Topic:

Clouded leopard (*Neofelis nebulosa*) communication behaviour.

Annotation Organization

The first category of organization contains articles which provide background information on the clouded leopard, including basic information about their ecology, distribution, population density, reproduction, extinction risk assessment, and areas where there is little to no information known, while the other articles are sorted into categories according to the form of behaviour within communication that the paper discusses, including scent marking, vocalizations, and ear movement signals, as well as an innovative paper on emerging camera trap technology to enhance data collection. All articles within each category are sorted chronologically, with the newest articles at the beginning of each section and the older ones further back.

Background Information on Clouded Leopards

1) **Citation**

Chiang, P.J. (2017). A review of our current knowledge of clouded leopards (*Neofelis nebulosa*). *International Journal of Avian & Wildlife Biology, 2*(5), 148-154. https://doi.org/10.15406/ijawb.2017.02.00032

Article Summary

This review focused on summarizing all known aspects of clouded leopard behaviour and ecology. Clouded leopards inhabit fragmented regions of southern Asia, including parts of China, Thailand, Cambodia, and Malaysia. Some studies suggest their range may be expanding in some areas, however so little is known about their habitat preference and home range that it is difficult to tell. Similarly, population density estimates range from 0.58 to 6.53 individuals per 100km^2, although the increasing use of camera traps for monitoring will hopefully aid in establishing a more concrete number.

Advances in genetics have been made since they were first discovered, with the current conclusion being that within *Neofelis* there are serval subspecies and at least two species based on haplotypes and pelage. Studies on wild clouded leopards are few, with only seven cats ever radio

collared. Most prior knowledge learned comes from captive cats with the understanding that while captivity is useful for biological understanding of concepts like reproduction, it also has the capacity to change behaviour. To date, information regarding reproduction has been collected via captive cat studies and only one study has evaluated communication in the wild (Allen et al. 2016). Arboreal behaviour and habitat use was also discussed, showing a discrepancy in the literature as some studies concluded they prefer lower elevations, while others showed the opposite, and many determined that they inhabit a wide variety of habitats aside from dense primary forests.

Many studies concluded that the known aspects of their ecology and behaviour are similar to that of other felids, especially other solitary cats, and as such many authors have speculated that it is likely other aspects that are still unknown are likely similar as well. Further studies should place an emphasis on examining movement patterns, analysis of population, and their ecological niche.

Article Contribution

This review article briefly summarizes the current knowledge and understanding of clouded leopard ecology and behaviour. While it is not in-depth, it provides an overview of many aspects including population demographics, habitat use, arboreal behaviour, reproductive and communication behaviour, and food habits, while demonstrating the lack of information on clouded leopards. As part of the review the authors established three main areas of focus for future work, and why it is important to fill these gaps. It was chosen as it provides a general overview of research on clouded leopards including communication behaviour, which is the focus of my review.

2) Citation

Hunter, L. (2015). Wild cats of the world. *Bloomsbury Publishing PLC,* New York.

Article Summary

This review focuses on providing basic information on the history of clouded leopards, and various aspects of their ecology and taxonomy, among other areas of knowledge. It chooses to discuss both species of clouded leopard (*Neofelis diardi, Neofelis nebulosa*), allowing for a comparison of the differences and similarities between the two species. It also suggests that they diverged from the other members of Panthera approximately 6.9 million years ago, which may account for their many

differences. Physical descriptions of both species were given, and a comparison between the clouded leopard and the marbled cat, an Asian cat similar in appearance and habitat but smaller in size, was also established as the two are not closely related yet are often mistaken for one another. Various studies and unpublished observations show that they typically kill prey with a bite to the back of the neck, which varies from the killing mechanism used by other felids, and is suggested to be related to their dentition and large canines. The article found there to be a severe lack of data related to reproduction, with most cases showing extreme aggression of males towards females in captivity. It is thought this is due to their captive situation, and does not represent actual behaviour in the wild. Future studies on clouded leopards can go in many directions, however the most important is to establish what behaviours exist in the wild, especially those for communication, as this field is largely understudied and has many gaps in understanding. A demographic study should also be done to confirm the exact distribution of the species, while many aspects of its ecology, especially its diet and how interactions with other cat species differs between island and mainland populations could be studied as well.

