Use of abandoned structures by Przewalski's wild horses and other wildlife in the Chernobyl Exclusion Zone

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Abstract

Przewalski's wild horses (*Equus ferus przewalski*) are an endangered species and current conservation efforts aim to maintain genetic diversity and reintroduce wild populations. From 1998-2004, 36 Przewalski's horses were introduced in the Chernobyl Exclusion Zone (CEZ) with no subsequent direct management, and current population size and genetic diversity are unknown. We used remote cameras positioned at the entrance of abandoned structures within the CEZ to elucidate visitation of these structures by Przewalski's horses and other large mammals to assess the use of this method for monitoring the horse population within the CEZ. We estimated frequency of structure use in winter (Nov 2016 – Feb 2017) and summer (Mar 2018 – Oct 2018) periods and estimated basic group characteristics such as group type (all male vs. mixed sex), group size, and number of foals. Przewalski's horses were detected 35 times at 9 of 10 monitored structures in winter and 149 times at all 8 monitored structures in summer. Eight other mammalian species were documented using abandoned structures. Mixed sex groups of horses contained 5.30 ± 0.25 adults and 1.00 ± 0.12 foals (Mean± S.E.). All-male groups contained 1.59 ± 0.15 individuals. Our data suggest Przewalski's horses routinely use abandoned structures in the CEZ with visitation patterns tending to be nocturnal in winter and crepuscular in summer. Congregation of horses in these structures could have implications for future monitoring of the population by providing detailed information on demographics, population size, and genetic diversity which would benefit management plans for this population and provide a baseline for future work.

Key words: camera traps, Chernobyl Exclusion Zone, population monitoring, Przewalski's wild horse

Introduction

The Chernobyl nuclear accident in 1986 created an unprecedented radiological containment issue, resulting in the creation of a 4,300 km² restricted access area spanning the modern borders of Ukraine and Belarus. This area, referred to as the Chernobyl Exclusion Zone (CEZ), has remained relatively untouched, allowing for natural reclamation of a primarily agricultural and forest matrix. Over 190 abandoned human villages and towns are interspersed throughout the landscape, consisting of thousands of abandoned structures. These structures range from abandoned apartment complexes to barns and other former livestock holding facilities, and represent unique habitat for the diverse wildlife that now inhabit the CEZ (Baker and Chesser 2000; Deryabina et al. 2015; Webster et al. 2016; Schlichting et al. 2019). The large size and restricted human access also has made the CEZ a target for the introduction of species of conservation concern including European bison (*Bison bonasus*) and Przewalski's wild horses (*Equus ferus przewalski*).

The endangered Przewalski's horse is the last remaining subspecies of wild horse (King et al. 2015), whose populations declined rapidly due to hunting, habitat loss, harsh winters, and competition with domestic livestock, leading to their extinction in the wild in the mid-20th century (Ryder 1993; Bouman and Bouman 1994). All extant Przewalski's horses are descended from a small number of captive individuals (n = 13), and captive populations are subject to a comprehensive breeding program where maintenance of genetic diversity is a priority. A second management priority is the reintroduction of sustainable wild populations, which has occurred at five locations in Mongolia and China. In addition, from 1998-2004, 36 Przewalski's horses were released into the CEZ near the town of Chernobyl as an experimental population and this population gradually spread north throughout the zone (Zharkikh and Yasynetska 2008) and occupied the Belarussian portion of the CEZ, the Polesie State Radiation Ecological Reserve

(PSRER), by 2007 (Deryabina 2015). The CEZ population was monitored 10 years post-release and increased to a maximum of 65 individuals, but because of their small population size, poaching, and limited gene flow, the population remains at risk (Zharkikh and Yasynetska 2008). Evidence suggests that Przewalski's horses use abandoned structures in the CEZ, based on the presence of feces (Klich et al. 2017), and these structures are assumed to be used as thermal refugia. However, the frequency and extent to which horses (and other wildlife) use these structures is currently unknown.

