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Risk vs. Reward: A Systematic Review on the Threat Faced by Mobbers

Katharine H. Stenstrom[1], Moriah J. Deimeke[1], Prateek K. Sahu[1], Sarah M.L. Smeltz[1], and Christopher B. Sturdy[1,2]*

[1]Department of Psychology, University of Alberta, Edmonton, AB, Canada
[2]Neuroscience and Mental Health Institute, University of Alberta, Edmonton, AB, Canada

*Corresponding author (Email: csturdy@ualberta.ca)

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Abstract – This systematic review uses a Population, Intervention, Comparison, Outcome, and Study type (PICOS) framework to identify papers on mobbing behavior in the family Paridae, comparing non-threat, low-threat, and high-threat stimulus presentations. Using the family Paridae, we discuss how using a theoretical framework of risk and reward can help us assess if mobbing behavior carries a risk to the mobber. Paridae use different strategies, weighing the cost of mobbing with the benefits of antipredator behavior, where high and low threat predators elicit different responses. This suggests that Parids may selectively respond to different threats in an effort to mitigate risks inherent to mobbing behavior. Our results show that Parids primarily use a graded mobbing response strategy, mobbing high threats more than low threats, while ignoring non threats. We suggest that our results indicate that there is risk to the mobber that must be mitigated, and that Parids most likely use a graded strategy to best balance the costs and benefits of mobbing.

Keywords – Mobbing behavior, Antipredator behavior, Rescue behavior, Risk management strategies

Risk is inherent in almost every choice an individual makes, and it can be difficult for a researcher to define a behavior as "dangerous" or "risky" when both costs and benefits are present. One such behavior where both costs and benefits exist but appear to be species and situation-specific is cooperative antipredator behavior where two or more individuals work together to reduce the risk of predation. Cooperative antipredator behavior involves multiple risk assessments including the energetic cost to the mobbers (Crofoot, 2012), attracting other predators (Fang et al., 2020), and also the risk of being predated upon by the subject of the mobbing. Cooperative antipredator behavior is relatively well-studied in the family Paridae (chickadees, tits, and titmice) since they readily produce stereotyped mobbing responses in the presence of a predator or perceived threat (Courter & Ritchison, 2010; Kalb & Randler, 2019).

Mobbing behavior occurs when one or more individuals approach and harass a threat to reduce risk of predation and communicate to others about the threat present (Carlson & Griesser, 2022). This includes individuals producing referential alarm calls that encode information about a threat (e.g., the type of calls given, the number of elements within the calls, or the rate of calling; Carlson, Healy, & Templeton, 2017a; Templeton et al., 2005), and behavior that serves to deter predation (e.g., approaching, pursuing, or physically attacking the threat; Cordonnier et al., 2023; Courter & Ritchison, 2012; e.g., visual signals such as posturing, Carlson & Griesser, 2022). Mobbing is hypothesized to persist due to four general benefits: physically removing the predator, disrupting the predator's hunting behavior, communicating with other potential prey, and benefits that are not related to the predator (Carlson & Griesser, 2022). To what extent these costs and benefits are present among a particular community, species, or context is not well understood.

While mobbing behavior is most commonly studied in birds, and very often in the family Paridae, there is a lack of quantitative studies assessing the danger level associated with mobbing occurrences (Carlson & Griesser, 2022). Many studies on mobbing behavior show that Parids encode information about a predator's relative threat level in their calls by modulating acoustic features such as the number of elements in their calls and their overall call rates (Congdon et al., 2016; Templeton et al., 2005; Wilson & Mennill, 2010). Parids also modify their overall mobbing behavior (Dutour et al., 2016), and approach behavior depending on the threat level (Kalb & Randler, 2019; Soard & Ritchison, 2009).

The strength of Parids' differential response between "high" and "low" threat predators (where threat level is defined by the researcher) varies between experiments. The threats presented in the existing literature are primarily avian, with "high" threat presentations consisting of smaller raptors of various species, and "low" threat presentations consisting of larger raptors. Non-threats are also primarily avian, often heterospecifics (Billings et al., 2015; Hetrick & Sieving, 2012), but occasionally a completely neutral stimulus like a wood block (Baker & Becker, 2002). Some studies show that Parids may not fully discriminate between non-threats and low-threats (Billings et al., 2015; Carlson, Healy, & Templeton 2017; Hetrick & Sieving, 2012). Other experiments show discrimination between non-threats, low-threats, and high-threats (Baker & Becker, 2002; Congdon et al., 2016; Courter & Ritchison, 2010). Some studies show that Parids do not discriminate between high and low threats, but they do discriminate between potential threats and non-threats (Carlson, Healy, & Templeton 2017; Hetrick & Sieving, 2012; Suzuki, 2012; Book & Freeberg, 2015).