Article Contribution

This review discusses valuable information regarding all aspects of the clouded leopard's ecology, and debates the rationale for several interesting features they have. It also suggests the reason for why reproductive behaviour is extreme in captivity and emphasizes the need to study this in the wild. It coincides with other papers in the field, especially in regard to their evolutionary history, demographics, and what is known. I chose this article specifically because of the evolutionary relationships and distinctions it made, especially between clouded leopards and the other members of Panthera, which coincides with other papers selected on the topic.

3) Citation

Rabinowitz, A., Andau, P., & Chai, P. P. K. (1987). The clouded leopard in Malaysian Borneo. *Oryx, 21*(2), 107–111. https://doi.org/10.1017/S0030605300026648

Article Summary

Prior to this study, very little was known about the clouded leopard except for that it inhabited forests in Asia and had many morphological characteristics that fell between small and large cats. Some previous studies tried to compare it to sabre-toothed cats due to its large canines in proportion to the

rest of its body. The purpose of this papers was to reassess the extinction risk assessment of the clouded leopard in Borneo. It also focused on gaining knowledge of clouded leopards. To do this, one researcher travelled to different villages within their home range to take notes on first-hand sightings by locals and look for tracks. This study was conducted from January 15 to March 15 in 1986 in Sabah and Sarawak, Borneo. While interviewing locals, accurate pictures of clouded leopards were used to avoid confusion with the marbled cat, a small cat species that looks similar. In Sabah, they collected 90 first-hand sightings, with 25% of sightings occurring that year, while in Sarawak 37% of 71 sightings occurred within the past year. This suggested clouded leopards inhabited these regions still. Additionally, the researchers found that hunting pressures were reduced, with several laws in place and a shift in hunting perspectives in different cultures. They also found that 82% of sightings were on the ground, which contradicted the previous belief that clouded leopards were mainly arboreal in nature and suggests they may use trees for sleeping or other activities. A lack of evidence was also found for marking behaviours, which indicates the cats may avoid others or occur in low densities. Further studies should be done to determine whether melanistic, or dark forms, of clouded leopards exist, which would coincide with four unconfirmed sightings. Detailed studies should be conducted to determine their behaviours and relationship with selective logging.

Article Contribution

In 1987, this article made major contributions to the information on clouded leopards, especially towards their extinction risk assessment classification. It was chosen, because although it is outdated and contradicts newer papers, it shows how far research on these cats has come, even if they are still quite hard to find. While it agrees with newer papers on some topics, such as how they are likely less arboreal than previously thought, it also disagrees, especially about their marking behaviors as Allen et al. (2016) suggested they use ten forms of communication behaviours, including multiple which are used with scent marking.

Scent Marking

4) Citation

Palomares, F., González-Borrajo, N., Chávez, C., Rubio, Y., Verdade, L. M., Monsa, R., Harmsen, B., Adrados, B., & Zanin, M. (2018). Scraping marking behaviour of the largest Neotropical felids. *PeerJ, 6*, e4983. https://doi.org/10.7717/peerj.4983

Annotated Bibliography

Article Summary

In carnivorous mammals, scent-marking has been recorded frequently and involves scat, urine, scratching the ground and other signals which provide visual and olfactory intraspecific communication cues. In felids, scraping is a known behavior which involves using their hind feet to create impressions in the ground, although the intentions and conditions of this scent-marking behaviour are largely unknown. This study aimed to examine this behaviour by studying it in jaguars and pumas of five different areas within the Neotropic region that had varying habitats. They studied whether scrapes were used to mark proposals, communicate with conspecifics, or signal points of interest. This was done by recording scrapes and scrape location information using search teams of two people with GPS devices, as well as collecting faeces to determine which species performed the scrape. In total, 467 km of path systems were scouted, with 347 scrapes in 207 sites located, meaning that there were approximately 0.576 scrapes per kilometer. Scrapes were done mainly in leafy areas, and sites appeared to be chosen based on substrate scale and site level. This suggests felids intentionally mark sites and potentially concentrate them in the best quality areas of their home ranges, marking areas of optimal habitat. The results also suggest that scrapes are used as communication methods, although it is unclear if they signify territories or things like health and reproduction. Additionally, males performed scraping more than females in both species, although females do investigate these sites. Pumas used scraping more often than jaguars, although the number of scrapes did not vary significantly between areas of species overlap and areas where a single species lived. Further studies should focus on investigating the exact purpose of scrapes, as well as how this communication behavior exists in other cats, especially those that are understudied like the clouded leopard.

