UPDATES FROM CAMERA TRAPS USED TO MONITOR THE ELK POPULATION IN THE LAKE OF THE WOODS AREA

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UPDATES FROM CAMERA TRAPS USED TO MONITOR THE ELK POPULATION IN THE LAKE OF THE WOODS AREA

by

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ABSTRACT

Elk (*Cervus elaphus* L. *canadensis*), once widespread across North America, severely declined due to overhunting and habitat conversion in the 1900s. The Lake of the Woods are was one of four locations chosen to reintroduce elk populations in Ontario with the release of 104 elk between 1998-2001. Using data from approximately six to seven camera traps over 9 years (2013-2021), this study updates the status of the Lake of the Woods elk population. Age and sex ratios were determined, as well as the current distribution of the population. A minimum population estimate was calculated with a mark-capture-recapture design. Camera capture frequency of individuals in the elk population was compared to the frequency of captures of the predator population in the region, as well as to the frequency of camera captures of individuals of other cervid prey species. The results show bias from non-random camera placements, which also lead to more adult male elk than female elk being captured on camera and to an inaccurate population size estimate. This study also found a decrease in frequency of camera captures of predators and other prey populations consistent with an increase in the elk population estimates. For more accurate population estimates, this study recommends using more camera traps and using random camera placements.

Key words: *Cervus elaphus*, wapiti, distribution, capture-mark-recapture, predator-prey.

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INTRODUCTION

Cervus elaphus (L.), known as elk or wapiti in Canada, were once widespread across North America, including in Ontario, but then saw great decline due to habitat loss and overhunting (Seton 1927; O'Gara and Dundas 2002). Numerous reintroduction attempts have seen varying degrees of success and failure (O'Gara and Dundas 2002). Since 2001, Ontario has had some success in introducing elk from Alberta (Rosatte et al. 2007; OMNR 2010). Traditional monitoring of population abundance has usually consisted of aerial surveys or mark and recapture sampling. However, a good capture-mark-recapture design can be challenging to accomplish due to limited resources and difficulty handling animals, and there are limitations to aerial surveys such as weather conditions (Gilbert et al. 2020).

With technological advances, camera traps have become an invaluable tool for wildlife sampling including in estimating populations in a mark-recapture design; uses for camera traps include distribution, abundance, behaviour and community structure for many wildlife species (Burton et al. 2015).

In 1998/99, a formal proposal for elk release in the Lake of the Woods (LOW) area was submitted and approved (OMNR 2010). A total of 104 elk were released in the LOW area by 2001, their source was from Elk Island National Park in Alberta (Rosatte et al. 2002). Population size and survival of these elk depends on factors such as environmental conditions and predator abundance (OMNR 2010). Initially, the majority of the released elk were radio collared and monitoring occurred with aerial surveys (Rosatte et al. 2007).

This study aims to update the current population status of the elk of the Lake of the Woods area using 9 years of camera trap data. The objectives of this study are: firstly, to determine the age and sex ratios for the elk population; secondly, to describe the population distribution using the location of the cameras; thirdly to compare the number of elk to the number of predators seen on camera in the area, fourth, to determine whether a minimum population size can be estimated and; lastly, to compare these statistics to those of previous studies on the Lake of the Woods elk population. The predications for this study are: if there are more predators captured by the cameras than elk, the elk population may be in decline; and that there may be more adult males captured and recaptured than females due to their different behaviours.

LITERATURE REVIEW

Elk: biology, habitat, social system, behaviours

Elk are generalist herbivores or mixed feeders whose diet varies depending on what is available and the environmental conditions of their habitat (Jost et al. 1999). They are opportunistic and generally consume all forage classes, including grasses and twigs of trees and shrubs (Bellhouse and Rosatte 2005). In mixedwood forests, elk primarily consume browse material and leaves of woody species and forbs. Elk of coniferous-mixedwood regions have been known to browse on grasses, sedges and forbs in the summer, forbs, grasses and deciduous shrubs more in fall, and more conifers in the winter months (Jost et al. 1999).

Historically in Ontario, elk inhabited deciduous forests (Ryckman et al. 2010). Presently, North American elk are found in a broad range of habitats (Irwin and Peek 1983). Food availability plays an important role in various factors of elk life; the availability of food is an important determining factor of the suitability of elk habitat. Food availability influences the social structure and dispersal patterns of a population and it is involved in predator-avoidance strategies (Jost et al. 1999).

Distribution and dispersal distance of members of an elk population influence their reproduction. Mean dispersal distances of elk reintroductions in Ontario range from 13.0-22.2 km (Ryckman et al. 2010). The rut, or period of maximum reproductive activity by adult males, occurs between September and October in Ontario. During this time males will advertise their dominance to females and competing males, especially when the sex ratio of a population has more females than males. When this is the case, females will form a harem to a polyamorous male. Harems range from a few to more than 50 females. Males will often chase off yearling males who are capable of mating but as social order will have it, usually do not mate until they are older. A male may also herd his harem to discourage females from leaving (Geist 2002).

Male elk tend to disperse longer distances and more frequently than females, sometimes sacrificing security of a group for food (Ryckman et al. 2010; Geist 2002). Females, on the other hand, will sacrifice food for the security of a group (Geist 2002). Elk benefit from forming groups because this behaviour increases an individual's chance of survival of a predator attack. As well, a group has a better potential of detecting a predator prior to an attack (Hebblewhite and Pletscher 2002). Groups generally form after the rut and consist of adult females, calves and yearlings. Adult males will occasionally remain with a group throughout winter, but typically they will leave and live in a small group of males or alone (Wolff and van Horn 2003).

Elk predators

Wolf (*Canis lupus* L.) predation is among the top causes of death among elk (Barber-Meyer et al. 2008). Calves are particularly at risk to predators; high elk calf mortality is primarily due to wolf predation. Black bears (*Ursus americanus* Pallus) have also been confirmed important predators of calves in Ontario (Rosatte et al. 2007). While black bears are generally regarded as opportunistic, consuming ungulate when vegetation lacks or when scavenging opportunities are present, wolves are known to have selective diets and have been known to prefer elk over other ungulate species (Popp et al. 2018). Elk dispersal within wolf territory affects the risk of predation on the elk. In grasslands and open conifer areas, the risk of predation is less than in pine stands with decreasing elevation (Hebblewhite et al. 2005).

Lake of the Woods elk population history

Historically, elk were native across much of Canada and the US (Rosatte et al. 2005). At the time European explorers came, they were abundant in Ontario (Ryckman et al. 2010). However, anthropogenic disturbances severely depressed elk populations through overhunting and habitat conversion. The Lake of the Woods elk population is one of many populations founded by a reintroduction effort (Rosatte et al. 2005). The Lake of the Woods region is a transition zone between the Great Lakes-St. Lawrence and Boreal Forest regions. It hosts a combination of conifer and conifer/deciduous mixedwood forests and agricultural areas (Ryckman et al. 2010). The Lake of the Woods area was chosen for elk reintroduction based on the low white-tailed deer (*Odocoileus virginianus* Zimmermann), moose (*Alces alces* L.) and wolf populations, low human density, and low road density in the area, combined with the high availability of seasonal habitat (Hutchison et al. unpublished).

Elk reintroduced to the LOW area came from Elk Island National Park near Edmonton, Alberta, which is a fenced enclosure with few predators and where there is a surplus of elk. Elk that were relocated were given a health inspection and treated for parasites and disease; the majority were fitted with radio collars and ear tags, before being shipped by truck to Ontario (Rosatte et al. 2007).

Identifying elk

Elk are the second largest member of the cervid family. Adult males, commonly referred to as bulls, measure approximately 2.4 m in length and 1.5 m in height at the shoulder; females, commonly referred to as cows, measure approximately 1.3 m in height at the shoulder (O'Gara 2002). Adult males carry large antlers, which they shed between January and April and regrow in the summer of each year. Young males grow their first antlers as yearlings, and the first set of antlers are usually spikes. Calves display a white spotted pattern on their coat, similar to white-tailed deer calves, which transitions to a light to dark brown colour with maturity (Hudson and Haigh 2002). Elk calves look are similar in appearance to white-tailed deer calves, however, are much larger. Where moose calves are typically solid brown in colour.

Camera traps – use and data analysis

With technological advances, camera traps have become an invaluable tool for wildlife sampling (Burton et al. 2015). The rapid improvements to camera traps have revolutionized monitoring of wildlife. Traditional sampling and monitoring methods, which often consist of physical capture, can be challenging and require a great deal of time and personnel to accomplish

(Gilbert et al. 2020). However, camera traps have been a successful tool in estimating density for several species (Heilburn et al. 2006). Measuring abundance of unmarked animals can be especially challenging, as not all individuals of a species are easily distinguishable from other members of the species. However, identifying unmarked individuals can be done with camera traps by distinguishing individuals based on pelage patterns, natural markings, antler patterns or scars on the coat (Gilbert et al. 2020; Burton et al. 2015).

