The use of chemical communication to establish dominance in deer.

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Abstract

Within the scope of animal communication, less is known about chemical communication. Among some mammals like deer, chemical communication is used to communicate dominance, age, reproductive information, etc. Researchers have developed mating system networks to be able to study male-male and male-female communication during the breeding season. Scraping is a commonly exhibited behavior that is exhibited by males to establish territory and dominance. In breeding networks, the more domineering deer tend to have more female responses. Additionally, chemical analyses have been performed to determine the proportions of volatiles in inter- and intrasexual signals. Many of the proportions of volatile compounds are variable with age and competition level. This review article explores the relationship between age, dominance, and chemical signaling.

Introduction

Communication is a well-studied animal behavior that has interested scientists and humans for millennia. It is the process where a signal is sent, and it modifies the behavior of the receiver. Communication between animals evolves if it becomes beneficial for the individual (Peña et al 2019). Animals adapt their mode of communication based on the conditions of their environment, and to avoid competition within the signaling world. The differences among signal structures are to maintain species specificity, so that animals can distinguish themselves from one another (Marler 1967). There are several modes that an animal may communicate with, such as acoustical, tactile, visual, and chemical. Mammals are generally adept with acoustical and visual, but some species have the ability to interpret chemical signals.

Chemical communication is a mode of communication amongst mammals that is often overlooked because it is more difficult to observe and study. Even though humans cannot visualize chemical signals, chemical communication is one of the most important modes of communication; its range of uses is very broad. Chemical signals can convey territoriality, search for food, sex pheromones, aggression, dominance (Surov et al. 2016). Chemical reception is a trait that has been around since bacteria began to proliferate on earth. While we understand the evolutionary background of chemical communication, factors that influence its uses (age, sex, social status) in different animal taxa are not as well understood. Deer use chemical communication to convey seasonal-specific messages through scraping, urinating, rubbing, etc.

Many researchers use video captures to assess deer breeding behavior and establish observable social networks within the herd. Additionally, many chemical ecologists perform gas

chromatography-mass spectrometry (GC-MS) to analyze the volatiles found in these signals (Miller et al. 1998). As previously mentioned, the factors that influence the use of chemical communication in deer during the breeding season are not as well understood.

In polygynous species such as deer, the purpose of chemical communication is to signal fitness, territoriality, and dominance (Peña et al. 2019). In many species of deer, chemical signals can be used for inter- and intra-sexual purposes. Deer need to be able to send wide-encompassing messages to both groups of females and groups of males. Investigating these signals can allow us to understand sociality, dominance, importance, and hierarchy within herds of deer (Hearst et al. 2021). Researchers have investigated the morphological changes that occur to mating deer, and have found that body size, size of antlers, tarsal tuft are highly indicative of increased rutting behavior in male deer (Peña et al. 2019). Additionally, the research suggests that older deer are more likely to engage in rutting behavior within breeding networks (Gasset et al. 1999). In this paper, we will investigate current research on chemical communication in deer and strive to answer the question: do older male deer exhibit more domineering chemical signaling?

Male-male signaling

There are a variety of ways and reasons why males send messages to each other. Most of the time, males send messages to each other to scent-mark territory or indicate social status (Martin et al. 2014). Research has shown that scraping, a form of chemical communication, is exhibited by deer in captivity (Miller et al. 1987).

Researchers from Georgia conducted an experiment observing the dominance, testosterone levels, and scraping activity in captive groups of white-tailed deer males. The

researchers observed 10 groups of bucks of three to five individuals. They observed that only bucks over three and a half years old produced scrapes, and in one group, only the highest-ranking male produced scrapes (Miller et al. 1987). The researchers also tested the testosterone levels of the deer and found that testosterone levels were highest during October and December and then dropped during the summer months. The older males (3.5 years and older) had higher levels of testosterone as well. The younger males had testosterone levels that ranged from 0.3 to 2.2 ng/ml while testosterone levels from older males ranged from 0.7 to 6.8 ng/ml. The researchers go on to say that testosterone was associated with aggressive behavior, while dominance was affected by other factors such as age, experience, morphology, etc (Miller et al. 1987).

Other research has shown that scraping is just as relevant in wild deer populations too. Researchers from Mississippi developed a method to observe and quantify chemical signals being sent in mating systems. Male-male messages are included in the mating system because many males will send messages to advertise sociosexual status with competing males (Hearst et al. 2021). The researchers set up cameras on their local college campus to remotely monitor eight scrape sites.