Article Contribution

This article provides knowledge about scraping, a specific behaviour associated with scent-marking in felids. It advances the field by investigating how this behaviour is used in marking proposals and habitat knowledge. It was chosen as jaguars are part of Panthera, which relates them phylogenetically to clouded leopards. As many studies have determined that solitary cats exhibit similar behaviours for similar reasons, it allows for inferences about the ecology and behaviour of clouded leopards. The article appeared to support the other literature on scraping in felids, as it reconfirmed several aspects of scaping morphology and location that had previously been discussed.

5) Citation

Allen, M. L., Wittmer, H. U., Setiawan, E., Jaffe, S., & Marshall, A. J. (2016). Scent marking in Sunda clouded leopards (*Neofelis diardi*): Novel observations close a key gap in understanding felid communication behaviours. *Scientific Reports, 6*(1), 35433. https://doi.org/10.1038/srep35433

Article Summary

This article examined several topics within the behaviour of clouded leopards. As very little is known about their behaviour this aimed to address the knowledge gap and assist in furthering the information bank on solitary felids. It focused on examining their recurrent uses of scent marking locations, geographic dispersal within various environments, and the number of times different communication behaviours were displayed. This was investigated using 28 motion-triggered video camera monitoring sites in seven different forest habitats that ranged in elevation, and were all located in Gunung Palung National Park, West Kalimantan, Indonesia from June 2015-February 2016. Four camera traps were placed in each forest type and the resulting videos were analyzed and statistically processed. 65 visits to 13 monitoring sites occurred, and Allen et al. (2016) found that clouded leopards use ten different communication behaviours. Three behaviours were the most common, scraping, cheek rubbing, and olfaction. Additionally, males tended to revisit sites to investigate and remark, while females did not. These results were novel for clouded leopards, but coincided with other members of Panthera, especially leopards and snow leopards despite environmental variation. This suggests other aspects of clouded leopard behaviour may be similar to other solitary felids. They also found that the cats occupied all forest types but were more common in the three highest elevation sites.

Tail wrapping, a new behaviour that is undocumented in any other species of cat, was also documented, which implies that there may be other unique aspects to their communication behaviour compared to other cats. This raises the question of whether tail-wrapping is a communication behaviour or an arboreal one, as they are well-adapted to living in trees. Furthermore, additional studies could focus on how scent marking operates differently within members of the Felidae family based on age, sex, and individual preference.

Article Contribution

As one of the newest papers on clouded leopards, it presents key concepts about scent marking behaviour and enhances the understanding of communication behaviours of clouded leopards and other solitary felids. It also depicts new communication behaviours observed in clouded leopards that have not been see in other felids. While the results contradict previous studies, it uses new technology and methods to collect data on wild populations and may assist in furthering conservation efforts by advancing knowledge on their ecology and behaviour. It was chosen because it is newer and focuses exclusively on clouded leopards, unlike some other articles chosen.

Vocalization

6) Citation

Peters, G. (2002). Purring and similar vocalizations in mammals. *Mammal Review, 32*(4), 245–271. https://doi.org/10.1046/j.1365-2907.2002.00113.x

Article Summary

Purring as a vocalization form is thought to be used for three main reasons in animals, to show that the animal is friendly and content and the situation it is in is pleasing, to show placation when in pain, or to calm the sender of the signal in painful or stressful situations. It is a low amplitude vocalization with specific frequency limits, and is thought to potentially be homologous across members of the Carnivora family, of which cats are part of. In this review, the focus was to assess all literature involving the words purr or purring in different groups of mammals including Felidae and related taxa to determine which taxa exhibit purring and which exhibit a similar vocalization that should be classified differently. Sonograms and evidence within individual papers were analyzed and compared to the feline purr to determine similarities and differences. Within Felidae, it was found that all members use purring except for the members of Panthera. Snow leopards and clouded leopards remain unclear as they produced sound when inhaling and exhaling, however they likely do not purr given their phylogenetic classification. Within Carnivora, no other families appeared to use purring expect for Viverridae, the cat-like carnivores (civets, genets, and linsangs), which suggests that purring is homologous between these groups. Hyaenidae (hyenas and aardwolves) potentially use purring although this remains severely understudied. Other mammals such as primates have a form of vocalization similar to the purr, which

suggests there may be an evolutionary adaptation across Mammalia to this form of communication although other studies disagree. Further studies should focus on whether purring in Viverridae and Felidae is indeed homologous, whether Hyaenidae uses this form of vocalization as well, and how other members of Carnivora and Mammalia use purring or purr-like vocalizations to determine the exact evolutionary origin.