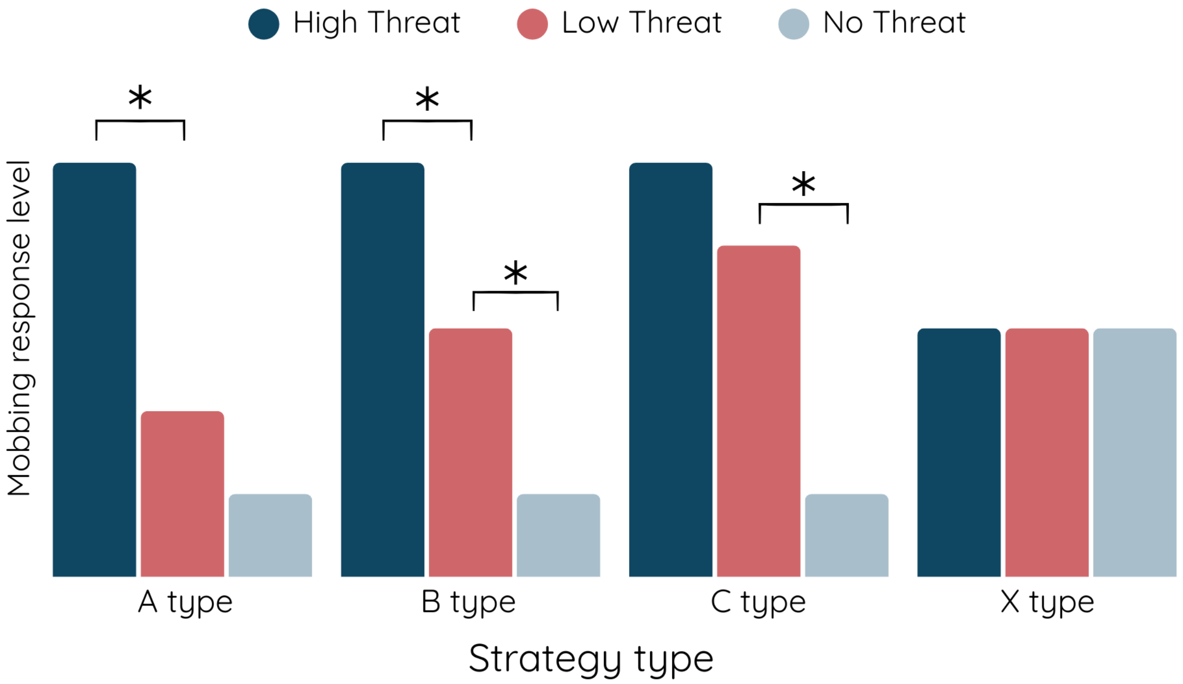
Here, we suggest three true potential mobbing strategies that change as a function of the level of risk from the predator and energetic cost to the mobber (Figure 1):

1. *Strategy A* involves only mobbing predators that are considered "high" threat and ignoring "low" threat predators. This strategy reduces risks associated with mobbing, but increases risk of being predated upon. This strategy would be most beneficial under conditions where mobbing risks are high, and the risk of being injured or killed by a lower threat predator is low. This strategy requires the mobber to be able to accurately discriminate between a "high" and "low" threat.
2. *Strategy B* is a graded response, it involves mobbing "low" threat predators, and mobbing "high" threat predators more intensely than "low" threat predators. This strategy is slightly riskier than Strategy A in terms of the risks associated with mobbing, but less risky in terms of the risk of predation. This is the most flexible strategy, but requires the mobber to be able to accurately discriminate between a "high" and "low" threat.
3. *Strategy C* involves mobbing both "low" and "high" risk predators with the same intensity. This strategy reduces risk from predation, but is costlier in terms of the energy expended during mobbing. This strategy would be beneficial if the "low" threat predator and "high" threat predator are difficult to discriminate, or the threat of predation is especially high and the cost of mobbing is low.
4. *Strategy X* involves not changing mobbing intensity in either an ABC pattern (i.e. low threats are mobbed more intensely than high threats) or not changing mobbing intensity between threat levels ("high" = "low" = "non").

