyama et al. 2021). These results indicate that
vocalization-based surveys have high potential for monitoring the Northern Pika in its natural
habitat and contributing to understanding the effects of environmental change on their
populations.

276 Occupancy survey.—The effectiveness of auditory observation increased significantly 277 as survey duration increased. This result is intuitive because a longer duration increases the 278 chance of recording vocalization activities. Pikas often vocalize for alarm and territorial 279 purposes (Somers 1973; Kawamichi 1981; Lissovsky 2005; Trefry and Hik 2009), as well as 280 for positioning and localizing other individuals (Conner 1982). Since these natural events are 281 likely to occur randomly over time, shorter survey durations are likely to include more false-282 negative detections. Our initial expectation was that detection of Northern Pikas would 283 require survey durations longer than 5 min, a timeframe used in bird surveys (Ralph et al. 284 1995), because of their low conspicuity. Nonetheless, our results revealed that detection 285 efficacy reached a plateau when auditory observation was conducted for more than 30 min. 286 This suggests that continuing the survey after 30 min does not provide significant gains in 287 information relative to the effort invested-this saturation effect was also reported previously 288 in a study that used a similar point-count method (Hutschenreiter et al. 2021).

Notably, the five-minute playback survey reached a similar level of efficacy as the longest auditory observation survey in detecting the presence of Northern Pikas. Moreover, the playback method detected, on average, their presence approximately four times earlier than the auditory observation method. Therefore, cues broadcast by the audio speaker are highly effective in eliciting vocal responses. Although this phenomenon has been observed and effectively used in previous studies to understand the behavioral nature of vocalization

295 (Somers 1973; Conner 1982; Trefry and Hik 2009), our results suggest that it can also be used 296 as a highly effective, fast, and affordable method for surveying site occupancy in this species. 297 Another significant advantage of the aural detection survey was that it enabled detection 298 of presence of Northern Pikas at lower elevations, including areas previously unreported as 299 pika habitat (i.e., along the Horoka-Piribetsu river). These landscapes are characterized by 300 denser vegetation structure and fewer rock interstices than higher elevations (Sakiyama et al. 301 2021), hampering traditional visual approaches for detection. Moreover, vocalization 302 activities were not easily detected upon arrival at their habitats at lower elevations, in contrast 303 to higher elevations (Supplementary Data SD5), making aural detection method the only 304 effective approach. Lower-elevation populations inhabit marginal regions of their distribution, 305 whereas core populations are located at higher elevations (Sakiyama et al. 2021). Therefore, 306 aural detection provides a promising tool for efficient monitoring of Northern Pikas that might 307 be more vulnerable to climate change and human land uses at lower elevations. 308 We found that the number of sites at which presences was detected increased gradually

309 during the summer (Supplementary Data SD6), suggesting that occupancy could be detected 310 by vocalization during and after the reproductive season, as expected from previous studies 311 (Kawamichi 1971). This trend was more apparent at lower elevations, and it could be a result 312 of false-negative observations, even though they did inhabit the site from early in the season. 313 This finding emphasizes the importance of repeating the survey throughout the summer to 314 improve chances of detecting presence. However, Northern Pikas have been reported to 315 disperse from late July to August at lower elevations (Kawamichi 1971), whereas American 316 Pikas disperse from mid-May to mid-August at high altitude (2000 m) habitats (Smith 1974). 317 Therefore, the increase in number of sites at which they are present over the summer could 318 instead be a result of dispersal events from adjacent sites. If this was the case, then the 319 assumption of a closed population for our survey would not have been met. Although we

primarily considered the timing of snowmelt to determine our survey season, a more precise
definition may be needed to better accommodate the population setting in future studies.
Fixing survey season prior to or after dispersal, for example, could enhance accuracy. To this
end, further studies into the dispersal ecology of the Northern Pika are urgently needed.

324 *Advantages and disadvantages of aural detection methods.*—Our results suggest that 325 both auditory observation and playback are effective in surveying the presence of the 326 Northern Pika, but each has advantages and disadvantages.

327 A common advantage of using point-count aural detection is that the surveyor need not 328 venture into densely vegetated and potentially dangerous habitats. Talus slopes consist of 329 piles of large, loose rocks with interspersed vegetation of various types and structures 330 including lichens, moss, herbaceous plants, shrubs, and trees (Sakiyama et al. 2021). Hence, 331 walking steadily within the site requires care, and the simultaneous search for signs of pikas is 332 laborious and time-consuming. Alternatively, when the surveyor does not move, vocalization 333 is less influenced by these factors, although the observational environment (e.g., strong wind) 334 needs to be considered in terms of its effect on auditory detection. Moreover, use of the point-335 count survey is advantageous because it avoids trampling on and damaging vegetation, which 336 is the main dietary resource of Northern Pikas. Furthermore, while feces can represent 337 incomplete signs of recent activity (Nichols 2011), vocalization-based surveys only detect 338 active signs of occupancy.