Wildlife camera traps are set up at strategic locations and positioned to capture an animal's activity in an area through an exclusive point of view. Camera traps capture images automatically in one of two ways: through motion sensors, where one or more images are taken when a sensor detects movement in the field of view; or through a timelapse, where images are taken at regular time intervals. After camera traps are serviced, analyses are done on the image data. Tagging refers to encoding an image of interest as descriptive or quantitative based on its attributes (Greenberg et al. 2019). This data then gets put into a spreadsheet or database for statistical analysis and other processing.

Tagging an image can be based on detecting whether wildlife is present in the image, identifying the species present, identifying individuals, determining health of an animal, or distinguishing animal behaviours (Greenberg et al. 2019). Images can be used for monitoring distribution, abundance, behaviour and community structure (Burton et al. 2015). Abundance estimates using image data can be done using capture-recapture or spatial capture-recapture analyses (Amburgey et al. 2021). Like many sampling methods, camera traps are prone to some types of error; for example, they come with bias of imperfect detection, such that if an individual is not mobile or passing through a small camera detection zone it may not be detected or if the individual is outside of the detection zone of the camera it will not be detected (Burton et al.

2015). The detection of an individual using camera traps depends on the zone size, sensitivity and placement of the cameras used.

MATERIALS AND METHODS

This study used photo data from camera traps over the course of nine years, 2013-2021, to update the status of the Lake of the Woods elk (LOW) population. Approximately 6-7 cameras were set up at different locations each year (generally from May to October), the number and model of cameras varied slightly from year to year. The make of camera used was Reconyx game cameras. The Reconyx models used to take colour photos were the HyperFire and HyperFire2. Standard settings were used to take still photos, and infrared flash was used to capture night images. Cameras were housed in metal security boxes secured with a lock and heavy safety wire, for safety from animal interactions. Cameras were secured to trees, typically one meter off the ground. The camera traps were set up in various locations throughout the LOW study area during the period of study. Camera placement was not random; cameras were set up in locations mostly in or adjacent to areas where elk were identified by tracks or other evidence. Cameras were usually moved to a new location when evidence of elk disappeared, but not always. Exceptions included locations where other animals (such as moose) were very present. The photo data was used to determine a minimum population size, approximate age and sex ratios of the population, population distribution, and predator-prey ratios comparing the elk population to predator populations and other cervid prey populations. First, all images were viewed for relevance. Photos that contained usable data, i.e., if they contained an image of an animal, were tagged. Tagged photos were then analysed while other photos that did not contain usable data (i.e., vegetation moving from wind) were discarded. The following information was documented for photos that had an image of an animal present: camera identification, date of photo, number of individuals captured on camera, species identification, as well as age, sex, and if possible, identification of elk if present. Identification of elk was done using presence of a radio collar, tags, scars/pelage markings, or antler patters for males. Each elk captured on camera was given an identification code if it could be easily identified; if not they were marked as an unknown adult male, unknown adult female, unknown yearling, unknown calf, or unknown elk. A dataset was compiled of this information for each year of the study period. Animals captured were only those that are thought to have an effect on the elk population, this includes elk, deer, moose, black bear and wolves. Others, such as fox, lynx, or squirrels were excluded from the database. Repeat captures of individuals within the same hour were also not included to illuminate some recapture bias, as they were most likely recaptures of the same individual and could not be considered a new capture/recapture as the individual did not move from the capture location.

Age and sex ratios

All elk individuals captured or recaptured on camera were put into an estimated age class of calf, yearling, or adult, or unknown if age identification was not possible. These age classes were chosen because elk of these age classes show different behavioural and dispersal patterns. Adult elk were then sexed as male or female when possible, or unknown. The elk data was sorted out of the master dataset and the number of unique individuals in each age class was totaled for each year of camera trap data and reported as a set of ratios for each year in the study period. An adult male to female sex ratio was calculated for each year during the study period. An adult, yearling and calf sex ratio were also calculated.

Elk population distribution

Distribution maps were made by using the locations of the camera traps with ArcGIS Online and ArcGIS Pro software. Each year, each camera trap had its location and date logged; this dataset was used to create a map to show the distribution of camera captures among the elk population as well as the other animals of interest. The maps were designed to show the total count of individuals captured on camera at each location by using size sensitive points, and to show the relative abundance of all species captured on camera at each location using pie charts as symbology for each point on the maps. Assumptions about these maps are that the cameras are placed in non-random locations, biased towards known locations of elk. Considerations when viewing elk distribution include land barriers, such as the numerous lakes in the area. Roads and clearings where cameras were often purposefully set up to capture elk.

Predator-prey ratio

Species considered predators of elk are black bear and wolves. The number of predators captured on camera was totalled for each year and compared to the total number of prey (elk) captured on camera each year. The combined number of all white-tailed deer individuals and moose calves captured on camera was also compared to the number of predators and elk captures or recaptured on camera. Repeat captures of black bears, wolves, deer, and moose calves captured within one hour of each other were counted as a single capture or recapture, because it was not possible to determine whether these were the same individuals as previous captures. Black bears and wolves were grouped together and considered as an overall predator population. White-tailed deer and moose calves were also grouped together in the results to compare the elk population to other cervid prey populations.

Minimum population size

The capture records of each elk identification code throughout the year were made into a binomial dataset for each date that a camera was deployed, i.e., was an identified elk captured on camera (coded 1) or not (coded 0), and the resulting dataset was analyzed using a behaviour model where $p_i \neq c_i$ (suggesting that after first camera capture there will be more or fewer subsequent captures), a time model where $p_i = c_i$ (suggesting that date of camera deployment, e.g. weather, influences camera capture probability), and a null model where $p_i = c$ (suggesting that there is no pattern in the camera captures), p_i being the probability of catching an animal for the first time in session i, and c_i being the probability of re-capturing an animal in session i. This was done with the assumption of a closed-population. This analysis is consistent with a capture-mark-recapture design for closed-population estimates, and was run in the program MARK (Colorado State University, phidot.org). The analysis was repeated for each year in the study period treating each summer season of camera deployment as a separate event.

RESULTS

Of all of the species captured and recaptured on camera, white-tailed deer were generally the most common, elk were the second most commonly captured species (Table 1). Of the elk identified, adults significantly comprised the largest age class each year of the study period (Figure 1). The sex ratio by number of camera captures shows that more adult male elk were captured on camera than adult female elk (Figure 2). However, the sex ratio by number of individuals shows that the male to female ratio is fairly even, with more adult male elk captured on camera than adult female elk, only during 2014-2017 (Figure 3).

Table 1. Number of camera captures by species and year, 2013-2021, in the Lake of the Woods (LOW) study area.

	Species				
Year	Black Bear	White-tailed deer	Elk	Moose (all ages)	Wolf
2013	27	187	108	21	31
2014	37	161	49	11	21
2015	71	201	153	4	13
2016	34	210	108	12	16
2017	33	177	64	17	20
2018	37	134	86	7	7
2019	35	39	99	15	4
2020	16	36	150	13	6
2021	30	42	240	45	1
Total	320	1187	1057	145	119

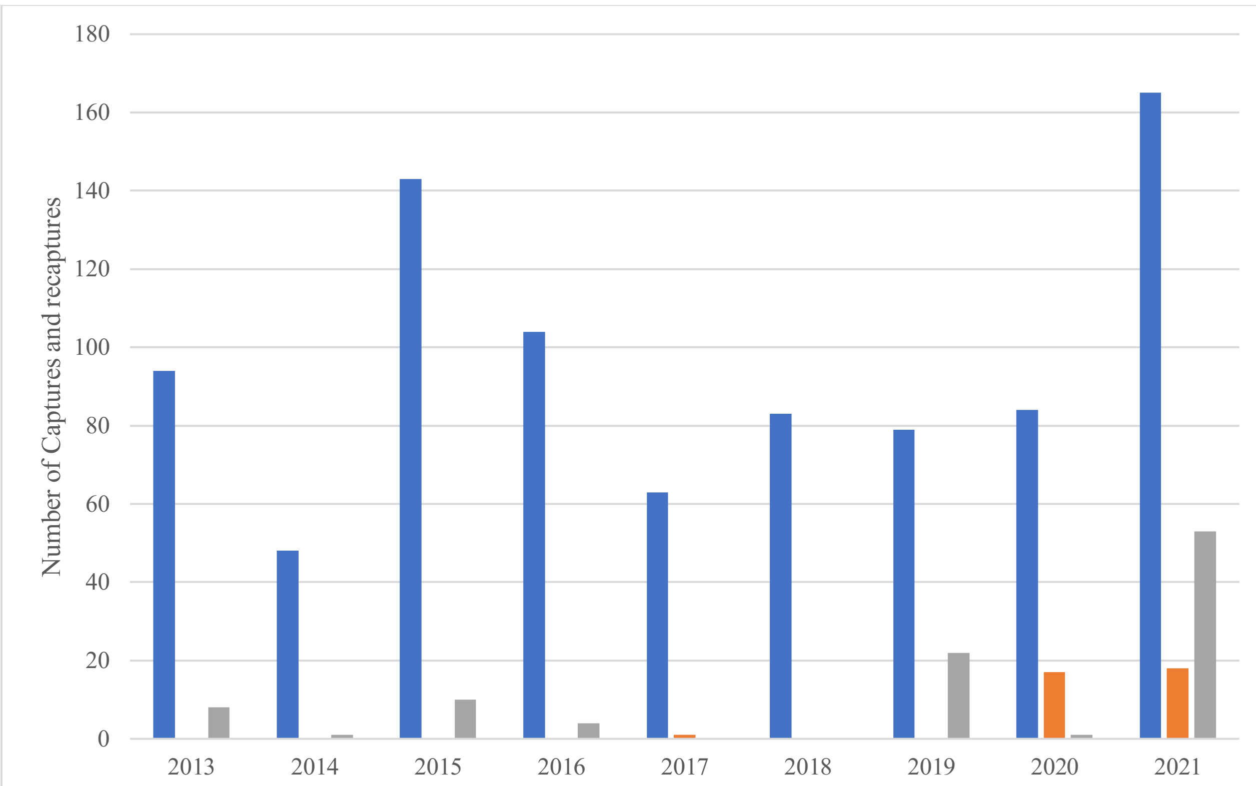

Figure 1. Age ratios of elk from 2013 to 2021 in the LOW study area. Comparing adults (blue), yearlings (orange), and calves (grey) by total of all camera captures during each year.

