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| **Author (s):** | Rabia Afzal, Narjis Batool, Salwa Anoosh Butt, Aniza Iftikhar, Aqsa Noreen, and Mubashar Hussain |
| **Affiliation (s):** | University of Gujrat, Gujrat, Pakistan |
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# Territorial Defense: Aggressive Behavior in Beetles

Rabia Afzal*, Narjis Batool, Salwa Anoosh Butt, Aniza Iftikhar, Aqsa Noreen, and Mubashar Hussain

Department of Zoology, University of Gujrat, Pakistan

**ABSTRACT**

Territoriality, referring to the defense of a designated area, is one of the common animal behaviors observed in many insect species. In insects, territorial behavior contributes to survival and reproductive success by ensuring resource availability. Beetles (Coleoptera: Hexapoda) comprise one of the largest insect groups, with approximately 0.4 million estimated species. This study critically reviews the published literature collected from journals, books, magazines, and other resources to explore the use of aggressive behavior shown by the dung beetles, blister beetles, burying beetles, bombardier beetles, and bark beetles in territorial defense. In many Coleopterans, aggression has been observed as a behavioral tool of paramount importance in territorial defense (marking and protecting areas), leading ultimately to their continuity and reproductive success. To protect their territory, beetles show aggression using various chemicals, such as cantharidin (blister beetles), pygidial secretions (dung beetles), aggression pheromones like turpentine (bark beetles), and other noxious substances (bombardier beetles), along with the use of elytra (burying beetles). These chemicals play an important part in the success of aggressive behavior in beetles by repelling potential competitors or predators. Beetles in various families also use other behavioral tools, such as dung rolling and storage (as nesting behavior) used by dung beetles. Visual and acoustic signals also contribute significantly to territorial defense. Territorial ownership influences the intensity of aggression among beetles which helps them to deter rivals, sustain their territory, and access crucial resources including food, mate, and shelter without risk.

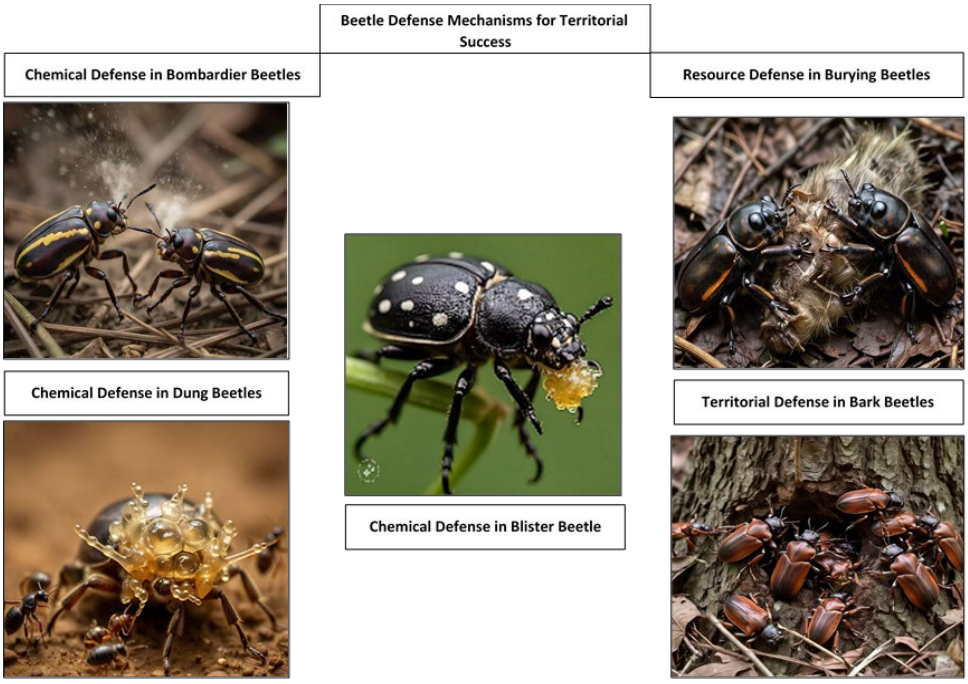
**Keywords:** aggression, beetles, coleopterans, insect ethology, territorial defense, visual behavior

**Highlights**

- Beetles defend their territories by using chemicals and other body parts showing aggressive behavior.
- Important chemicals used in territorial defense include cantharidin, turpentine, and other noxious chemical sprays.
- Territorial behavior is significant for their ecological success and diversity.