In the following systematic literature review of studies on mobbing in the family Paridae, we evaluate support for each mobbing strategy. If mobbing carries a threat to the mobber, then A and B type strategies should be more common than C type strategies (A+B>C). We expect B type strategies to be most common since it is the best balance between cost and benefit for the mobbers (B>A or C). We also assess strategy responses for both primary information (seeing or hearing a predator itself) and secondary information (hearing referential alarm calls). Being able to both send and receive the information available in referential alarm calls can carry adaptive benefits (Gill & Bierema, 2013; Macedonia & Evans, 1993). It is suggested that Parids are able to use the information in referential alarm calls, becoming more aroused to "high threat" mobbing calls than "low threat" mobbing calls (Kalb & Randler, 2019; Templeton et al., 2005).

Figure 1

Mobbing Response Strategies: From left to right: mobbing strategy A, B, and C



Note. From left to right: mobbing strategy A, B, and C. Hypothetical graphs show relative strength of mobbing response. A type responses show a difference between high and low level threats, but not a difference between low and non-threats. B type responses show a graded response, with high, low, and non-threats showing distinct responses. C type responses show no difference between high and low threats, but a difference between threats and non-threats. X type responses do not follow an ABC type pattern, or do not have differences between threat levels.

Methods

We searched the published literature through Web of Science and Scopus using the following search terms: "mobbing behav* chickadee" and "mobbing behav* tit". We only included studies that met the following criteria:

1. Studies had to experimentally test for mobbing responses in the family Paridae using either a model/skin/live stimulus presentation and/or a playback including Paridae mobbing calls;
2. Experiments had to compare mobbing responses to a high threat, low threat, and non-threat stimulus presentation, as defined by the researcher. Nest threats were allowed if the threat predated upon nestlings or eggs. Brood parasites are distinct threats from predators (Lawson et al., 2021) and were not included. Silence and empty cages/containers as controls were excluded;
3. Mobbing response had to be quantified either physically (e.g., approach distance, number of birds approaching the stimulus) or vocally (e.g., the number of mobbing calls produced, number of D-note or similar note types produced per call) and compared across all condition types. Studies that examined proxies of mobbing, such as latency to resume foraging post stimulus exposure were excluded;
4. Observational studies, case studies, operant conditioning experiments, and surveys were excluded.

The above requirements were created by following a Population, Intervention, Comparison, Outcome, and Study type (PICOS) framework designed to evaluate mobbing strategies across Paridae. A PICOS framework was chosen to address this question because it allows us to test the applicability of our three-strategy theory while controlling for research methods.

We labeled predators/threat presentations as high, low, or non-threat based on the author's own categorization. If not present, we used other publications to categorize the threat level (Templeton et al., 2005; Johnsguard, 1990). In these cases, threat level was based on how much of the predator's diet consists of small birds, particularly those under 30g. In the case of nest predators, threat level was determined by how easily the predator was able to access the nest's contents (Suzuki, 2014), or the local nest predation risk by that predator type (Liu et al., 2025). We only considered silence as a behavioral control, and not an experimental treatment. Studies that had only silence as non-threat playbacks were excluded. We also only considered an empty perch/cage/container as a procedural control and not as a non-threat presentation. Studies with only empty presentations as non-threats were excluded.

Multiple studies contained more than one comparison that met inclusion criteria. Comparisons refer to one type of measured response over the experimental conditions (i.e., the number of D-notes produced in the low, high, and non-threat conditions), or different species responses to the experimental conditions (the number of D-notes produced in the low, high, and non-threat conditions by mountain chickadees). Comparisons were categorized into A, B, or C strategies with statistically significant results between groups. If there were no statistically significant differences, or if the comparison did not fit into either of the three strategies, the comparison would be classified as an X type.

Results

Our initial search resulted in 178 unique articles across both databases and search terms, including articles found via inspecting the literature cited portions of articles which met the PICOS requirements. After applying our inclusion criteria, the literature review resulted in 17 publications that met our criteria. Multiple articles investigated the mobbing behavior of more than one species, with 12 species in total: the black-capped chickadee (*Poecile atricapillus*), Carolina chickadee (*Poecile carolinensis*), chestnut-backed chickadee (*Poecile rufescens*), mountain chickadee (*Poecile gambeli*), tufted titmouse (*Baeolophus bicolor*), blue tit (*Cyanistes caeruleus*), coal tit (*Periparus ater*), crested tit (*Lophophanes cristatus*), great tit (*Parus major*), Japanese tit (*Parus minor*), marsh tit (*Poecile palustris*), and willow tit (*Poecile montanus*).

Twelve articles were field studies, three were laboratory studies, and two were performed in semi-natural aviaries. Three articles had both a visual and acoustic predator presentation component, though they did not give the presentations simultaneously. Eight articles had visual presentations only, and the remaining six had acoustic presentations only. Two studies, both on Japanese tits, focused on nest predators specifically (Suzuki, 2012; Liu et al., 2025). All other studies focused on adult predators. One study, Tvardikova & Fuchs, 2012, combined results from four Parid species. One study, by Avey et al. (2011), examined neural responses to threat levels instead of behavioral responses.