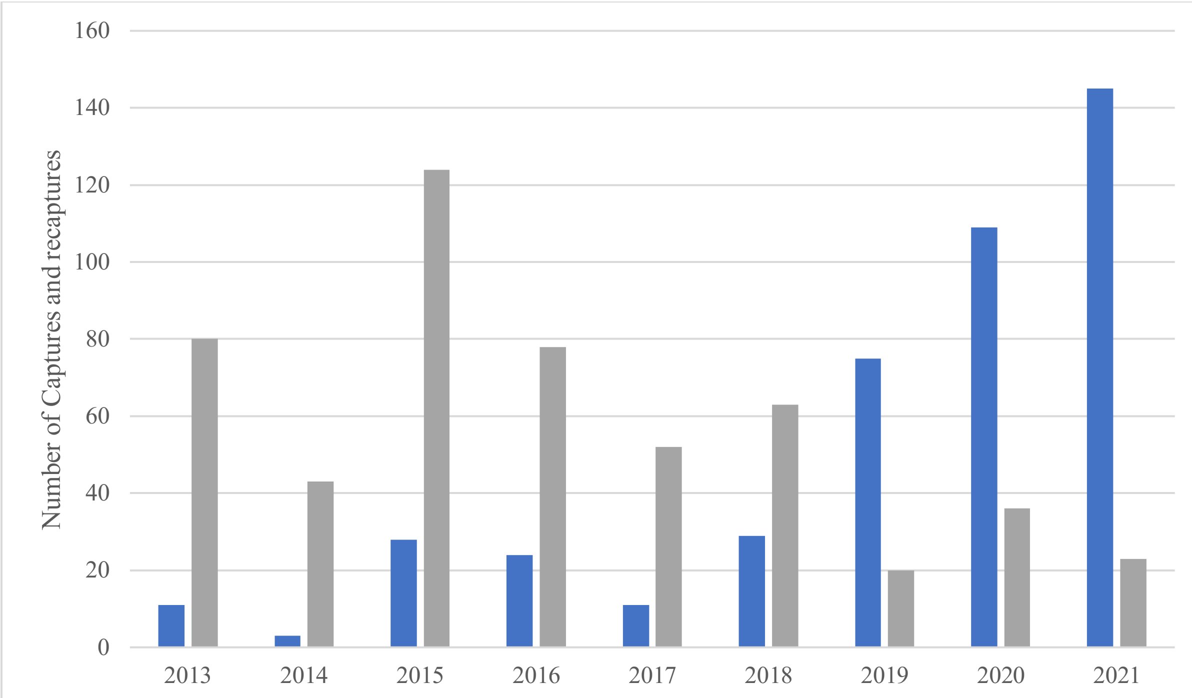

Figure 2. Sex-ratio of elk from 2013 to 2021 in the LOW study area. Comparing male (grey) to female (blue) over all camera captures each year.

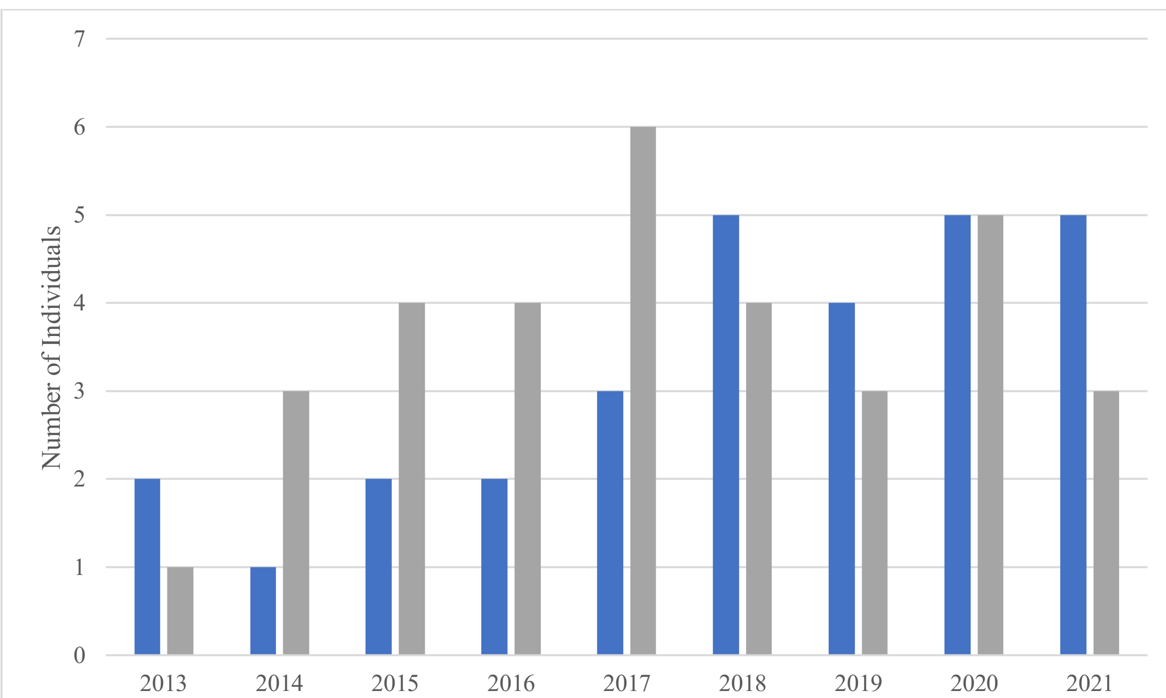

Figure 3. Sex-ratio of elk from 2013 to 2021 in the LOW study area. Comparing male (grey) to female (blue) by number of individuals identified in camera captures and recaptures each year.

The most active cameras were located around Kakagi Lake (Figures 4-12). Usually, where there were more predators captured on camera, there were less prey. Specifically, where there were high wolf camera captures there were little to no elk captures. Generally, where there more elk camera captures there were less moose (Figures 4-12). Generally, there are more elk captured on camera than predators (Figure 13). The population trend is an overall decline in predator captures over the course of the study period (Figure 14).