To address this knowledge gap, we conducted a pilot study to assess the use of human structures by Przewalski's horses and other wildlife in the CEZ. By placing motion activated cameras at the entrances of abandoned structures, we estimated frequency and diel patterns of use by Przewalski's horses in winter and summer seasons. In addition, we assessed population characteristics of groups visiting structures including group size, group type (mixed sex or all-male groups), and number of foals in mixed sex groups during summer. Finally, we examined the role of abandoned structures as refugia during summer. This information can be used to improve monitoring and management strategies for the Przewalski's horse population in the CEZ.

Methods

We deployed motion activated game cameras (A-25i, Moultrie, USA; Attack IR, Cuddeback, USA; 2.6C Willfine, Suntek, China) to assess winter (n=10, November 20, 2016 to February 14, 2017) and summer (n=8, March 23, 2018 to October 23, 2018) use of abandoned structures by Przewalski's horses and other wildlife in the PSRER (Figure 1). Cameras were placed within structures originally used for livestock husbandry (cattle, sheep, and horses) where the presence of Przewalski's horses was anticipated based on observations of horse fecal

material. Cameras were set ~1.2 m off the ground at entrances to maximize detection of horses and other large mammals and programmed to record a burst of three photos when triggered. Photos were delineated into independent visits per species separated by a minimum of 6 hours. Visits were used to determine presence, visits per structure, and visits per trap night in winter and summer trials. In addition, we evaluated visits by horses during the winter and summer periods by creating activity curves using a non-parametric kernel density approach (Ridout and Linkie 2009). Activity curves were created with the package "overlap" (Meredith and Ridout 2018) in program R (R Development Core Team 2018).

Extreme cold during winter trials made cameras less reliable, meaning group composition and the role of structures as refugia was estimated for summer trials only. Group size was determined by recording the maximum number of individuals present in a single photo within a visit. The lack of identifiable marks on Przewalski's horses and difficulty in differentiating sub-adults from adults meant that group composition could only be reliably recorded into two types: mixed sex (at least one male and female identified) and all-male groups (all individuals identified as male). Groups where a female could not be verified but included a foal were considered a mixed sex group. Visits where group composition could not be determined were labeled as unknown. The role of structures as thermal refugia was tested by comparing maximum temperatures (T-test) and days with rainfall (Chi-squared test) on days with visits to days without. Meteorological data were obtained within the PRSER at the Masany Research Station (Figure 1).

Results

Przewalski's horses were detected 35 times at 9 of 10 monitored structures (Fig. 2a and b.) in winter trials and visited all 8 monitored structures 149 times in summer (Fig. 2 c. and d.).

Structures were visited an average of 3.89 ± 0.77 times (range 1-8) during 655 trap nights in winter (0.05 visits/trap night). Summer trials totaled 1,339 trap nights (0.11 visits/trap night) with an average of 18.63 ± 4.06 horse detections per structure (range 5-34). Przewalski's horses used structures for extended periods of time (>5 hours), including as loafing, breeding, and sleeping locations (Figure 2b), resulting in 4,668 and 7,685 photos in winter and summer, respectively. Horses primarily used structures nocturnally in winter while summer visits occurred throughout the day with greater use during crepuscular periods (Figure 3). The number of days between visits averaged 6.27 ± 0.65 during summer. We detected eight other mid- to large-sized mammals using abandoned structures in summer including brown hare (*Lepus europaeus*, n=34 detections), red deer (*Cervus elaphus*, n=13 detections), moose (Fig. 2e., *Alces alces*, n=63 detections), wild boar (*Sus scrofa*, n=2), red fox (*Vulpes vulpes*, n=5 detections), raccoon dogs (*Nyctereutes procyonoides*, n=9 detections detections), Eurasian lynx (Fig. 2f., *Lynx lynx*, n=9 detections), and wolves (*Canis lupus*, n=8 detections), along with several avian and bat species.

Przewalski's wild horse groups averaged 3.31 ± 0.22 individuals per visit across all group types during summer. Mixed sex group were detected visiting structures on 53 occasions and contained 5.30 (± 0.25) adults and 1.00 (± 0.12) foals on average. Mixed groups contained 2-11 adults and 0-3 foals and foals were first detected May 4th. All-male groups visited monitored structures on 44 occasions and were smaller than mixed sex groups, containing 1.59 ± 0.15 individuals on average and ranging from 1-4 adults. Groups of unknown composition averaged 1.73 ± 0.11 individuals. Groups of similar type and size were commonly detected on the same camera for several consecutive days followed by extended periods without visits (>40 days). Temperature (p=0.81) and days with rainfall (p=0.91) did not differ between days with and without visits.