Nevertheless, the use of vocalization-based methods has several disadvantages. First, it is difficult to define the area where pika vocalizations can be detected by the human ear. We conservatively assumed that the aurally-detectable range of the Northern Pika is 100 m, although complex topography could alter this range. Our results show that detection of the vocalization activities were more prevalent in frontward and sideward directions (Fig. 4), suggesting that choice of surveying point and facing direction will influence results.

345 Moreover, if the study area is larger than the range of detection by ear (approx. 100–200 m; 346 Kawamichi 1969), it will be important to conduct the survey at multiple points. Second, aural 347 detection methods require training of the surveyor to differentiate Northern Pika vocalizations 348 from other animals. While no other small mammals cooccurring in rocky patches make 349 vocalizations identical to the Northern Pika, the Eurasian Woodcock (Scolopax rusticola) 350 makes a vocalization similar to the 'short call/alarm call' during their nocturnal flights (T. 351 Sakiyama personal observation). Therefore, we ensured no potential confusion by planning 352 our surveys during the morning, and likewise avoiding the active time of other animals are 353 likely to reduce false detections. Third, although we were cautious to minimize these factors, 354 we did not assess if and how the presence of the surveyor could affect results. For example, 355 although we stayed silent before and during the survey, animals could still have detected our 356 presence through olfaction. If this was the case and their vocalizing behavior was reduced as a 357 result, our estimation of presence frequency would likely have been underestimated. Fourth, it 358 remains unclear how behavioral differences at different life stages will affect aural detection 359 results. For example, younger individuals might vocalize at lower volume and less frequently 360 than older individuals, which could also lead to a reduction in detection probability.

361 The methodological differences between auditory observation and playback included 362 duration of the survey (survey durations were up to 50 min for auditory observation method 363 and 5 min for playback) and for the latter, broadcast of a prerecorded call to stimulate pika 364 vocalizations. However, detection results between playback and auditory observation were 365 comparable. Thus, playback has an advantage over auditory observation because it reduces 366 survey duration and, therefore, effort and cost. Resource allocation is key in planning field 367 surveys. With limited resources, researchers frequently face the challenging task of balancing 368 the number of sites and survey effort within each site. A reduction in survey time enables an 369 increase in the number of sites, which increases robustness of research results.

370 Playback was conducted by broadcasting prerecorded vocalizations to elicit responding 371 calls from inhabiting individuals. The implementation of playback requires important 372 considerations that are not required for auditory observation. First, pikas could become 373 habituated to playback audio if it were played frequently (Trefry and Hik 2009). Habituation 374 of target species should be avoided because it may increase false-negative observations and 375 preclude consistent surveys. This problem can be avoided by designing surveys such that they 376 are sufficiently spaced over time (i.e., once a month in this study)—broadcasting audios 377 recorded from different individuals could also reduce habituation. Second, the effect of the 378 prerecording source on response remains unclear. If the response behavior differs depending 379 on the spatial source of the broadcast (i.e., place of prerecording), as was reported for the 380 American Pika (Conner 1983), the efficacy of playback will likely be spatially biased. 381 However, this effect was likely minimal in our study because only a single acoustic dialect is 382 found in Northern Pika populations in Hokkaido (Lissovsky 2005; Lissovsky et al. 2021). 383 Conversely, the choice of prerecording source will require in-depth consideration in situations 384 where playback is conducted at a broader spatial extent, increasing the likelihood of including 385 multiple dialects—in these kinds of surveys, the simplicity and passivity of auditory 386 observation could be advantageous.

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395	
396	CONFLICT OF INTEREST
397	The authors declare they have no conflict of interest.
398	
399	AUTHOR CONTRIBUTIONS
400	TS contributed to conceptualization and design of methodology; TS contributed to fieldwork
401	for data collection, data analysis, funding acquisition, and writing the original draft; TS and
402	JGM contributed to discussion of results, writing the final manuscript and gave final approval
403	for publication.
404	
405	DATA AVAILABILITY
406	The data that support the findings of this study are available from the corresponding author
407	(TS) upon reasonable request.
408	
409	SUPPLEMENTARY DATA
410	Supplementary Data SD1.— Spectrographs of the audio file used in the playback
411	survey. The actual audio could be heard from the audio embedded in the file.
412	Supplementary Data SD2.— Audio file used in the playback survey.

- 413 Supplementary Data SD3.— A scatter plot showing the auditory capability of the
 414 surveyor in estimating the location of the sound source in a talus patch.
 415 Supplementary Data SD4.— Organization process of the terminologies used for the
 416 Northern Pika vocalizations in previous literature.
 417 Supplementary Data SD5.— Raw detection result of occupancy from the surveys.
 418 Supplementary Data SD6.— Bar plots indicating the number of sites detected during
 419 the surveys for each method and vocalization type.