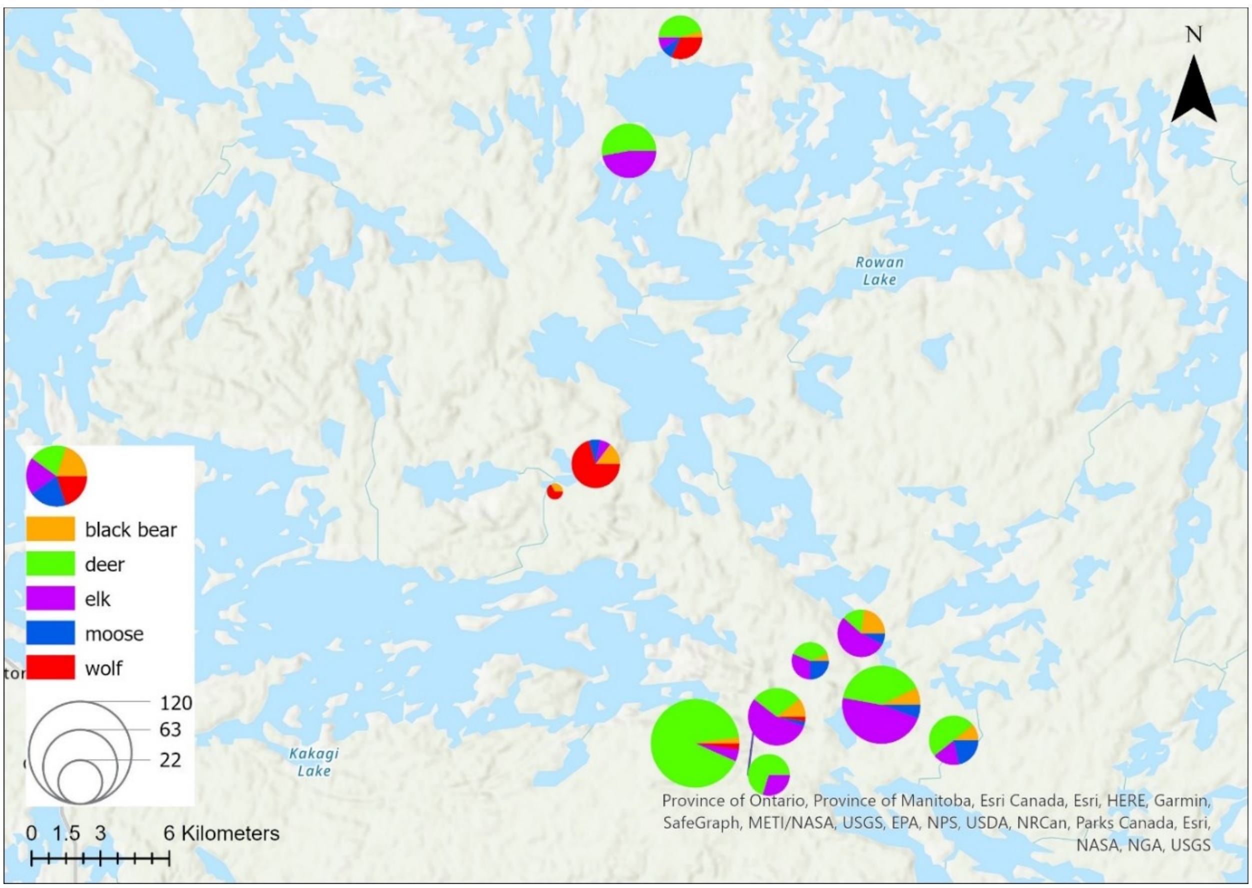

Figure 4. Distribution map for the LOW study area in 2013. Showing the distribution of the camera locations. The size of the points represents the total number of camera captures and the pie charts show the relative abundance of all captures by species.

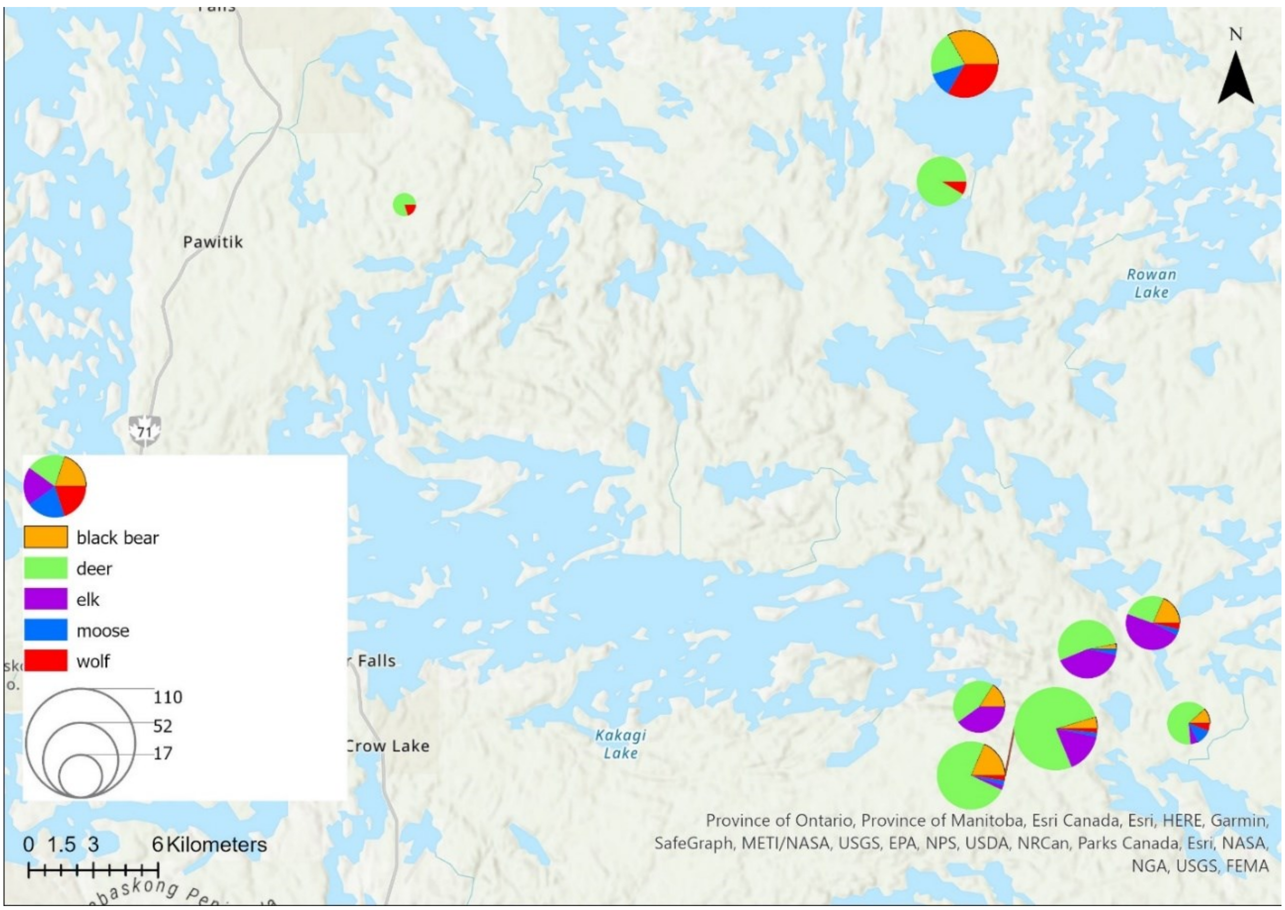

Figure 5. Distribution map for 2014. Details as in Figure 4.

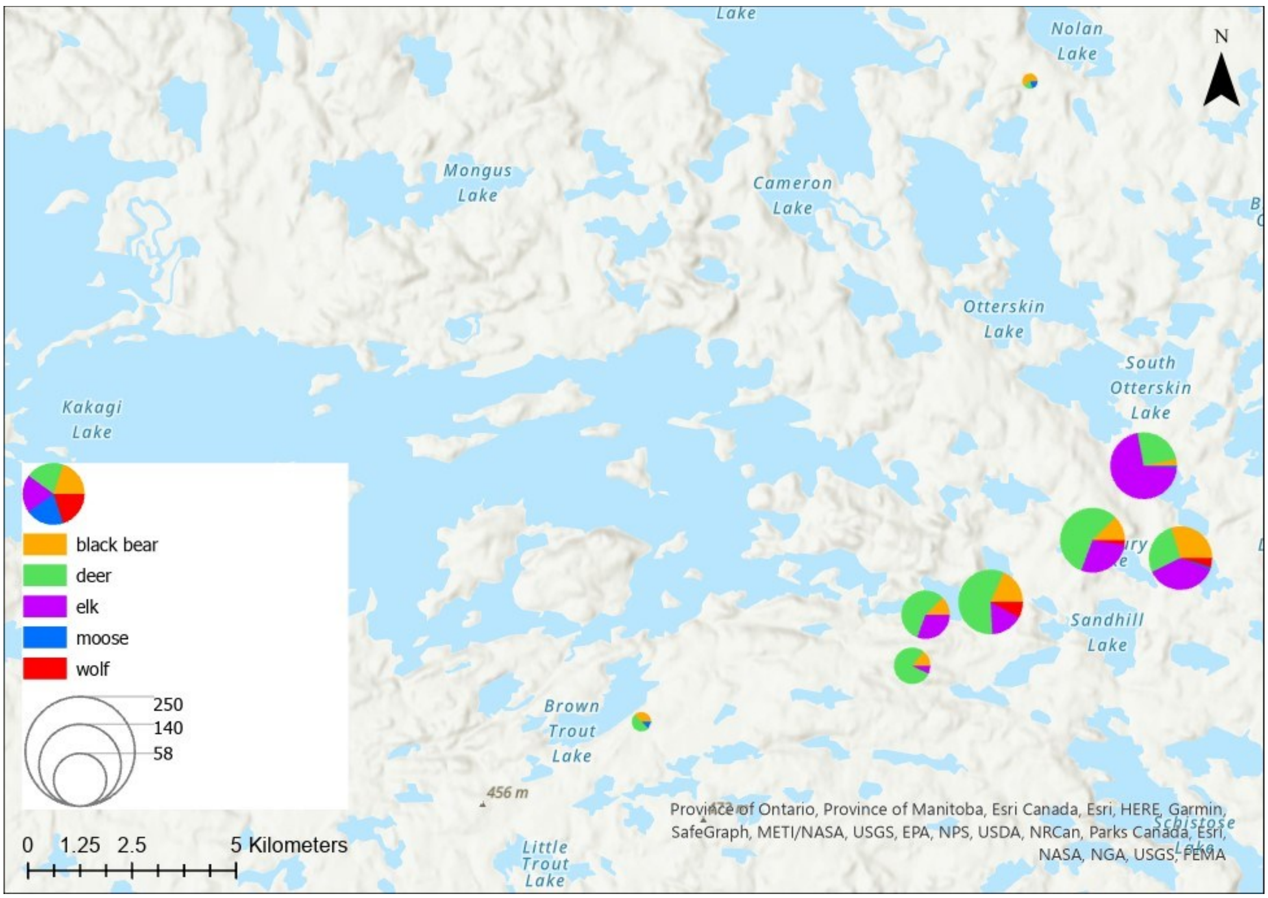

Figure 6. Distribution map for 2015. Details as in Figure 4.