The objective of this study was to develop social network analyses to reveal dominance, importance, and sociality. Most of the scraping observed by the cameras was done by older mature males, and mature males also displayed more scraping per day than females. The researchers also found that the two male deer in the observed herd that sent the most messages to each other ended up having physical altercations caught on camera, suggesting that scraping networks may be important predictors of rivalry and physical conflict (Hearst 2021). Scraping behavior is not exclusive to male-male signaling, as it can also be used in male-female signaling.

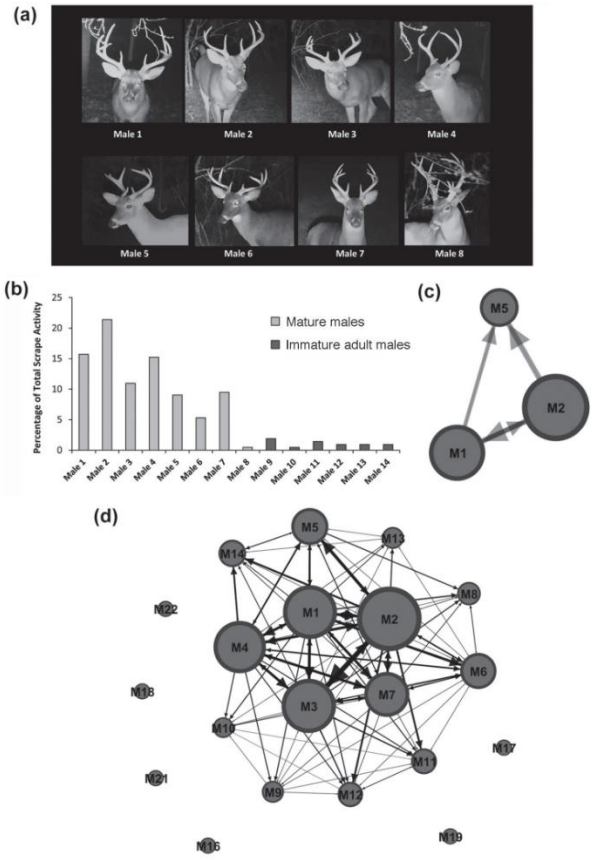

Figure 1. (a) Pictures of eight mature male deer in the study. (b) Data showing percentage of total scraping activity. (c) Network of communication of male 3 at a specific scrape site. (d) Representation of the male scraping network.

Male-female signaling

During the breeding season, males will perform scrapes, and antler rubs to communicate reproductive information as well as dominance status within the breeding males (Sawyer and Miller 1989). Females respond to these cues with their own messages directed at males (Gasset et. al 1997). Using centrality measures of breeding networks, researchers can establish sociometrics such as dominance (Wey et. al. 2008, Hearst et. al. 2021).

The researchers from Mississippi used centrality measures to analyze the breeding networks and establish dominance hierarchies based on male-female signaling. They ranked

males by in-degree centrality (number of messages received) and out-degree centrality (messages sent). Out-degree centrality is an indicator of dominance within social networks (Wey et. al. 2008, Hearst et. al. 2021). The males in their system that had the highest out-degree centrality, which could be seen as a rank of dominance, also had the highest proportion of female response. The male with the second highest out-degree centrality also had multiple responses from multiple groups of females. The males that had the highest out-degree centralities were mature, antlered males all over 2.5 years old (Hearst et. al. 2021).

Rutting behavior during the breeding season is when deer of both sexes abandon their normal habits and go in search of a mate (Mass.gov). During this time, white-tailed deer bucks cruise around trying to gauge chemical signals from does in estrous. The same can be applied for Iberian red deer. Another study by Peña et. al. from 2021 explored how the size of their ventral patch is correlated with the degree of involvement in rutting behavior. Much like the tarsal tufts in white-tailed deer, the ventral patches are impregnated by strong odors from their urine, and it is used to convey reproductive information. The researchers observed the behavior of male deer during the rut and compared them to the size of the ventral patch along with other factors such as age. The researchers found that the size of the ventral patch was positively correlated with more rutting activity such as roaring and flehmen. Roaring is a territorial behavior and is considered an index of fighting ability (Martin et al. 2014). Additionally, they found that territorial behaviors such as roaring were only displayed by older adult deer. Since the size of the ventral patch would imply more chemical signaling, this research suggests that deer that send more chemical signals also exhibit more aggressive territorial behaviors during the rut.