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Fig. 1.—Map of the study area in Hokkaido, Japan (top-right panel) and the study sites within to survey the occupancy of the Northern Pika (left panel), differentiated by occupancy status and elevation class (black indicates presence, white indicates absence, circle indicates higher elevations, and triangle indicates lower elevations). Aggregated sites are shown in higher resolution (mid-right panel). Regional boundary is indicated in dotted lines and the area of Daisetsuzan National Park is shown as a solid line.

558 Fig. 2.—Relationship between confusion matrix indices and duration of the survey to detect

559 presence of Northern Pikas. Note that auditory observation (circle) was conducted for ten

560 survey periods (five minutes × ten periods), whereas playback (triangle) was conducted only

561 for one survey period (five minutes).

562 Fig. 3.—Difference between time of first detection of the animal using auditory observation

and playback method. Error bars indicate the 95% confidence interval around the mean.

564 Fig. 4.—Circular histograms showing frequency of the directions from which the

565 vocalization activities were detected, plotted separately for the survey method and detected

566 vocalization type.

567

Table 1.—Parameters and performance of generalized linear mixed models to assess the

570 difference of time until first detection of the Northern Pika between auditory observation and

571 playback.

Parameter	β	SE	Z	Р
Auditory observation	4.849	0.267	18.142	< 0.001
Playback	3.171	0.343	9.246	< 0.001











Fig. 4

Aural detection methods enable detection of northern pika occupancy in densely vegetated habitats

Supplementary Data SD1



Spectrographs of the audio file used in the playback survey, showing the whole length (top) and the first three seconds in zoom (bottom) of one "long call" or the "song" of the northern pika. Three repeats of this long call was broadcasted from an audio speaker in the actual survey. Audio could be heard from the input audio on the right. Actual audio file used for the playback is archived in Supplementary Data SD2.



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vegetated habitats

Supplementary Data SD3



We evaluated the auditory capability of the surveyor to detect the presence of the northern pika. Given that controlling the location of the animal vocalization is impossible, a survey assistant instead broadcasted the northern pika vocalization from an audio speaker hidden at a random location in the talus patch and the surveyor estimated the distance and direction to the sound source from the site center. These records were then compared with the correct location of the sound source. The plot shows the estimated and correct location of the sound source, indicating that the surveyor was efficient in detecting the northern pika vocalization heard from various directions and distances.

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Supplementary Data SD4

Various types of vocalizations are known to be used for specific functions in northern pikas, as described in detail in Kawamichi (1981) and Lissovsky (2005) (described in Russian). However, different terminologies were used between these literatures to describe the vocalization system of northern pikas. Moreover, since such terminological ambiguity remained untouched for unification, successive literature often refer to either terminological system for citation, which hamper comparison between studies. For example, Kojima et al. (2006) followed terminologies in Kawamichi (1981), whereas Lissovsky et al. (2021) followed Lissovsky (2005).

To reach a unified understanding of the vocalization system of the northern pika between Kawamichi (1981) and Lissovsky (2005), we referred to the characteristics and functions of each vocalization type and situations in which they are used for qualitative comparison. We also considered the spectrographs (= sonograms) of the vocalizations to enable quantitative comparison. Since large geographical variation are known to exist even within a same vocalization type in northern pikas (Lissovsky 2005; Lissovsky et al. 2021), we referred to geographically close population pairs between the literature for spectrograph comparison (i.e., Hokkaido, Japan in Kawamichi (1981) and Sakhalin and Sikhote-Alin, Russia in Lissovsky (2005)).

Various terms such as *long call, short call, trill*, and *submission call* have been used in Kawamichi (1981) with reference to American pika literature. And *alarm call* (Предупреждающий об опасности сигнал), *song* (Песня), and *chirring* (Стрекотание) have been used in Russian terms in Lissovsky (2005), and song of the northern pika consist of vocalization elements such as the trill (Трель) and modulated call (модулированный сигнал) (Note that these Russian-English translations follow the English abstract of Lissovsky 2005). As we compared the qualitative and quantitative characteristics between the literature, we organized the vocalization terminology as follows (Fig. SD4-1, SD4-2): long call in Kawamichi (1981) matched with the song in Lissovsky (2005) because elements of the long call showed similar spectrographic shape of modulation with the modulation call of a song (W-shaped waves) and both are explained as being made by males only and for territorial demonstration; short call in the former matched with alarm call in the latter because both showed similar spectrographic shape (upward stroke) and are described as being emitted in single or multiple vocalizations with irregular intervals in response to an approaching danger or without any reason; *trill* in the former matched with *chirring* in the latter because both showed similar spectrographic shape (diminishing upward strokes) and are explained as being heard when the animal escapes into the rock under fright conditions. We could not obtain detailed information of function and spectrogram for submission call in Kawamichi (1981) and trill in Lissovsky (2005). The term trill was used differently between the literature, but we classified them as different vocalization types since the spectrographic shape and situation of their use were not resembling, suggesting that their use requires care (Lissovsky 2005).