Fourteen papers reported more than one comparison that met inclusion criteria. Comparisons will be counted separately and used in this systematic review instead of papers for the following vote counting. See table 1 for mobbing response strategy, presentation type, and measured response variable by species. Figure 2 summarizes the results at each step of our search using The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines (Page et al., 2021).

Table 1

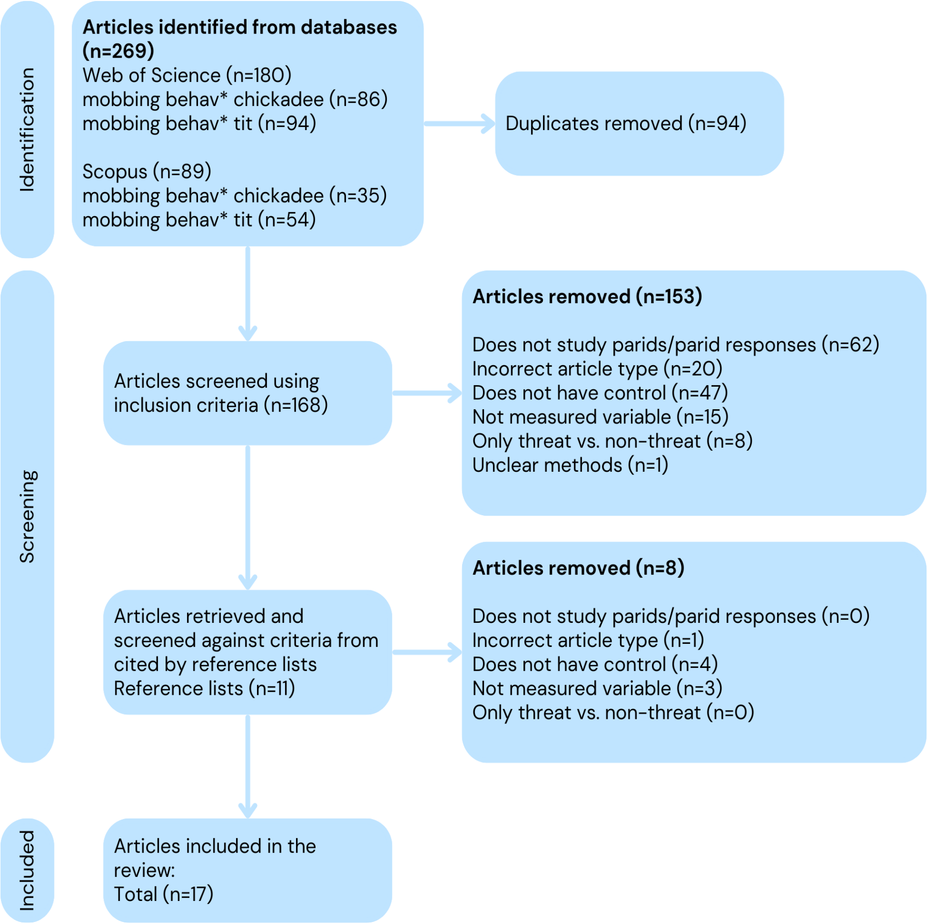
Summary of Studies that Compared Mobbing Responses to High, Low, and Non-Threat Presentations, by Species