Discussion

Przewalski's horses and other wildlife appear to regularly use abandoned structures in the CEZ. Visits occurred throughout both night and day, and horses were documented loafing, breeding, and sleeping in structures. Successive visits tended to be temporally clustered, indicating groups repeatedly use structures when in that portion of their home range, but structures may go unvisited for extended periods of time. No other species documented using abandoned structures appeared to stay in them for extended periods, but we likely missed detections of small bodied species because cameras were set specifically to detect horses and other large ungulates (>1m high). Horses were documented visiting structures more during summer trials but this is likely an artifact of poor camera performance in extreme cold temperatures. Alternatively, summer months with the greatest number of visits corresponded to increases in blood sucking flies (families Ceratopogonidae, Simuliidae, and Tabanidae) and horses could be visiting abandoned structures as a respite from these pests. Horses used unmonitored barns (based on the presence of feces) as well as the barns we monitored, and the lack of climatic influences based on detections could be misleading based on our small sample size. Horses primarily used barns at night in winter suggesting they may serve as thermal refugia, but this hypothesis should be more thoroughly tested, possibly with paired climate loggers in a greater number of structures.

The extensive and repeated congregation of Przewalski's horses in abandoned structures could have implications for future monitoring of the population in the CEZ. Przewalski's wild horses in the Ukrainian portion of the CEZ also use abandoned structures (Klich et al. 2017), suggesting these congregation areas represent unique focal points for which monitoring of horses with remote cameras may be feasible across the CEZ. Our results provided estimates of group

size and usage, but monitoring a greater number of structures, using multiple cameras per structure, and incorporating video surveillance could allow for more accurate estimates of population structure including age/sex ratio, birth rates, herd number, herd composition, and abundance. These represent critical population parameters that, in conjunction with climatic variables, influence the long-term viability of reintroduced Przewalski's horse populations (Slotta-Bachmayr et al 2004). Identification of key parameters for population growth and their threshold values could help optimize management objectives for this population.

Congregation of Przewalski's horses in abandoned structures could also provide valuable information about population characteristics and viability using non-invasive genetic sampling (King et al. 2018). Genetic capture-recapture methods (Lukacs and Burnham 2005) could provide abundance estimates as well as estimates of survival and population growth if the population were repeatedly sampled. Other reintroduced Przewalski's horse populations have displayed increased genetic drift and inbreeding compared to their founding population (Liu et al. 2014). Although genetic diversity is currently unknown, the CEZ population has likely experienced similar losses in diversity since introduction. Comparisons of genetic diversity and inbreeding coefficients to reintroduced populations in China and Mongolia as well as the founding population in Askania Nova Biosphere Reserve would benefit management plans for this species and provide baseline population information for future work in the CEZ.

The future of Przewalski's horses in the wild depends on introductions that maintain sustainable and genetically diverse populations (Sarrazin and Barbault 1996; Van Dierendonck and Wallies de Vries 1996). Successful reintroduction of Przewalski's wild horses have generally included intensive monitoring and periodic supplementation with individuals from captivity (Boyd and Bandi 2002; Souris et al. 2007; Xia et al. 2014). The population in the CEZ

offers a unique opportunity to evaluate a reintroduction with limited direct management and future investigations could identify potential management needs such as mitigating the genetic consequences of founder effect and limited gene flow. In addition, the use of a range of structures by a wide array of species offers an opportunity to understand the importance and impact of former human settlements on wildlife populations in the CEZ and other areas abandoned by people, as well as the potential importance of these structures to horses in the CEZ.