Article Contribution

This article provides an overview of purring and similar vocalizations within the cat family, as well as the order it is found within (Carnivora) to express the potential evolutionary origins of this communication form. I chose it because of this, as well as its discussion of where the clouded leopard fits on the phylogenetic tree and its relation to the other members of the big cats. This article supports other studies on vocalizations as well as the relationship between clouded leopards and snow leopards, however, it does contradict several articles on which groups purring is actually found in.

7) Citation

Peters, G., & Tonkin-Leyhausen, B. A. (1999). Evolution of acoustic communication signals of mammals: friendly close-range vocalizations in Felidae (Carnivora). *Journal of Mammalian Evolution, 6*(2), 129–159. https://doi.org/10.1023/A:1020620121416

Article Summary

The phylogeny of Felidae is relatively well-established, with approximately 36 living species that vary in size and appearance yet have remarkably similar habits and behaviours. It was known that vocalization is used by felids across all sound ranges (short, medium, long) and is essential for intraspecific communication. Cats exhibit 12 different sounds, which appear genetically fixed and cannot be learned. The purpose of this study was to recreate the molecular phylogenetic tree proposed by previous researchers using close-range acoustic signals to determine the evolutionary history of vocalizations in cats. Adults and juveniles of both sexes of 28 species in captivity were examined using tape recorders to create sonographs. These were analyzed and categorized into one of three sounds, the gurgle, prusten, or puff, based on a variety of factors. These vocalizations sound similar to how they are pronounced, and each species only uses one. Gurgles were found in 22 species, with another eight likely to use them as well. The prusten was found in four species, and puffing in two. Clouded leopards were

found to use the prusten, along with tigers, snow leopards, and jaguars, all of which are members of Panthera. Within this genus, the prusten of clouded leopards is most like that of snow leopards. When cross-examined with the phylogenetic tree, the two were agreeable, with each sound type appearing homologous. The gurgle is likely the primitive sound, with the prusten and puff being derived. This coincides with the phylogenetic tree, as gurgles are found across the earlier lineages of cats, while prustens are found within Panthera, and puffing in lions and leopards, the last two members of Panthera to diverge. Further studies should be directed towards establishing how these sounds are produced, and if the gurgle is an ancestral character or unique to Felidae.

Article Contribution

This article was chosen because it is the first to examine acoustic communication in felids in conjunction with phylogenetic trees to reconstruct the evolutionary history of this behaviour. It focused on close-range vocalizations and suggested that there exists a phylogenetic transformation series between the three sound types (gurgle, prusten, puffing). It also furthers the information known about clouded leopards and provides evidence for the evolution of their communication behaviour. The results coincide with other phylogenetic trees at the time, as well as the paper by Allen et al. (2016) which suggests snow leopard and clouded leopards share many behavioural traits.

8) Citation

Hast, M.H. (1988). The larynx of roaring and non-roaring cats. *Journal of Anatomy, 163*, 117-121.

Article Summary

Previously, it was known what four bones connect the hyoid bone to the skull in felids, as well as that the larynx, or voice box, of the lion, snow leopard, tiger, and jaguar differ from that of other cats. Their larynx is longer and has an elastic ligament that replaces the epihyal, one of the important connection bones. It was unknown what the mechanism that caused roaring in cats was, as snow leopards did not roar yet were still part of Panthera. In this study, the larynx was examined to determine how it produced a roar in most members of Panthera but not in snow leopards or smaller cats. This was done through the dissection the larynges of 14 species of 26 adult cats from across all genera that died of natural causes in captivity. Measurements of different aspects of the vocal tract were completed for each larynx, as was a histological examination using light microscopy. All roaring cats except snow

leopards were found to have a pad of fibro-elastic tissue in each vocal fold, which differed from the small cats. The snow leopard was found to have a larynx similar to that of the other members of Panthera, but lacked this pad of tissue, which prevented them from roaring. Similarly, the clouded leopard larynx was found to be comparable to that of Felis, the genus which includes the domestic cat and other small species, and therefore cannot roar. This study suggests that sound is generated by the larynx through the vocal cords, while the vocal tract is responsible for sound projection. Future area of study could involve focusing on the remaining species not examined, as well as whether this theory is still applicable today with the changes that have been made to the Felidae phylogenetic tree since 1988.

Article Contribution

This study provided a valuable contribution to understanding the mechanisms and morphology of roaring in cats. It examined how the ability to roar was distributed within Felidae, suggesting that it is only found within the last four members to diverge. The results coincide with other papers, as both snow leopards and clouded leopards lack roaring capabilities, thus showing another similarity between these two members of Panthera. I chose this article for this reason, as it affirms the evolutionary relationship of these species and creates a stronger case for arguing that clouded leopard communication behaviour is like that of snow leopards.