*Corresponding Author: dr.mubashar@uog.edu.pk

## GRAPHICAL ABSTRACT




## 1. INTRODUCTION

### 1.1. Taxonomic Diversity of Beetles

Coleoptera (Insecta: Hexapoda), with approximately 0.4 million recognized species, accounts for 40% of all described species of arthropods, with an estimated 1.5 million species of beetles and 5.5 million species of insects [1]. Most families of beetles (approximately 1.5 million beetle species) [1] are distributed worldwide and provide equivalent ecological services wherever they are found [2]. Coleoptera reigns supreme in the insect kingdom as it holds the crown for the most species-rich order, accounting for a whopping 25% of all recognized living organisms [2]. Beetles are an astonishing 40% of the well-defined insect species, with new beetle discoveries following, suggesting that their reign will persist [3].

### 1.2. Evolutionary Perspectives

The existence of beetles has been reported for about 250 million years [4]. Two major faunal changes occurred during this long history. The first occurred during the mid-Jurassic period when primitive lineages of beetles lost their dominance. The second occurred during the mid-Cretaceous when modern beetle forms achieved dominance over all other terrestrial arthropods [5]. The total number of insect species, including those yet to be identified, may reach a staggering 100 million, though a more common estimate is 1 million [6]. Beetles are incredibly diverse and thrive in almost every habitat, except oceans and polar regions. This is because they can adapt to virtually any diet. The Scarabaeidae family, the largest insect family, boasts over 30,000 species globally [2]. Among insects, beetles are the most

diverse, widespread, abundant, and evenly distributed on the planet. They are also the third most abundant inhabitants of tropical rainforests in the spring, after ants and termites, comprising a full 12% of the total insect population [7].

### 1.3. Structural Diversity of Coleoptera

Beetles, one of the most structurally diverse groups of organisms, show great variations in their body size, wings [8], mouthparts, antennae, leg adaptations, coloration and camouflage, and sensory structure, as well as in specialized adaptations such as bioluminescence [8, 9].

## 2. AGGRESSION AND TERRITORIALITY

Aggression is fundamental for the continued existence and breeding of several species [10]. Insects adopt several tactics to protect themselves and their resources from threats [11]. Beetles have to rapidly choose whether to fight or fly when facing danger. The extent of threat and fighting history are two of the many aspects that determine this choice [12]. Aggression means assigning prospective destruction or causing corporal loss. It is a complex behavior shown in different circumstances, such as erotic, maternal, hunter-victim, and defensive battles. It differs extensively from species to species. Beetles have been observed to produce defensive sounds. These sounds are produced across various life stages and sexes. The mechanisms employed to produce these sounds involve stridulation, percussion, tymbalation, tremulation, and forced air expulsion [13].

The level of aggression in insects is controlled by the chemicals in their brains called biogenic amines. Male and female insects have independently evolved chemical pathways to modulate their aggressive responses [14]. Territorial aggression is mostly driven by the need to secure essential resources such as food, shelter, and mating opportunities. These behaviors help to ensure access to these resources and enhance an individual's capacity to establish and defend their territory. On the other hand, defensive offensiveness demands vitality, exclusivity, interval, and accumulated danger of preying and harm. Corporal violence may occur, such as grappling, in horned beetles like rhino (Dynastinae) and stag beetles (Lucanidae) [10]. Male stag beetles battle for females with their impressive, oversized mandibles [15]. Aggressive behaviors involve the internal and external factors to regulate responses, which are closely controlled by the neural and endocrine systems. For the protection and promotion of their territory, some species identify their zone with odors, particularly along with the borders. Whereas, other species use glowingly stained graphic cues or audile signs. The territory holder might go for corporal violence, such as brawling in horned beetles, stinging in rodents, and whizzing airlifts in fowl in the case when these signals fail to deter invaders [10].

### 2.1. Blister Beetles

The family Meloidae (blister beetles) has the highest variety in moderate savanna and barren areas and in subtropical (mild winters, hot summers, high humidity) and tropical (high temperatures and extreme humidity within dense rainforests) plains. Presently, it has 125 genera and 3000 kinds [16, 17]. As part of their protective mechanism, mature individuals of diverse beetle families are recognized for their ability to emit sacs or pustules [18], while the major insect protective agent is Cantharidin ($C_{10}$ $H_{12}$ $O_4$) [19, 20]. Blister beetles are known to actively synthesize cantharidin, a toxic terpene utilized for

defense and released externally through reflex bleeding [21]. Cantharic acid is a potent terpene anhydride that poses substantial risk to the health of most mammals (lions, elephants, humans), birds, and frogs [22]. These defensive compounds, including alkaloids (e.g., nicotine and caffeine) and glycosides (e.g., cyanogenic glycosides), are often derived from complex precursors to enhance the efficiency of the chemical defense systems. Additionally, many insect species exhibit biochemical adaptations such as camouflage chemicals (e.g., ant-treehopper and fig wasp) [23], venom (e.g., wasp venom), pheromone-based defense (e.g., alarm pheromones in insects), and other survival mechanisms that are vital for their existence [24]. Behavioral reactions including habitat selection (animal behavior), chemical resistance to venom (e.g., snake venom), and the diverse coloration of blister beetles (beetles: cantharids), are a testament to their various protective strategies. The main defensive activity in the case of blister beetles is the expulsion of internal visceral peels from their anal region. It comprises a proctodeal protrusion that appears bright red or orange-stained due to the visibility of the insect's hemolymph through the structure [24].