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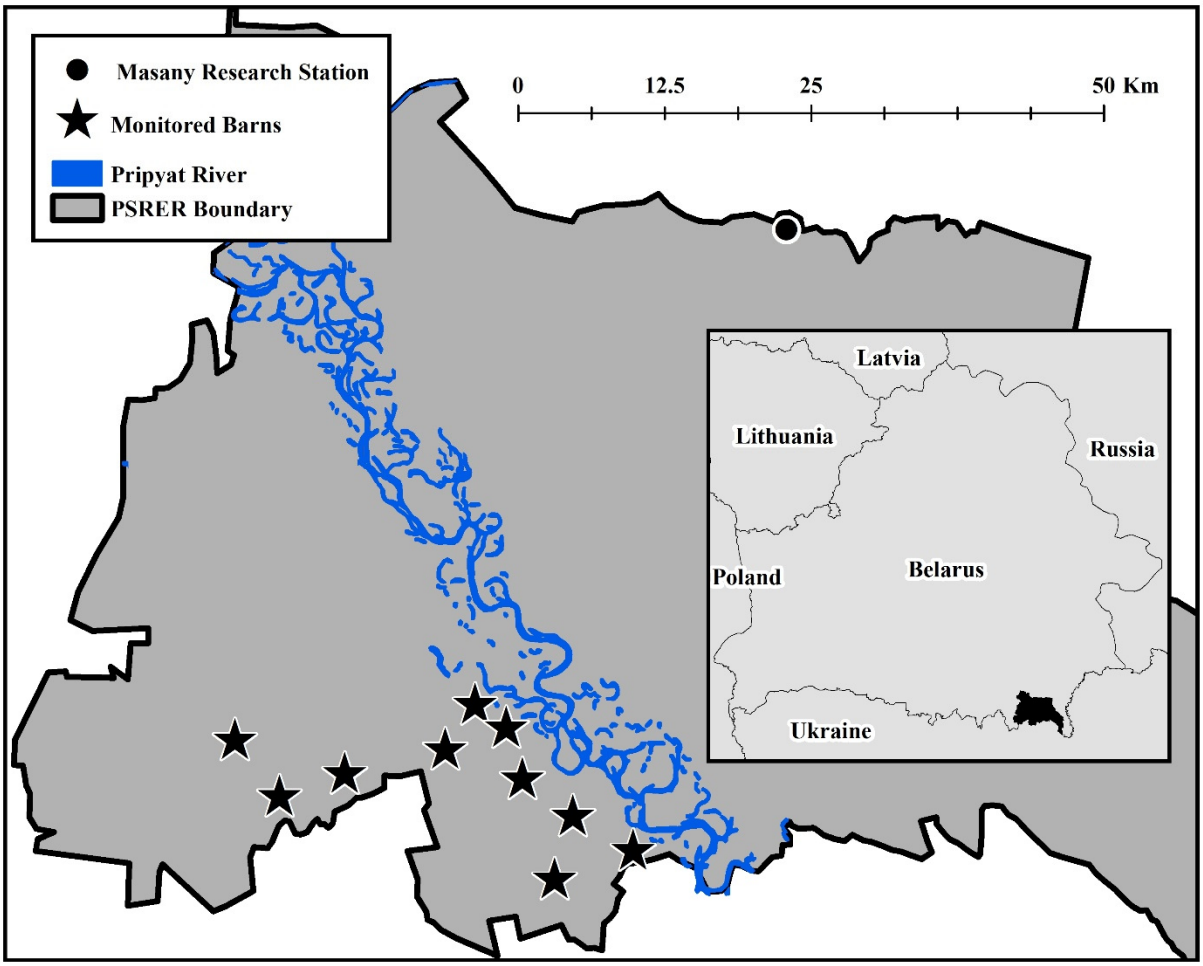

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247 **Fig. 1** Map of the Belarussian portion of the Chernobyl Exclusion Zone, the Polesie State