Signaling Using Ear Movement and Spots

9) Citation

Galván, I. (2020). Correlated evolution of white spots on ears and closed habitat preferences in felids. *Journal of Mammalian Evolution, 27*(3), 519–523. https://doi.org/10.1007/s10914-019-09464-x

Article Summary

Previous studies show that juxtaposing white spots on an animal's body are evolutionarily favoured, and often serve a purpose, although the exact purpose in felids remains unclear. It is proposed that ear movement is used by felids for intraspecific communication, and as such, white marks found on the backs of the ears (ear spots) are thought to act as amplifiers to enhance detection of ear movements in poor light by conspecifics, much like white plumage in birds. The purpose of this study was to analyze whether there is a correlation between white ear spots and felid habitat preference. Felids who lived in closed habitats, regions where light conditions are poor such as forested areas,

where thought to drive the evolution of ear spots. To examine this, the presence of ear spots was inspected for all felid species using images, while habitat preference was determined using guidelines proposed by previous studies, and mass was used as a potential parameter. A phylogenetic logistic regression model and other statistical analysis on R were used to analyze the data. The study found that 25 species had ear spots and 12 did not, while mass was found to not have a significant impact on the occurrence of ear spots. Habitat preference and ear spots were found to be correlated, with white ear spots being found more often in closed habitats. Ear spots were determined to be evolutionarily fixed, which suggests they may have contributed to closed habitat adaptations. Further studies should be done to examine if the frequency of long-range vocalizations is lower or if close-range vocalizations are higher in felids with white ear spots who inhabit closed habitats as opposed to those without ear spots. Studies should also be done to examine what is communicated using ear movements as well.

Article Contribution

This article contributes to the evolutionary knowledge of cats and focuses on a novel idea regarding communication behaviour. I chose it because it appeared to be a beneficial paper to read, as the concept is new and it introduces a new form of communication in felids that is relatively unstudied. It also uses clouded leopards in the study, which further relates to my literature review topic. The article agrees with several other sources, all of whom support the idea that ears are used for communication in cats, and that ear spots may be beneficial to the human understanding of felids.

Camera Trap Methodology

10) Citation

Tanner, D., & Zimmerman, P. (2012). Optimal attractants to increase visits by clouded leopards to remote-camera sets. *Wildlife Society Bulletin, 36*(3), 594–599. https://doi.org/10.1002/wsb.160

Article Summary

Prior to this study it was well-established that clouded leopards are notoriously difficult to study. It was also known that scents and visual attractants can be used at camera trap locations to entice animals, especially carnivores, to come to these sites or stay for longer periods of time, which allows more data to be collected about their behaviour. They are only beneficial if the sites are placed

along known corridors of animal use. This study used nine captive clouded leopards at the Smithsonian Conservation Biology Institute (SCBI) to examine which visual and scent attractants commonly used in other literature would be beneficial to studying clouded leopards. Five scents (skunk, Hawbaker's wild cat lure (WCL), scat from other clouded leopards, gusto and catnip, predator-survey scent disks) and two visual attractants (turkey feathers, metal pie tin) were used both on their own and in combinations. Clouded leopards were observed in one-hour periods for a total of 81 behavioral observations. The study found that for visual attractants, the turkey feathers had the best performance, while for scent Hawker's WCL with skunk gland and scent disks were tied. There was a more prolonged response when exposed to the scent disks compared to the Hawker's WCL and skunk gland, which suggests the scent disks may be more beneficial as attractants. When combined, the scent disks and turkey feathers showed a significant increase in response length compared to the scent disk alone but did not differ from the turkey feathers. With this combination however, the clouded leopards stayed at the sites longer, resulting in better-quality images and information gained, which suggests that this combination may be useful for improving information collected via camera traps. Further studies should involve field-testing these results with wild clouded leopards and seeing if feathers from other large birds are equally suitable.

Article Contribution

This study aims to improve the effectiveness of using camera traps to gather information about clouded leopards in the wild using different scent or visual attractants. This idea presents an opportunity to further develop the information known about these cats and improve conservation efforts on their behalf. It supports other articles in the field as it expands on previous studies done on other carnivores using the same attractants. I chose it because it relates to the other papers I have chosen that involve camera traps, and provides a novel idea on increasing the efficiency of these studies in the future.