The Spanish oil beetle (*Berberomeloe majalis*, and *Berberomeloe comunero*) and the coral-bearing blister beetle (*Physomeloe corallifer*) display a proctodeal bump before self-hemorrhage. This reaction persists even after the onset of other defensive strategies. The recurrent rectal expulsion differs among the various species depending on the force required and the possibility of proctodeal extrusion in response to a specific threatening stimulus. So, it was determined that proctodeal extrusion may be a potential self-protective tool in controlling Meloidae [17].

### 2.2. Burying Beetles

Burying beetles (*Nicrophorus vespilloides*) exhibit a unique and variable orange-black pattern on their wing covers and release an anal secretion from their abdomen when threatened [26]. They aggressively strive for the tenure of a small corpse, which is an essential and volatile reserve for burying beetles (*Nicrophorus spp*.). They use the corpse as a dietary origin. A reproductive pair of burying beetles rears their offspring and conceals the carcass for a food source and a breeding site. The retention and control of the carcass play a critical role in reproductive success, establishing the foundation for intrasexual competition. To slow down deterioration, the victors stay to the rear and make the corpse by developing it into a ball, smoothing the coating, and scattering secretions [25, 27, 28]. To provide their maggots with a diet, the burying beetles (*Nicrophorus spp*.), both male and female pairs, cooperate to bury small dead animals. Besides other burying beetles, both guardians (male and female pairs) protect their grubs and repair them for several days, while competing burying beetles often attempt to seize the corpse and this competition can lead to aggressive behavior. Male defense is mostly ineffective against attacks by larger congeneric species but highly effective in preventing takeovers by members of the same species [29]. The elytra of burying beetles endure a distinct and adaptable orange-black arrangement. In response to danger, they secrete a defensive secretion from their anus. During breeding, anal exudates play a major role in safeguarding the breeding ground from microbial contamination. The researchers investigated whether the beetles' distinctive

orange and black colouration, combined with the anal exudates, serves as a chemical detent to avian predators. It has been revealed that birds of prey easily detect orange and black colouration on burying beetles regardless of their prior experience. Moreover, the posterior excretions of silphids serve as a restraint to potential thieves [26]. In response to bacterial exposure, the maggots of the burying beetle (*Nicrophorus vespilloides*) secrete antimicrobial compounds during development to protect themselves [30]. Prothoracic thickness can be used to designate the aggressive ability and to show the consequences of struggle [25].

### 2.3. Bark Beetles

Globally, bark beetles (Coleoptera: Scolytidae) in many forests exist within complex communities that utilize resources provided by deceased and expiring trees. Numerous species of bark beetles aggregate on their host plants and subsequently develop within the host tissue, while their repellents facilitate the aggregation alongside other stimuli. Depending on the species, the habitat preferences vary; some may inhabit healthy trees while others prefer to utilize freshly fallen trees. The concerted efforts of numerous beetles can rapidly debilitate and destroy a previously healthy tree, as dead trees may be limited in supply; any available wood may dry up rapidly or be colonized by competing species. In any case, it is advantageous to colonize the host quickly, and the swift gathering of numerous beetles on trees or timber is referred to as a mass attack [31]. The defensive strategies of bark beetles are complex and dynamic, often interacting with various organisms involved in competitive or antagonistic relationships. A wound inflicted by one organism can serve as an opening for another to penetrate the surface of the bark. A prominent instance is the penetration by predatory bark beetles that can decimate vigorous trees in specific conditions. These beetles burrow into the bark, excavate tunnels, and deposit their eggs in the region below the phloem. Female mountain pine beetles (Scolytidae) secrete an aggregation pheromone called turpentine alcohol, made from turpentine and pinene oxide derived from pinene, a monoterpene established in the phloem tissues of trees once they accept a host and initiate boring [32]. Meanwhile, they allow in the pathogenic fungi that may immediately demolish the cambium and phloem; thus damaging plant defense, providing an ideal setting for mitotic development. Additionally, pathogens can disrupt water translocation in plants by making thromboembolism in tracheal bowls [33]. The genus *Dendroctonus* mainly targets live trees often valued for wood or shade and are of great economic importance. They gather on the trees, injure them, and reproduce in the bark and phloem tissues.