248 Radiation Ecological Reserve (PSRER), indicating the location of monitored barns and the

249 Masany Research Station. The inset displays the location of the PSRER (in black) within

250 Belarus.

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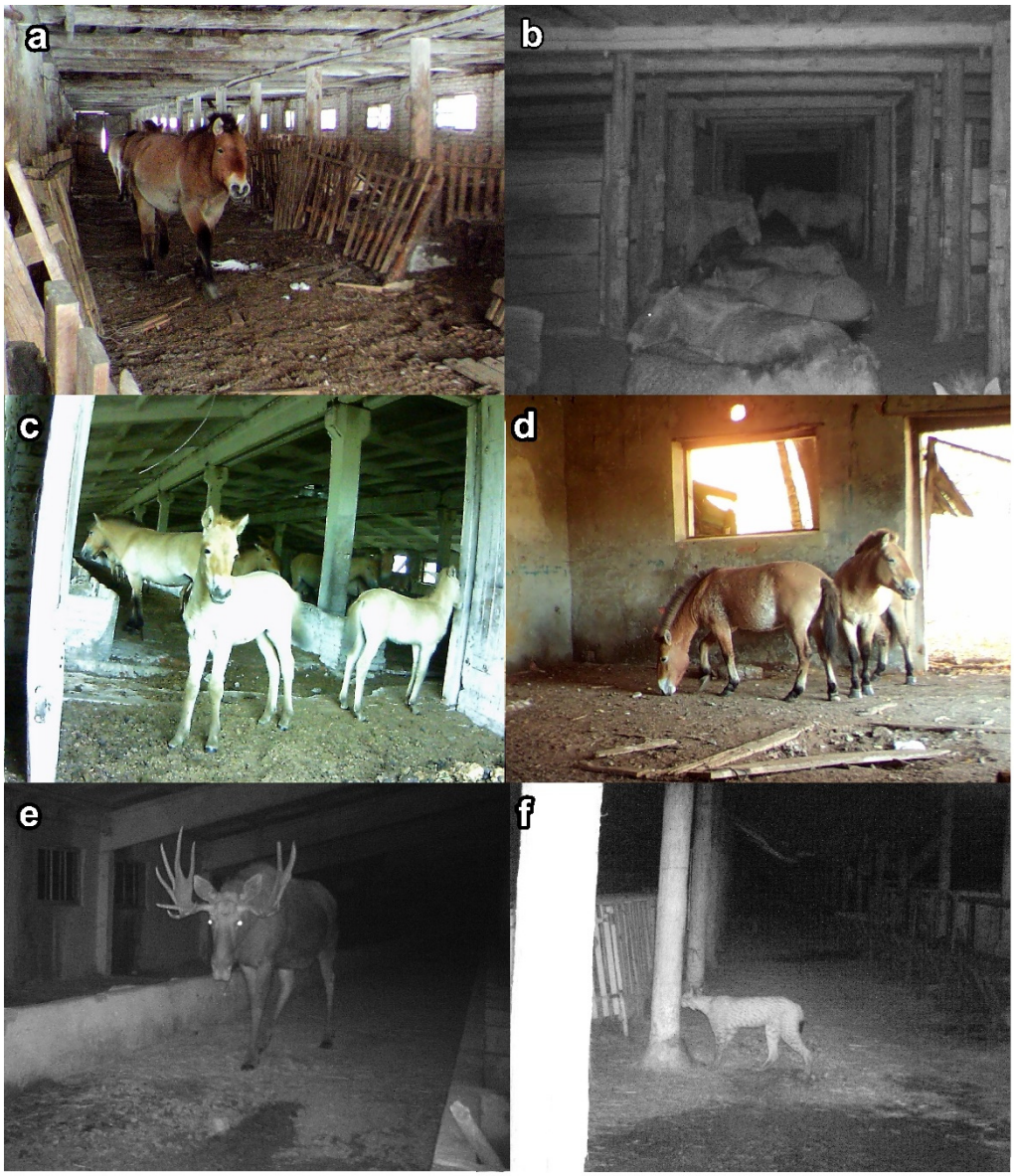
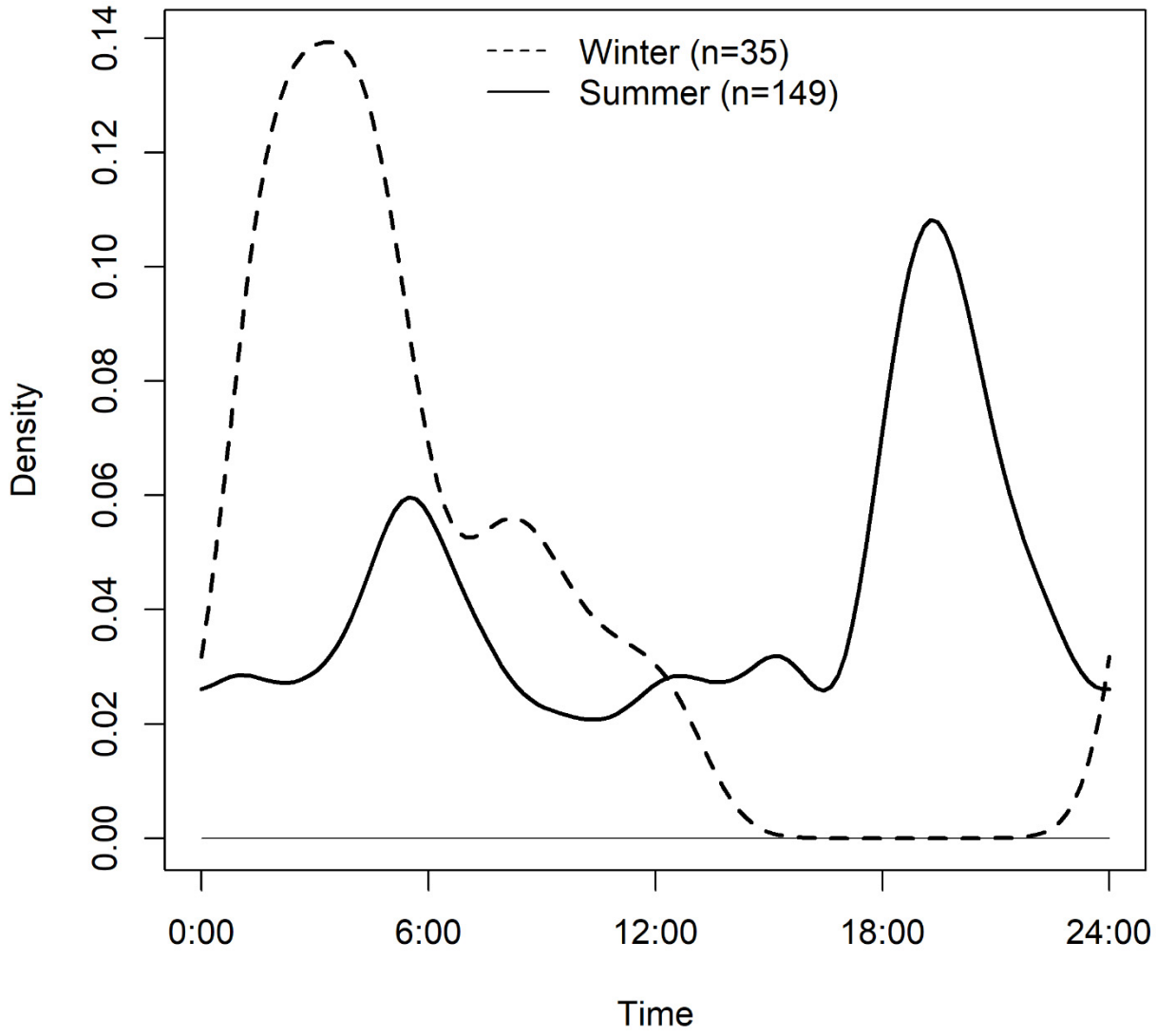


Fig. 2 Przewalski's horses (*Equus ferus przewalski)* and other wildlife occupying abandoned structures in the Chernobyl Exclusion Zone. Mixed sex groups (a. – c.) and all-male groups (d.) were documented occupying monitored barns previously used for livestock husbandry in winter (a. and b.) and summer (c. and d.). Eight other species, including moose (*Alces alces*, e.) and European lynx (*Lynx lynx*, f.) were detected utilizing abandoned structures



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260 **Fig 3.** Diel distribution of Przewalski's wild horse visits to abandoned structures in the

261 Chernobyl Exclusion Zone in winter and summer periods. Sample sizes (n) denote the number of

262 visits per sampling period.

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