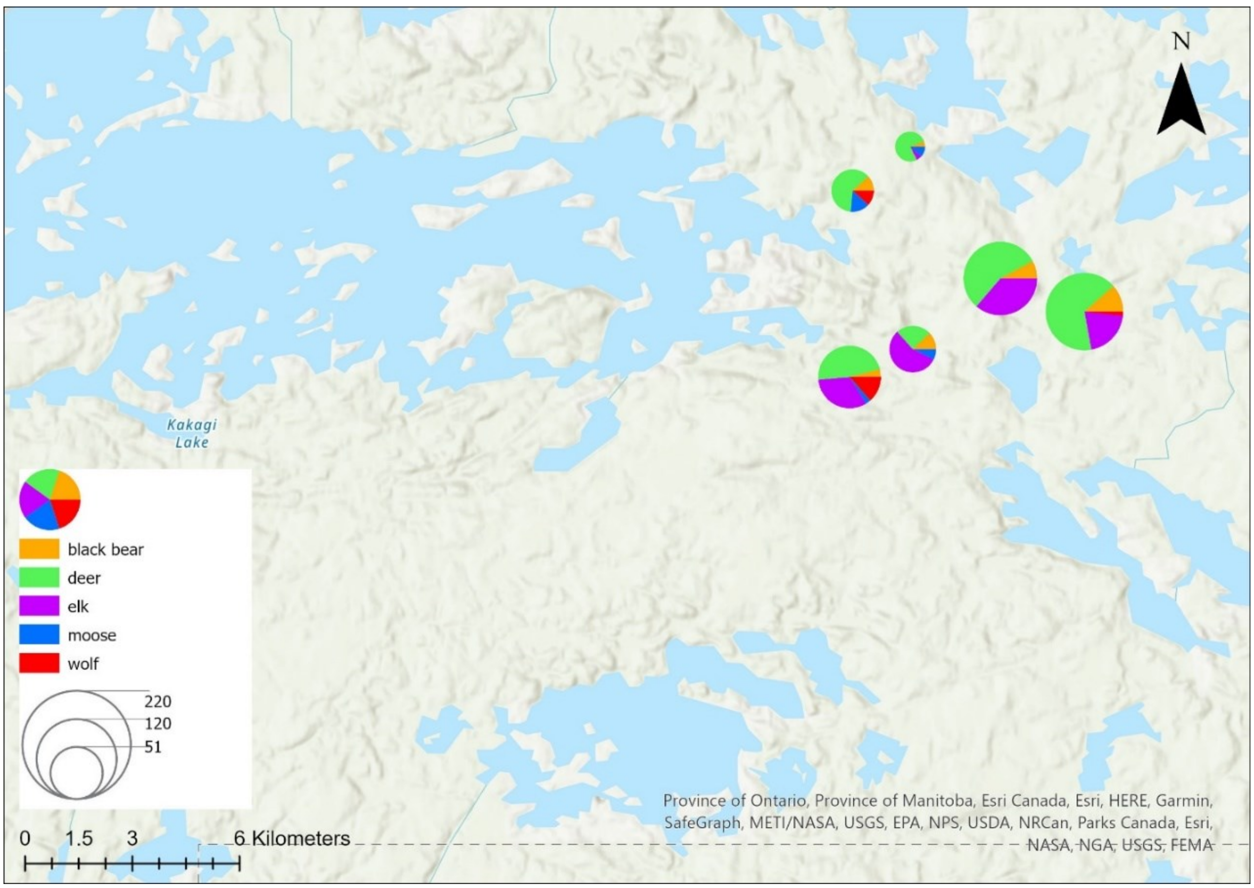

Figure 7. Distribution map for 2016. Details as in Figure 4.

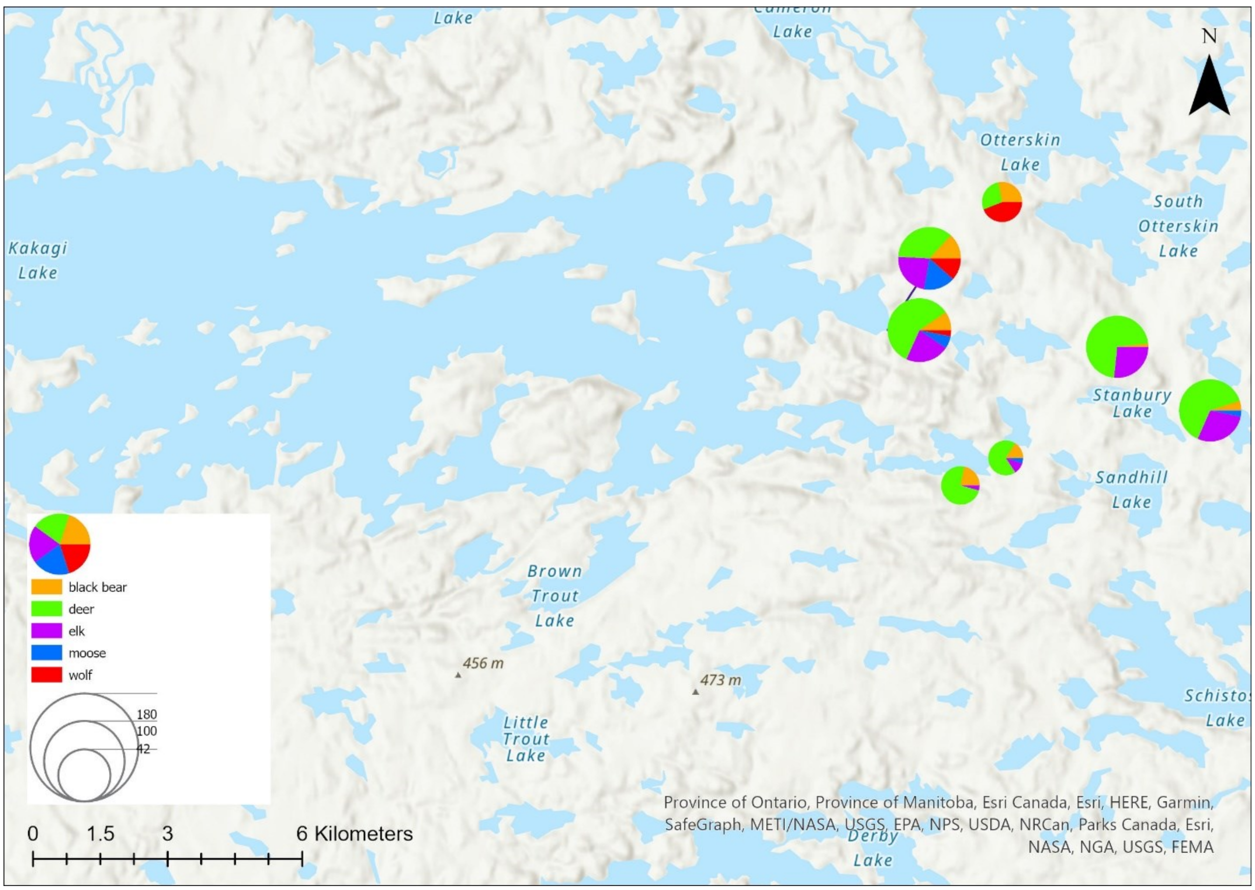

Figure 8. Distribution map for 2017. Details as in Figure 4.