Species	Stimulus Type	Measured Response Type	Mobbing Response Strategy	Citation
Black-capped chickadee	Taxidermic mounts	Breeding season calling rates	B	Apel, 1985
	Taxidermic mounts	Non-breeding season calling rates	B	Apel, 1985
	Predator calls, conspecific mobbing calls	ZENK expression	B	Avey et al., 2011
	Taxidermic mount, block of wood	Number of calls	B	Baker & Becker, 2002
	Taxidermic mount, block of wood	Latency to call	B	Baker & Becker, 2002
	Predator call, non-predator call	Number of calls during playback	B	Billings et al., 2015
	Predator call, non-predator call	Number of calls after playback	A	Billings et al., 2015
	Predator calls, conspecific mobbing calls	Number of calls	B	Congdon et al., 2016
	Predator calls, conspecific mobbing calls	Approach	X1	Congdon et al., 2016
	Live predators, non-predators	Alarm calls	B	Templeton et al., 2005
	Conspecific mobbing calls	D-notes	B	Templeton et al., 2005
	Conspecific mobbing calls	Approaches	B	Templeton et al., 2005
Carolina chickadee	Heterospecific calls	D-notes	B	Hetrick & Sieving, 2012
	Heterospecific calls	Number of calls	C	Hetrick & Sieving, 2012
	Heterospecific calls	Approach distance	A	Hetrick & Sieving, 2012
	Study skins	Calls per flock member	B	Soard & Ritchison, 2009
	Study skins	Approach distance	B	Soard & Ritchison, 2009
	Mobbing/non-mobbing calls	Calls per flock member	X2	Soard & Ritchison, 2009
	Mobbing/non-mobbing calls	Approach distance	B	Soard & Ritchison, 2009
Tufted titmouse	Plushie cat	D-notes	C	Book & Freeberg, 2015
	Study skins	Approach distance	X2	Courter & Ritchison, 2010
	Study skins	D-notes	B	Courter & Ritchison, 2010
	Study skins	Duration of mobbing response	B	Courter & Ritchison, 2010
	Live animal	D-notes	B	Hetrick & Sieving, 2012
	Live animal	Number of calls	A	Hetrick & Sieving, 2012
Japanese tit	Taxidermic mount	Nest defense (site 1)	C	Liu et al., 2025
	Taxidermic mount	Nest defense (site 2)	X1	Liu et al., 2025
	Taxidermic mount	Nest defense (site 3)	A	Liu et al., 2025
	Calls and noise	Vocalization %	B	Suzuki, 2012
	Calls and noise	Approach %	B	Suzuki, 2012
Great tit	Taxidermic mount	Calling rate	A	Carlson et al., 2017a
	Animal model	Mobbing level	B	Hogstad, 2017

	Calls and song	Approach distance	B	Kalb and Randler, 2019
	Calls and song	Proportion of approaches	X2	Salis et al., 2022
Mountain chickadee	Calls	Number of calls during playback	A	Billings et al., 2015
	Calls	Number of calls after playback	A	Billings et al., 2015
Blue tit	Taxidermic mount	Calling rate	C	Carlson et al., 2017a
	Animal model	Mobbing level	B	Hogstad, 2017
Willow tit	Taxidermic mount	Calling rate	C	Carlson et al., 2017a
	Animal model	Mobbing level	B	Hogstad, 2017
Coal tit	Taxidermic mount	Calling rate	A	Carlson et al., 2017a
Chestnut-backed chickadee	Calls	Number of calls during playback	X2	Billings et al., 2015
Marsh tit	Taxidermic mount	Calling rate	B	Carlson et al., 2017a
Multiple tit species assembly (Blue, Great, Marsh, and Willow)	Taxidermic mount	Number of approaches	B	Tvardikova and Fuchs, 2012

Figure 2

PRISMA Flow Diagram Indicating the Number of Articles at Each Step of the Review Process



Stimulus Type

There were 27 comparisons collected from experiments using a visual threat presentation, and 19 comparisons collected from experiments using an acoustic threat presentation. Visual stimuli presentations included taxidermic mounts, study skins, animal models, and live animals. Acoustic stimuli presentations included predator calls, conspecific and heterospecific alarm calls, conspecific and heterospecific non-alarm calls and songs, and background noise playbacks. Of these acoustic stimuli, 14 comparisons included referential alarm calls.

Comparisons

Forty-six comparisons were collected from 17 publications (Table 2). The majority (63.04%) of comparisons were vocal mobbing measures, such as number of D-notes per call, total mobbing calls, and mobbing call rate. Physical mobbing such as approach distance made up a smaller (21.74%) proportion of the comparisons. Fewer (13.04%) comparisons were a combination of physical and vocal mobbing, as defined by the author. Only one comparison (0.02%) involved neural measures (immediate early gene expression, ZENK).

Table 2

Mobbing Measures by Type, as a Percentage (Rounded to the Nearest Hundredth Place) and Total Number of Comparisons

Measured mobbing type	Percent of comparisons	Number of comparisons
Vocal mobbing	63.04	29
Physical mobbing	21.74	10
Combination vocal/physical	13.04	6
Neural measures	00.02	1

There were more North American species studied in both the comparisons (29/46, 63%) and total papers (10/17, 59%). There were more Western species in the comparisons (41/46, 89%) and total papers (15/17, 88%). Black-capped chickadees (12/46, 26%), Carolina chickadees (7/46, 15%), tufted titmice (7/46, 15%), and Japanese tits (5/46, 11%) were the only species with five or more comparisons over multiple studies. Together, these species made up 67% of the total response measures.