### 2.4. Dung Beetles

Scarabaeoid beetles (Scarabaeidae) are found worldwide, with coprophagy (consuming feces) being one of the most prevalent feeding behaviors among them. There are roughly 8,000 species of dung beetles. These beetles decompose substances and mostly consume dung, carrion, and rotting fruits. Dung beetles (Scarabaeidae) have evolved a sophisticated chemical system for intraspecies and interspecies communication. These insects generate antibacterial, antifungal, repelling substances, anti-rotting compounds, and the pheromones for sexual attraction and aggregation. Various chemical compounds are associated with their reproductive behaviors and feeding preferences, which include dung, carrion, and spoiled fruits.

Dung beetles are classified into three categories: dwellers, tunnelers, and rollers. Dwellers immediately deposit their eggs directly in the dung, tunnelers excavate subterranean galleries of varying depth, and rollers shape the dung into spherical balls which are subsequently shipped to a location where the beetles dig channels ending with brooding spaces [34]. Dung beetles embrace several behavioral methods for hiding faeces from other insects [35].

Numerous creatures produce foul-smelling secretions to deter rivals and the possible application of these discharges in controlling pests should be examined. The impact of the defensive secretion of emerald dung beetle (*Canthon smaragdulus*) on the movement patterns of animals in an urban environment was investigated with reference to insect ant *Tapinoma melanocephalum* (Hymenoptera: Formicidae), particularly how much these discharges deter the ants. The quantity of pygidial production affects *T. melanocephalum* locomotor activity. The exposure of *T. melanocephalum* to pygidial secretions from various dung beetles, such as pairs, solitary males, and single females, results in alternations in their locomotor activity. The pygidial spray of both masculine and feminine dung beetles may possess ant-repellent qualities, as the amount of pygidial secretion increases the locomotor behavior shift of *T. melanocephalum*. The outcomes indicate that the pygidial dung beetle discharges may be a natural repellent against *T. melanocephalum*. It has been suggested that the pygidial spray from dung beetles may offer a promising avenue for future research to create innovative residential pest control measures [36].

### 2.5. Bombardier Beetles

Bombardier beetles are a type of ground beetle. They are notable for their extraordinary defensive mechanism. In response to intense heat stress, they release a poisonous chemical discharge from the end of their abdomen [37–39]. Their defensive apparatus comprises two compartments: a reservoir and a reaction chamber. When confronted, the reservoir's muscles contract and propel chemical precursors into the reaction chamber. They interact with enzymes triggering an explosive discharge of a hot and noxious chemical spray comprising two main quinones: 1,4-benzoquinone and 2-methyl-1,4-benzoquinone (toluquinone) [40]. Ground beetles (such as *Brachinus spp.*) instantly discharge harmful mixtures at a temperature of around 100°C when confronted by toads [39]. The American toad (*Anaxyrus americanus*) is known to regurgitate *Brachinus* beetles when exposed to their chemical spray. Although, *Rhinella marina* (cane toad) may ingest and tolerate the same beetle species without harm [41]. It was suggested that the efficacy of this tactic is contingent on specific predator-prey interactions. Though the bombardier beetle tribe Brachinini boasts 649 species within 20 taxa, only a small fraction of the species' defensive behavior against predators has been examined.

## 3. CONCLUSION

Aggression through physical interactions (combat and use of elytra) and threat displays, such as using body parts to intimidate rivals without actual fighting, are key behaviors. Chemical defenses (cantharidin, pygidial secretions, aggression pheromones) are among the major strategies employed to protect territory. Other behavioral tools used by

beetles include dung rolling and hoarding, while visual and acoustic signals are also used in territorial defense. Beetles demonstrate aggressive behavior as a survival strategy to defend their territory and to secure resources, ultimately gaining reproductive success. This behavioral strategy can have both positive and negative consequences. Aggression, on the one hand, helps to protect resources in the area but trades off the risks of being damaged or killed. The existing data on territorial defense shows that many aspects of behavior have not been explored extensively yet, including an ecological assessment of many groups that are missing. Research has focused on individual species or on small groups of beetles, often ignoring extensive comparisons over different taxa. There should be comprehensive studies conducted on the territorial behavior of beetles in other families and genera, instead of merely examining single species.

## CONFLICT OF INTEREST

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

## DATA AVAILABILITY STATEMENT

Data availability is not applicable as no new data has been collected.

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