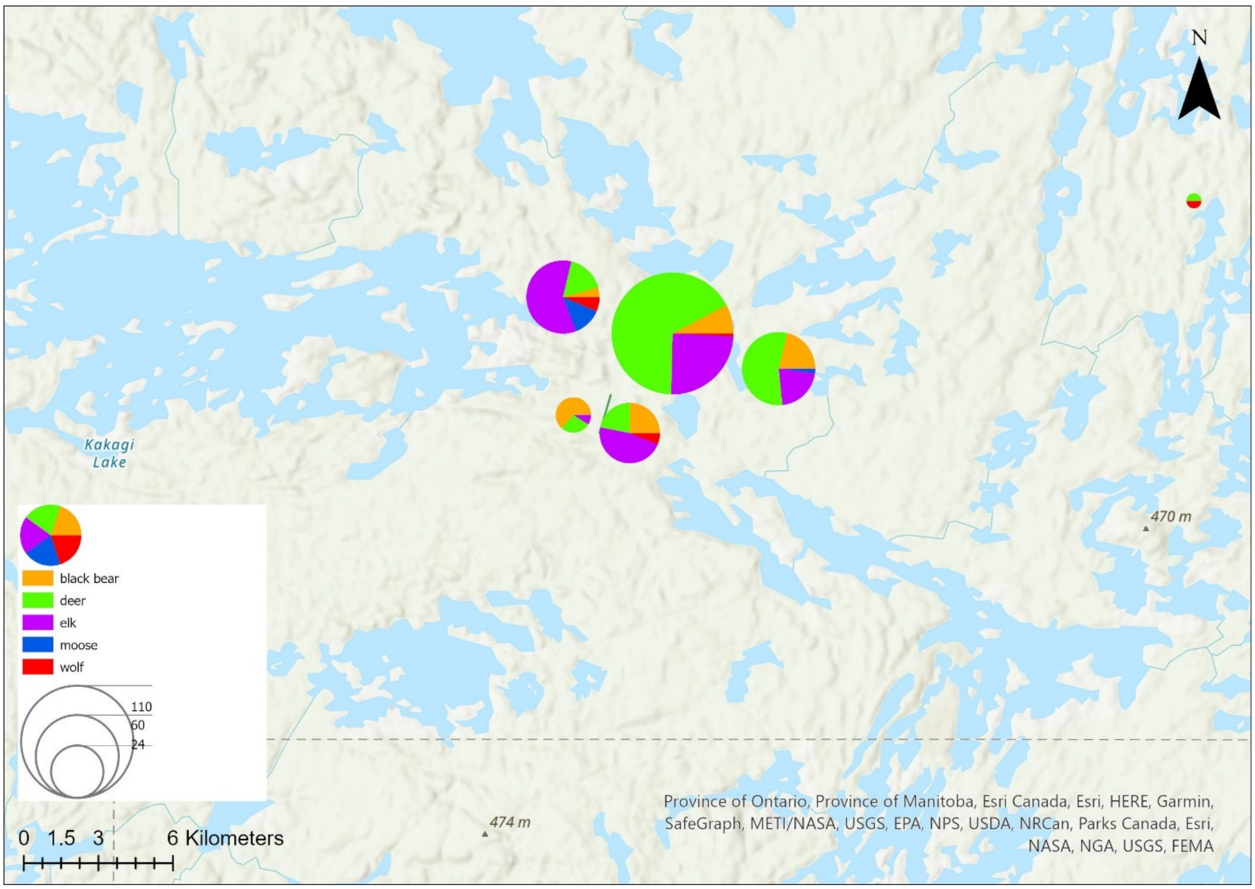

Figure 9. Distribution map for 2018. Details as in Figure 4.

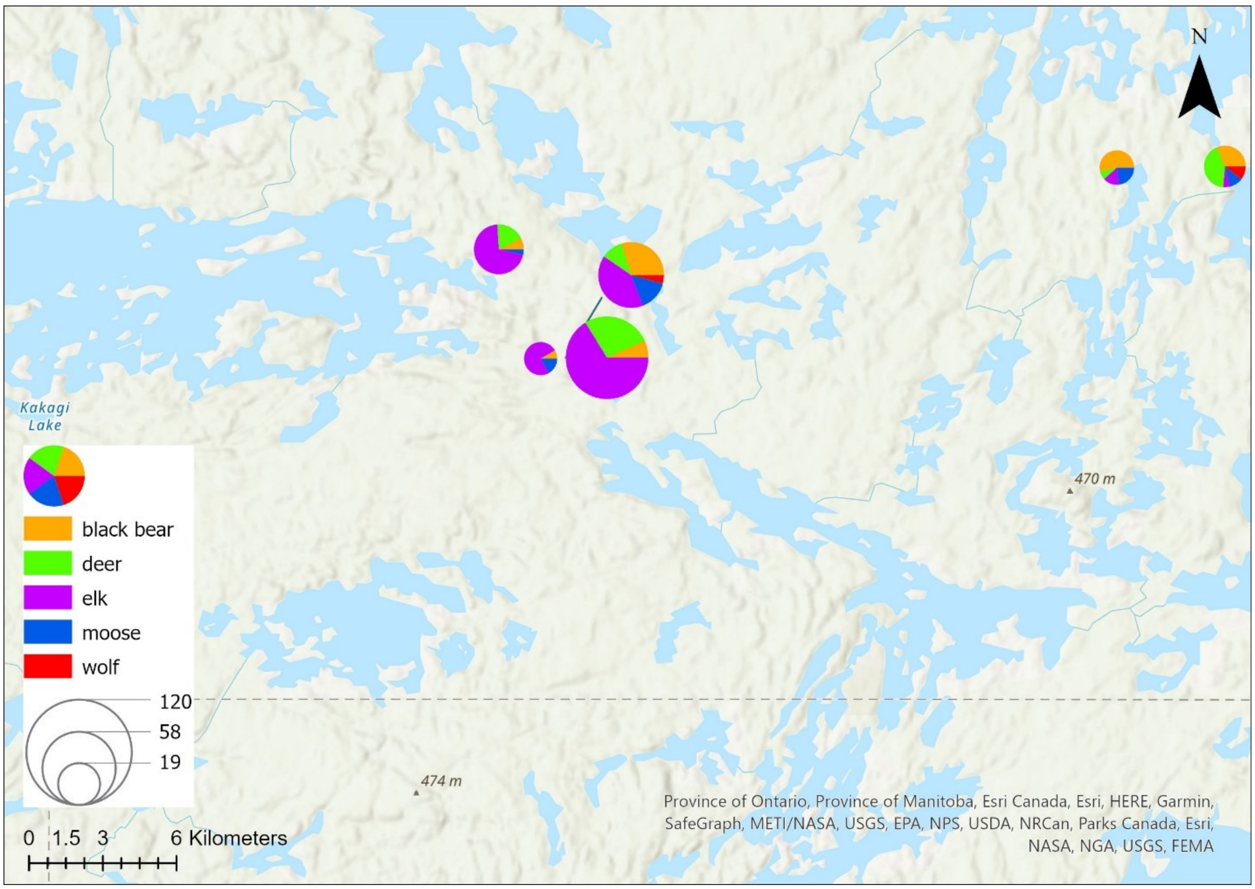

Figure 10. Distribution map for 2019. Details as in Figure 4.

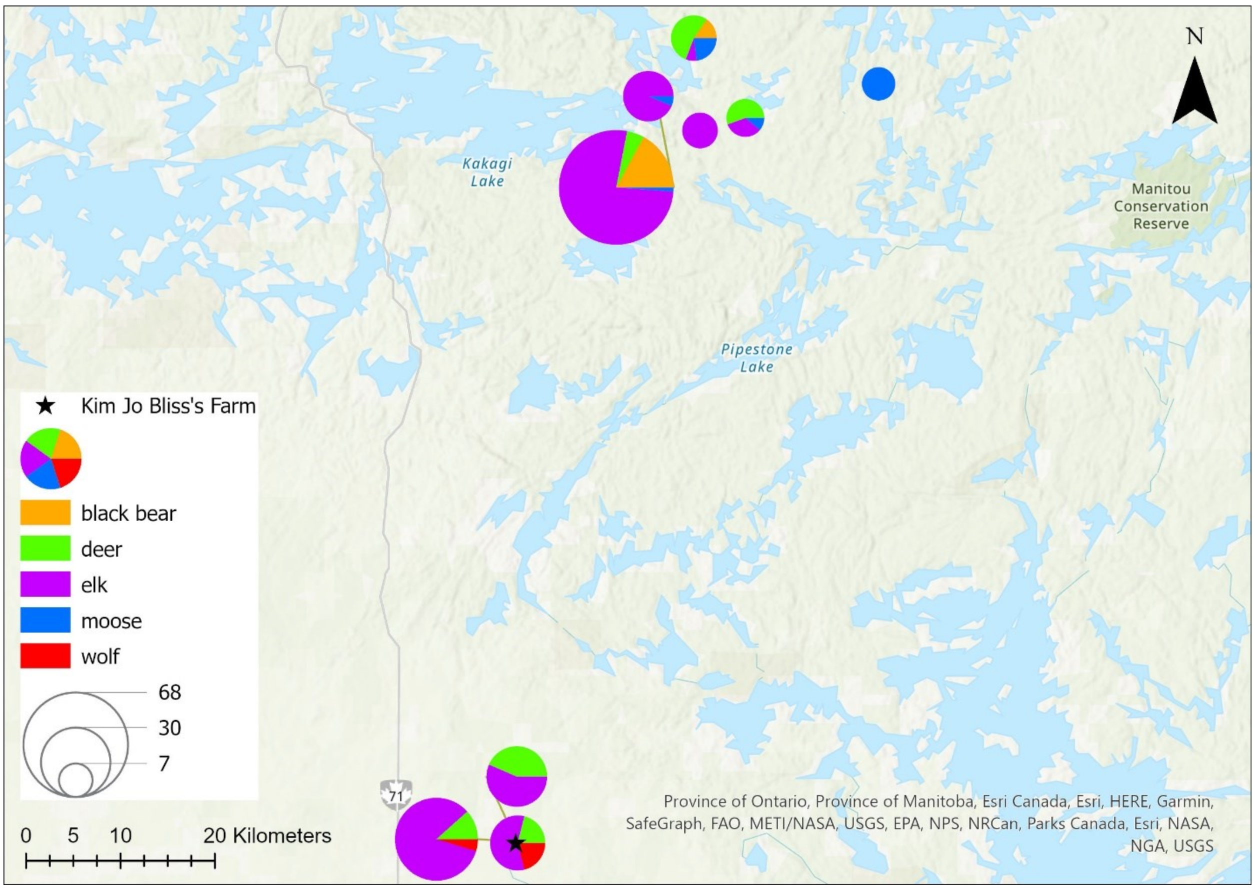

Figure 11. Distribution map for 2020. Details as in Figure 4.