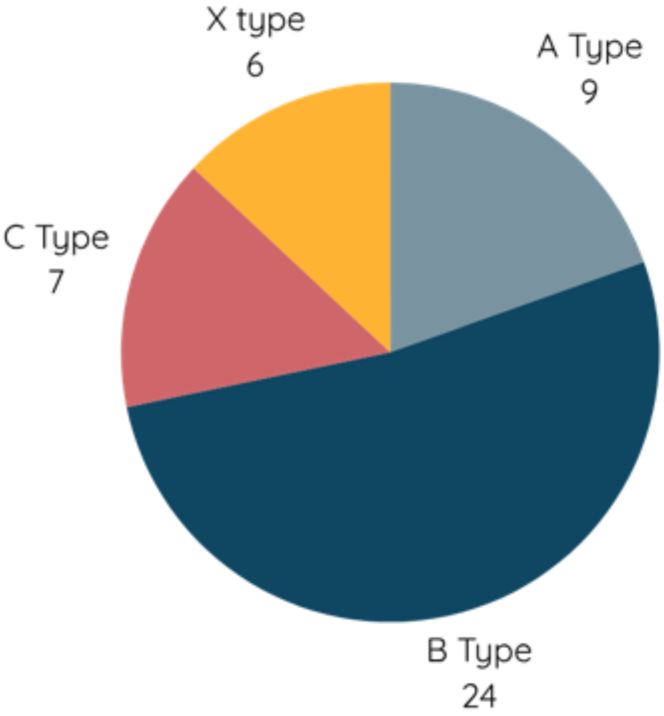
Studies investigating the responses to referential alarm calls, either conspecific or heterospecific, made up (14/46, 30%) of the comparisons and (8/17, 47%) of the total publications.

Response Strategy Type

Just over half, 24/46 (52.2%), of comparisons reported a “B” type strategy, or a graded mobbing response whereby the subject responded most strongly to the high threat predator stimulus, least strongly to the non-threat stimulus, and intermediately to the low-threat stimulus. The next most common (9/46, 19.6%) was an “A” type strategy, which involved only mobbing the high threat predator stimulus. Next, the “C” type strategy was employed in just over 15% of cases (7/46, 15.2%), which involved mobbing the high and low threat predator stimuli equally. Two comparisons did not follow either A/B/C pattern (4.3%), and 4/46 (8.7%) comparisons did not show significant differences between the experimental and control groups. All six of these comparisons were labeled as X type. Comparisons where subjects responded differentially to high and low threat predators made up the majority of the comparisons (35/46, 76%). This includes both A and B type strategies (Figure 3).

Figure 3

Mobbing Responses by Strategy Type



Note. Observed percentages of each strategy type, out of 46 total comparisons. A type responses show a difference between high and low level threats, but not a difference between low and non-threats. B type responses show a graded response, with high, low, and non-threats showing distinct responses. C type responses show no difference between high and low threats, but a difference between threats and non-threats. X type responses either did not follow an ABC pattern, or did not have differential responding between high, low, and non-threats.

Primary versus **Secondary Source**

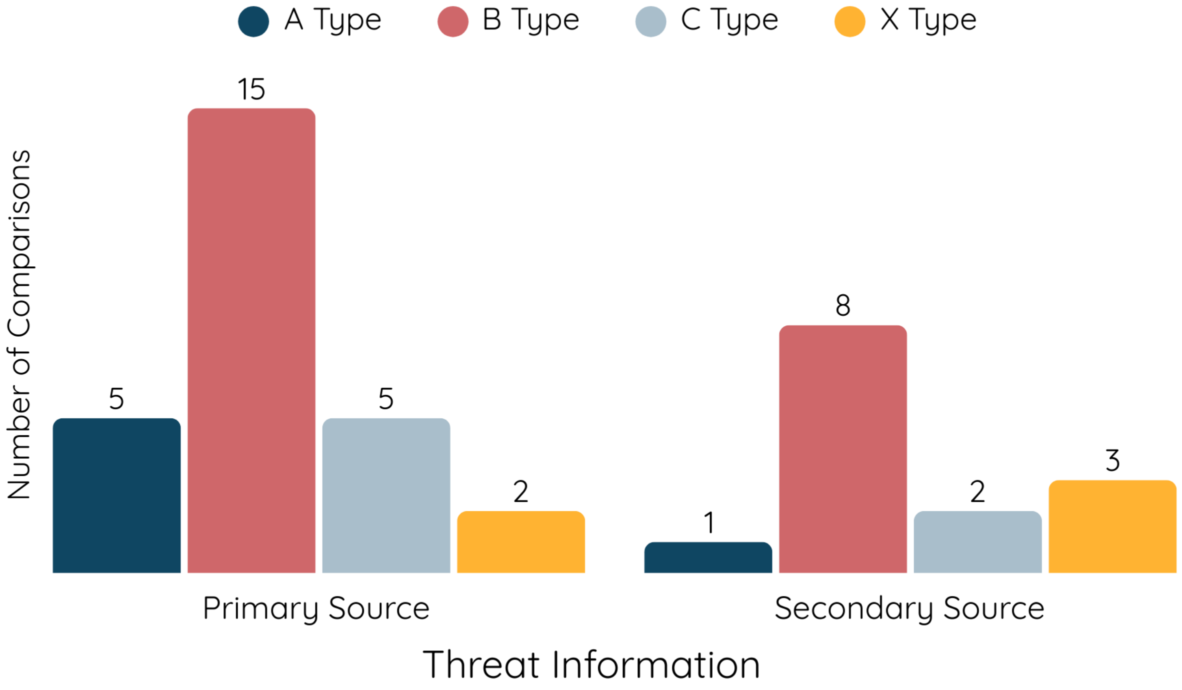
Primary sources included visual threat presentations (27/46, 58%) and predator calls (3/46, 6%; Figure 4). The studies that used predator calls also presented their subjects with conspecific mobbing calls, but not in tandem (Avey et al., 2011; Congdon et al., 2016). Both studies found that there was no difference in response between the primary and secondary information - though it is important to note that they used the same stimuli. Within the other primary presentations, a slight majority of comparisons (15/27, 56%) used a B type response. The remaining comparisons used A (5/27, 19%), C (5/27, 19%), or X (2/27, one with no difference between treatments, and one that did not follow any strategy type).