Chemical composition of signals

The constituents of chemical signals can also be indicative of a stag's dominance, age, and level of competition among the male population. Researchers from Spain wanted to find out how the intensity of competition and the age of the deer influences the composition of their chemical signaling. Iberian red deer males in Spain will develop a large dark ventral patch of hair whose size increases during the rutting season, and the size of this dark ventral patch increases with age (Pena et al. 2019). The dark coloration is caused by the deer urinating on themselves on the specific patch, to improve detectability of the chemical signals (Pena 2019). They collected hair samples from hunted deer and analyzed the constituents that make up the chemical signal. They also compared the chemical makeup from males in high-competition habitats and low-competition habitats.

The researchers found that the chemical profiles depended on the intensity of male-male competition in each environment (Pena et al. 2019). In the ventral patch of males in high intensity competition, there were lower proportions of aromatic compounds (used to signal territoriality and social rank) and higher proportions of carboxylic acids. Based on age, the data from this study showed significant differences between the chemical profiles of individuals (Pena 2019). Not only is age relevant to the chemical profiles of the ventral patch of Iberian red deer, but so is the level of competition.

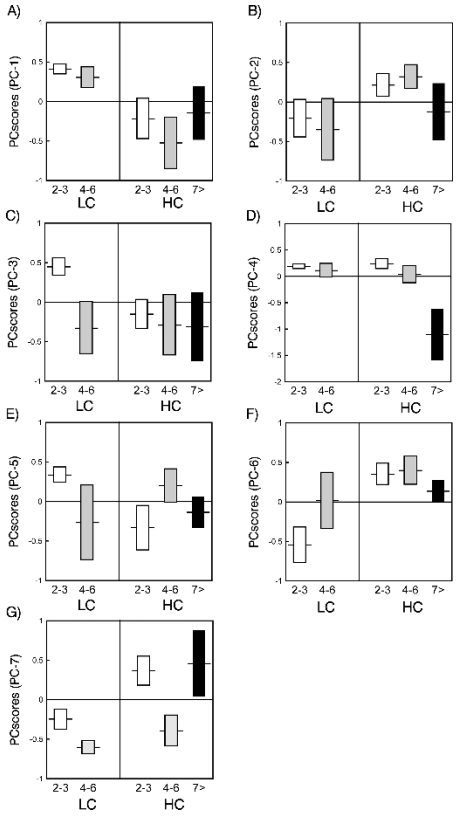

Figure 2. Factors scores for each volatile in low-competition (LC) or high competition (HC).

In white tailed deer (*Odocoileus virginianus*), the tarsal tuft is the main site for chemical communication (Wildlife Leadership Academy). There are glands under the tuft that secrete a substance that binds to the hairs. The substance that is secreted can retain fat-soluble compounds such as those in urine. Males and females will urinate on this tuft of hair frequently to establish these chemical signals. Many of the compounds in these tufts have not yet been identified, but the concentrations are thought to be directly related to dominance and age (Wildlife Leadership Academy).

Conclusion

The main objective of this paper is to explore the idea of dominance within chemical signaling. Many research articles have connected morphology to chemical signaling, or dominance to age, but there is little research done to connect chemical signaling dominance to age. It is a multi-faceted argument that needs to be researched directly. The arguments of this paper support the hypothesis, but a more thorough review of the literature could be done to have an in-depth understanding of the current knowledge.

Additionally, more research needs to be done on the topic of deer mating systems and female responsiveness to male chemical signals. Estrous females elicit courtship behaviors in breeding males (Murphy et al. 1994), but researchers do not understand how estrous signals change in response male chemical signals. Researchers have also discovered that scraping sites are potential sites of transmission for diseases like chronic wasting disease (CWD) (Egan et al. 2023). It would be interesting to know if chemically dominant deer are more likely to be vectors of disease.

Recent reports have estimated that there has been a 73% decline in global populations of mammals, fish, reptiles, birds, and amphibians since 1970 (World Wildlife Fund). Even though deer are relatively abundant and do not have many threats to their population, researching them will be a benefit to our deer management and conservation efforts. Understanding chemical communication in deer, or any communication in any animal, is beneficial to the population and to the ecosystem as a whole.

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