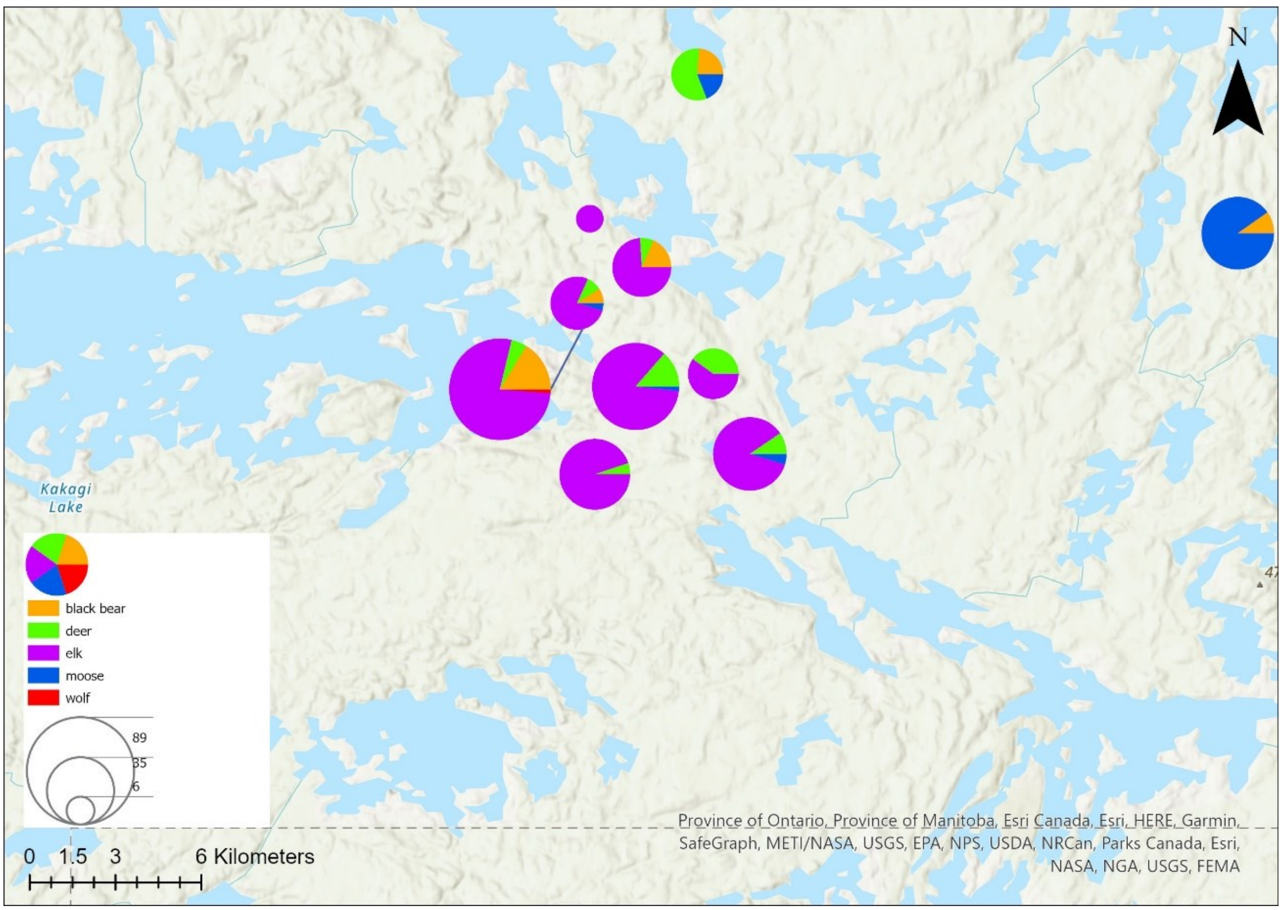

Figure 12. Distribution map for 2021. Details as in Figure 4.

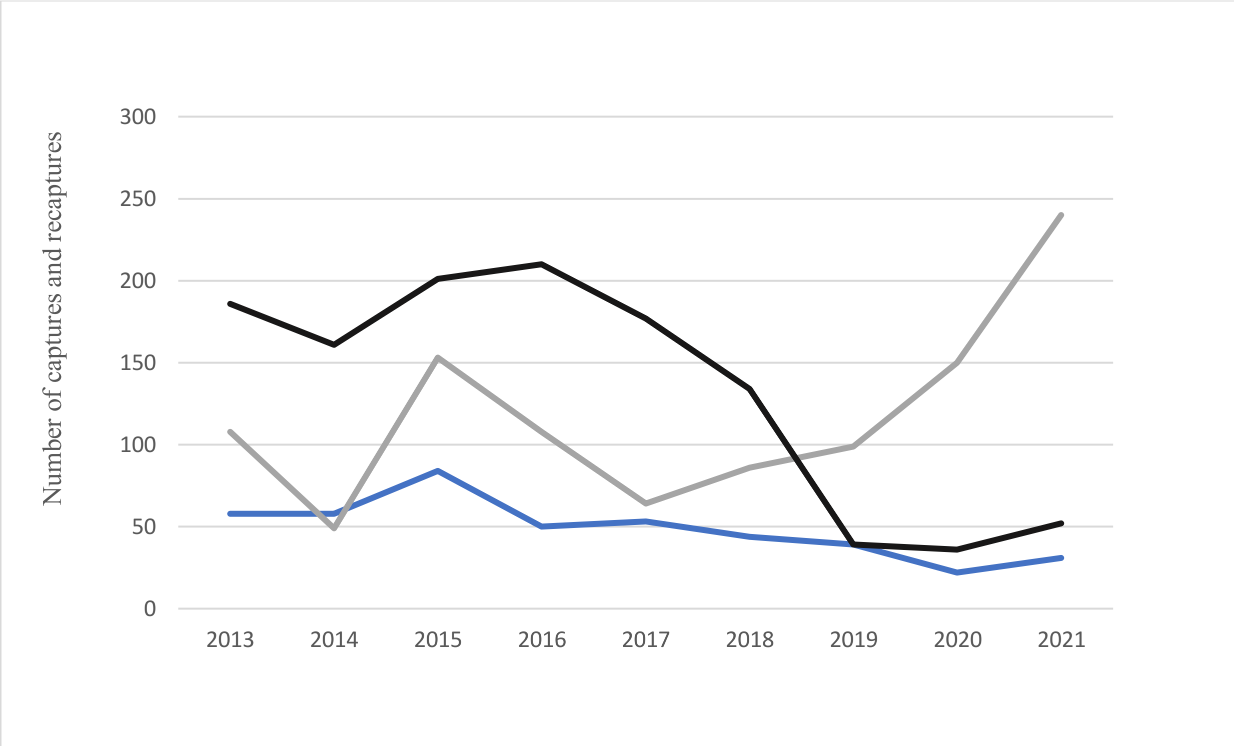

Figure 13. Predator-prey capture frequency population trends. Total camera captures and recaptures of predators (wolves and black bears) in blue and prey (elk in grey, deer and moose calf in black) from 2013 to 2021 in the LOW study area.

The behaviour model (where $p_i \neq c_i$), the model including the higher likelihood of recapture, was the model favoured each year (Table 2). This was a result of a limited number of camera placements that were capturing repeat visits by elk individuals each day. Due to the total number of individuals captured in any given year being fewer than 12, and many repeat captures, the minimum population estimate is the same number of elk identified on the camera, and likely not an accurate representation of the population size.

Table 2. Results of a capture-mark-recapture (MARK) analysis of the behaviour model from the LOW elk population, 2013-2021.

Year	% Support	Number of Elk identified	Probability of first capture per camera day (c)	SE of (c)	Probability of recapture (p)	SE of (p)	Population estimate ($\hat{N}$)	SE of ($\hat{N}$)
2013	91	5	0.12	+/- 0.02	0.38	+/- 0.13	5	+/- 0
2014	50	6	0.54	+/- 0.01	0.06	+/- 0.02	6	+/- 0
2015	100	8	0.13	+/- 0.01	0.02	+/- 0.01	8	+/- 0
2016	88	8	0.06	+/- 0.01	0.03	+/- 0.01	8	+/- 0
2017	51	10	0.03	+/- 0.01	0.03	+/- 0.01	10	+/- 0
2018	100	10	0.06	+/- 0.01	0.02	+/- 0.01	10	+/- 1
2019	100	8	0.09	+/- 0.01	0.02	+/- 0.01	8	+/- 0
2020	77	12	0.03	+/- 0.01	0.02	+/- 0.01	12	+/- 0
2021	100	12	0.09	+/- 0.01	0.02	+/- 0.01	12	+/- 1

DISCUSSION

Effort in the early period of camera monitoring in the LOW area was approximately 50% higher in terms of the number of camera locations, with a minimum number of elk estimated at approximately 50% higher than in this study (Mandula 2010). The MARK program was used to assess populations by first assessing three models: a time model, a behaviour model, and a null model. The behaviour model is called so because it looks at the behaviour of the animals; this model compares the initial capture probability to the probability of recapture of individuals of a population (Mills 2013). Random sampling, or the null model, implies that animals captured at one camera are equally as likely to or to not be captured at another camera (Moeller et al. 2018). The use of non-random camera placements could be the reason for the support of the behaviour model, a source of bias towards capturing and recapturing repeat elk individuals.