Secondary sources included referential alarm calls, where 8/14 (57%) reported a B type strategy (Figure 4). Only one comparison reported an A type strategy, making the total differential responses to high and low threats 9/14 (64%). Three comparisons (3/14, 21%) indicated the subjects did not respond differently to any of the treatment and control groups (X type response), and two comparisons (2/14, 14%) indicated that the subjects responded equally to referential alarm calls which indicated high and low threats while ignoring non-alarm calls (C type response).

Mobbing Responses by Information Type

Figure 4

Number of Each Strategy Type, out of 30 Primary Source Comparisons and 14 Secondary Source Comparisons



Note. A Type responses only respond to high level threats. B Type responses show a graded response to each level of threat. C Type responses show a difference between threats and non-threats. X Type responses either did not follow an ABC pattern, or did not have differential responding between high, low, and non-threats.

Within studies, a species might switch strategy type when comparing different response measures. For example, birds may not show any difference between control and experimental groups in how closely they approached a threat, but they might employ a B type strategy in the number of D-notes produced (Courter & Ritchison, 2010). Within studies but across response measures, there were six instances of non-aligning strategy type (Congdon et al., 2016; Hetrick & Sieving, 2012; Soard & Ritchison, 2009; Courter & Ritchison, 2010; Suzuki 2012). In all of these cases, birds were not consistent in their strategy type between their vocal mobbing responses (number of D-notes, total number of calls, etc.) and their physical responses (number of approaches, total approach number, etc.).

Three studies reported strategy switching, where subjects used one response type for one comparison, and a different response type for another comparison when presented with the same stimuli. Billings et al., 2015 reported that black-capped chickadees used a B type strategy in their overall call number during playback sessions, but an A type strategy in overall calls post-playback. Hetrick & Sieving, 2012 reported that Carolina chickadees used a B type strategy when responding with D-notes, but their overall number of calls followed a C type strategy. Hetrick and Sieving also reported that tufted titmice used a B type strategy when responding with D-notes, but their overall number of calls followed an A type strategy. Liu et al., 2025 found site specific differences in Japanese tits' mobbing responses, with one site employing an A type strategy, another site using a C type strategy, and one site using X type.

Discussion

Due to the low number of publications accepted during our search, and the biases towards specific species, we argue there is only enough literature to offer preliminary evidence to support any conclusions. Combined, A and B type responses made up roughly three-quarters of the total comparisons, which implies that mobbing carries relatively high risks for the mobber. Slightly more than half of the comparisons reported a B type strategy, which supports our prediction that B type strategies will be most common.

Being able to differentiate between more and less dangerous threats is particularly adaptive for Parids, who must often weigh the risks between morphologically similar predators (Templeton et al., 2005). Additionally, responding differently to high and low threats allows an individual to trade off the risks of a predator, the risks and energy consumption of mobbing, and the benefits of the level of response.