Kawamichi 1981 Study region: Hokkaido, Japan	Lissovsky 2005 Study region: Russia
Long call Explanation: Emitted in series, consisting of 4 -16 cries. Given only by males in both reproductive and non - reproductive season. May function as territorial advertisement.	Песня English translation: song Explanation: Emitted in series, consisting of 1-23 modulated calls (модулированный сигнал). Used only by males for roll -calls and territory demonstrations.
Shown as A-D in Fig.1 in Kawamichi 1981	12 6 6 6 6 6 7 7 8 6 7 8 6 7 8 6 7 8 6 7 8 7 8 8 9 8 9 9 9 9 9 9 9 9 9 9 9 9 9
Short call Explanation: Emitted singly or in series at irregular intervals. Produced by all individuals, irrespective of sex and age. Increase in the non -reproductive season and may be related with food storage.	Предупреждаю щий об опасности сигнал English translation: Alarm call Explanation: Emitted in series at irregular intervals, consisting of 1-20 cries. Produced both in response to an approaching danger: a person, a bird, or a rock fallen from a rock, and without any visible reason.
Shown as E-J in Fig.1 in Kawamichi 1981	с — Сахалин; d — Сихотэ-Алинь d - Sakhalin; e - Sikhote-Alin Modified Fig. 1 (1) from Lissovsky 2005
Trill Explanation: Produced by all individuals, irrespective of sex and age. Emitted singly when pikas quickly enter rock crevices.	Стрекотание English translation: Chirring, chirping Explanation: Consist of short chirp or a series of squeaks. Produced during a strong fright, when the animal unexpectedly collides with a human and rushes under rocks.
Shown as M and N in Fig.1 in Kawamichi 1981	Modified Fig. 1 (V) from Lissovsky 2005

Fig. SD4-1 Matching vocalization types between Kawamichi (1981) and Lissovsky (2005). Spectrograms with a red box in Lissovsky (2005) are from northern pikas in Sakhalin or Sikhote-Alin, which are the geographically closest populations from that in Kawamichi (1981).

Kawamichi 1981 Study region: Hokkaido, Japan	Lissovsky 2005 Study region: Russia				
	Трель English translation: Trill Explanation: Produced both independently and in combination with other vocalization types. Used for territorial and mating demonstrations. Given only by males.				
No matching vocalization type.	IV a a b a b a b a b a b a b a b a b a b				
Submission call Explanation: Whining sound. Repeated several times. Used when an individual was approached or chased by another.	No matching vocalization type.				
No spectrogram provided.					

Fig. SD4-2 Unmatching vocalization types between Kawamichi (1981) and Lissovsky (2005).

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Supplementary Data SD5

Detection result of occupancy upon arrival at the site, after auditory observation, and after playback. "0" and "1" indicate absence and presence, respectively.

Cita Flowation (m)		Class	Upon arrival		Aud	Auditory observation			Playba	ck	Truce a second and a	
	Jul		Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	True occupancy	
1	350	lower	0	0	0	0	0	0	0	0	0	0
2	350	lower	0	0	0	0	0	0	0	0	0	0
3	450	lower	0	0	0	0	0	0	0	0	0	0
4	450	lower	0	0	0	0	0	0	0	0	0	0
5	470	lower	0	0	0	0	1	0	0	1	1	1
6	510	lower	0	0	0	0	0	0	0	0	0	0
7	560	lower	0	1	0	1	1	1	1	1	1	1
8	590	lower	0	1	1	0	1	1	0	1	1	1
9	650	lower	0	0	0	0	0	0	0	0	0	0
10	900	higher	1	1	0	1	1	1	1	1	1	1
11	1010	higher	1	1	1	1	1	1	1	1	1	1
12	1010	higher	1	1	0	1	1	1	1	1	1	1
13	1150	higher	0	1	1	1	1	1	1	1	1	1
14	1160	higher	1	1	1	1	1	1	1	1	1	1
15	1190	higher	1	1	0	1	1	1	1	0	1	1
16	1420	higher	1	1	0	1	1	1	1	1	1	1
17	2100	higher	0	0	0	0	0	0	0	0	0	0
18	2220	higher	1	1	1	1	1	1	0	1	1	1

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habitats



Supplementary Data SD6

Bar plots indicating the number of sites where each vocalization type was heard by using auditory observation (blue) and playback (yellow) methods. Overall result shows the number of present sites including detection at arrival (gray). Darker and lighter colors indicate lower- and higher-elevation sites, respectively.