Non-random camera placements could also create bias in age and sex ratios, as the cameras are recapturing the same individuals. The cameras in this study were strategically placed in areas where elk were known to be habituated from their tracks, or other sings, and sometimes but not always moved if no evidence of elk was present for some time. This method of camera placement, while it may create bias, also increases the likelihood of captured elk on camera.

Elk were captured on camera more around Kakagi Lake than other camera locations, suggesting a localized distribution. Elk movement is directly affected by the distribution of available resources and access to them, which is also influenced by agricultural and recreational activities in the area (Van Dyke et al. 1998). Elk move to satisfy feeding requirements, while monitoring the risk of predation and maintaining social relations with their herd (Ryckman et al. 2010). Adult males also influence movement of a female herd as the female reproductive period is induced by the male population, therefore, the distribution of females will be directly related to the distribution of males during the mating season (Haydon et al. 2007). The camera placements of this study were strategic and based on known dispersal patterns of elk. Previous studies done on the reintroduced Ontario elk populations looked at the dispersal of elk after reintroduction to an area and showed similar results to this study; the elk populations tend to remain in a general area (Ryckman et al. 2010). The previous studies found that two years after release, elk that were released as calves or adult females did not disperse very far, while adult males traveled more extensively. Calves and females remaining near their release site suggests that there was a sufficient amount of food resources and limited predation as to not drive the herd away.

The distribution maps from this study show compelling evidence that supports the idea that predators influence elk distribution, in that where there were more wolves and black bear captured on camera, there were fewer camera captures of elk. Distribution patterns of predators are known to influence ungulate population distribution (Popp et al. 2018). In areas where wolves and black bears are abundant, there is evidence of lower elk use. Wolf populations are a major influence on elk populations as studies have shown that wolves may actually prefer elk over other ungulate prey species. Studies have found that although moose populations were 1.5 times amore abundant than elk, wolves still preferred elk, however, wolves are not the only predator influencing elk populations, as black bears are a major source of calf mortality (Popp et al. 2018).

Very few elk calves and yearlings were captured on camera in the LOW area compared to the number of adult elk. While this may allude to the population not growing, the total number of elk captured on camera each year does not show evidence of a decline in population, rather the opposite. Thus, this suggests that adults are more likely to be captured on camera than. Elk calves often remain hidden by their mother, resulting in calves not being captured on camera as often as adults. For a period of time after birth, a mother may hide her calf in brush or other cover and visit the calf at intervals for care (Altmann 1952). Elk calves also use "the hider" anti-prey strategy; that is, calves will hide in the presence of suspected predators (Geist 2002). Offspring remain with their mother for the first 1.5-2 years before they disperse on their own (Geist 1982).

More adult male elk were captured on camera than adult females. While this may suggest that there are more males in the population, the sex ratio by number of individuals shows that the male to female ratio is fairly even, suggesting instead male bias in camera captures. Equal sex ratios are expected if the fitness costs of producing male and female offspring are equal (Fisher 1930). However, in most ungulates, male offspring are generally larger than female offspring at the end of the lactation period and are therefore more costly (Kojola 1998). Additionally, low male-female ratios can result in negative offspring production (White et al. 2001). Male bias in dispersal could be the cause of male bias in camera captures and recaptures, as adult male elk are known to travel more extensively and greater distances (Ryckman et al. 2010). Prevot and Licoppe (2013) found travel distances of 4.82+/−4.17 km for males and 1.84+/−1.46 km for females and calves. Mate competition, resource competition, and inbreeding avoidance are all potential hypotheses to explain elk dispersal. These factors all suggest that dispersal is biased towards adult male elk, where reproductive success and foraging behaviour vary with the ability to spot males (Petersburg et al. 2000). No correlation was found between the timing of year and sex bias.

Generally, more elk were captured on camera than predators, population trends showed an overall decline in predator captures over the course of the study period, while there was an overall increase in elk captures. Predators can directly affect prey populations; while black bears are opportunistic predators, wolves are selective. Wolf diets are comprised mainly of ungulate species and studies have shown that wolves may prefer elk over other ungulate prey species (Popp et al. 2018). Vigilance behaviours in elk are influenced by risk of predation and risk of other elk. Vigilance varies with predation pressure as well as sex and social status, herd size, distance to cover and distance to nearest neighbour. Female vigilance shows to decrease with a larger herd size but herd size shows no effect on male vigilance (Lung and Childress 2006). Therefore, as the herd grows, females may become less vigilant and more susceptible to predation – a possible explanation for the varying population trend of elk captured and recaptured over the years 2013-2019. The decrease in camera captures of predators following 2019 is a potential explanation for an increase in the elk population of the same timeframe if it equates to fewer predators and thus less predation.

Another probable cause in the likely increase in elk population is the significant decrease in the white-tailed deer population. The number of deer was higher than the number of elk captured on camera for the majority of the study, until 2019, when the number of elk camera captures was greater than the number of deer. Deer are carriers of many diseases and pathogens including Chronic Wasting Disease (CWD) and the meningeal worm (*Parelaphostrongylus tenuis*) (Williams et al. 2002; Ranta and Lankester 2017). The meningeal worm has historically been known to determine trends in deer and moose populations in Ontario (Ranta and Lankester 2017).

Another determining factor of deer populations is winter temperatures and snow depth; the colder the temperature and deeper the snow, the less density of deer (Karns 1980). White-tailed deer numbers decreased from 2013 to 2014, while the snowfall records show an increased annual snowfall from 213.5 cm to 276.0 cm (Environment and Climate Change Canada 2022).

The same results were seen in the years 2017 and 2019 when snowfall records peaked, the number of deer decreased. The number of white-tailed deer can also determine the number of wolves in an area and vice versa (Ranta and Lankester 2017). Thus, the decrease in deer populations could have resulted in the decrease in wolf populations contributing to the rising elk populations as suggested by these results.

The Lake of the Woods elk population estimates from this study show a decline in population numbers from previous years. Surveys on the population done by the Ministry of Natural Resources estimated a population size of 25-35 in 2009, assuming that only half of the population was surveyed due to poor conditions. Surveys were done at the time using aerial surveying, radio collars, and camera traps. Camera traps identified 16 unique individuals using 6 cameras (Rodgers et al. 2009). This estimate is greater than the maximum number of individuals identified in this study, with similar number of camera traps. Additionally, cameras set up on a farm in the Fort Frances District, ON. (Kim Jo Bliss's Farm, Figure 11) captured a maximum of 12 elk, which coincides with reported sightings by the farmers. There have been many attempts to monitor reintroduced elk populations in North America. However, there is much uncertainty of the status of the elk populations as better information is required to improve restoration efforts in North America (Mcintosh et al. 2009). The population estimate from the 2009 study are much higher than the results of this study up to 2021. However, the results from 2009 were complied using multiple surveying techniques rather than relying on camera traps alone. Thus, this study may have had a higher population estimate if more resources were used to survey the population.

CONCLUSION

From this study it appears that the Lake of the Woods elk population may have declined from previous studies, but may now be on the rise again with the decrease in predators and less severity in winter seasons. The LOW population is estimated to have a fairly even male-female ratio, with more adults than calves or yearling in the population. The LOW elk appear to have limited distribution. The LOW area also appears to have had a decreasing predator population and a decrease in other cervid prey populations over the course of the study period, likely a factor of the meningeal worm affecting cervid populations causing fluctuation of population sizes (Ranta and Lankester 2017).

While camera traps are a useful tool for sampling wildlife, they do come with limitations for a capture-mark-recapture abundance estimate. The use of non-random camera placements in the capture-mark-recapture design reported here creates bias in the population estimate by limiting the number of new captures and increasing the number of recaptures of the same individuals. For future use of camera traps to monitor the elk population in the LOW area, it is recommended that a greater number cameras be deployed and at random locations to get a more accurate population estimate. Nevertheless, camera traps provide valuable information such as the confirmation that elk are in the area, they provide information on distribution and dispersion, as well camera traps can give an idea of population trends and other relevant animals in the area can be documented.

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APPENDICIES

Table 3. Results from MARK analysis showing the support weight for each model (behaviour, time, and null) for each year in the study period.

Year	Model type	% Support
2013	behaviour	91.48
	null	5.38
	time	3.14
2014	behaviour	50.57
	null	49.53
	time	0.00
2015	behaviour	100.00
	null	0.00
	time	0.00
2016	behaviour	88.33
	null	11.67
	time	0.00
2017	behaviour	51.48
	null	48.52
	time	0.00
2018	behaviour	99.96
	null	0.04
	time	0.00
2019	behaviour	100.00
	null	0.00
	time	0.00
2020	behaviour	77.33
	null	22.67
	time	0.00
2021	behaviour	100.00
	null	0.00
	time	0.00