Mobbing and responding to alarm calls may mostly follow a graded strategy for the risk-management benefits that both A and B type responses confer, but it is possible that Parids have the flexibility to use other strategies when environmental conditions change. With the exception of the studies performed on Japanese tits, all the literature in this review focused on predators that target adult birds. Responding to a nest predator with the same vigor in the non-breeding season as during the breeding season is energetically costly, and so moderating one's response based on context would be advantageous. Many non-migratory predators also experience dietary changes throughout the year in temperate zones as food availability changes. Sharp-shinned hawks are considered a common, high-threat predator to black-capped chickadees (Templeton et al., 2005; Apel, 1985; Smith, 1991), but hawk's diets vary both by sex (Johnsgard, 1990) and season (Roth et al., 2006); with females targeting larger prey than males, and hawks of both sexes targeting larger and more solitary prey during the winter.

There is an adaptive benefit of referential alarm calls, or transferring information about the type of predator or what kind of threat it poses (Gill & Bierema, 2013; Macedonia & Evans, 1993). Providing a referential or risk-based alarm call, at least to some extent, appears to be common and present in multiple species of Parid. The literature generally states that Parids are able to use the information present in the referential alarm call, (Kalb & Randler, 2019; Templeton et al., 2005) though based on our systematic review this may not always present as an individual responding strongly to a high threat referential call, responding less strongly to a low threat referential call, and ignoring a non-threat call. We suggest that not responding to referential alarm calls with the "appropriate" mobbing level may not be due to an inability to distinguish between the high and low threat mobbing calls, but could be a function or byproduct of multi-species flocking.

Many Parids create multi-species flocks where one species is dominant over the others. These so-called "nuclear" species are the social hub around which a mixed species flock forms (Hetrick & Sieving, 2012). Nuclear species often act as community informants, they are aggressive towards perched predators and readily provide referential or risk-based alarm calls which heterospecifics eavesdrop on (Hetrick & Sieving, 2012; Carlson, Healy, & Templeton, 2020). A key component to a reaction to an alarm call is the relationship between the caller and the receiver (Coppinger, Sanchez de Launay, & Freeberg, 2017). While there is not enough literature present to make claims about species-level mobbing strategies, the mixed flocking behavior of Parids should be considered. Certain nuclear species may have greater influence on the mobbing intensity of heterospecifics than others (Nolen & Lucas, 2009).

Other factors that could influence mobbing behavior could include the time of year in which the study was conducted (Scott & Robinson, 2023), the subject's experience with the threat presented (Avey et al., 2011; Carlson, Healy, & Templeton, 2017b), whether the information was direct or indirect (Carlson, Greene, & Templeton, 2020), and the makeup of the mobbing assembly (Coppinger, Sanchez de Launay, & Freeberg, 2017; Nolen & Lucas, 2009). Future experiments could seek out how these factors influence mobbing not just on a species level, but also on a family and class.

A major source of variability in these studies overall is that the threat level of the predator was determined using a variety of methods, leading to inconsistencies. Many papers published post-2005 used Templeton et al., 2005 as their justification for the predators chosen (Avey et al., 2011; Congdon et al., 2016; Hetrick & Sieving, 2012; Soard & Ritchison, 2009). Others used the body size (Templeton et al.,

2005) of the predator, arguing that smaller predators are more dangerous to Parids than larger birds. Still others argued for the diet of the predator (Billings et al., 2015 - note that this study did also consider the size and hunting strategy; Book & Freeberg, 2015; Carlson et al., 2017a; Courter & Ritchison, 2010; Hogstad, 2017; Kalb & Randler, 2019; Tvardikova & Fuchs, 2012), or its presence in the area where the studies were conducted (Baker & Becker, 2002; Liu et al., 2025). In some cases, there was no justification for the predators chosen (Apel, 1985). At the individual level, each threat presentation was justified, but when considering the body of research as a whole this has an unknown impact on the strength of the mobbing response from the subjects.

What constituted a "high threat" and "low threat" was determined by the researchers, and varied by study. High threat predators were almost always small raptors, though they varied from the diminutive northern pygmy owl (*Glaucidium gnoma*, 50-65g) to the comparatively gigantic sparrowhawk (*Accipiter nisus*, 150-220g). The logic that many researchers followed was that smaller raptors, including pygmy owls, sharp-shinned hawks, and sparrowhawks, target smaller songbirds, like Parids. While this logic is not necessarily flawed, there seems to be some evidence that slightly larger songbirds like sparrows (20-30g) are preferred over most Parids (8-15g) by smaller raptors (Holt & Leroux, 1996; Gotmark & Post, 1996; Millon et al., 2009; Roth et al., 2006). While Parids are present in these small raptors' diets, they are not the primary target, at least in areas that have abundant sparrow populations. Also in raptors, males are smaller than females and this can influence their prey preferences (Johnsgard, 1990) - though none of the studies we found mentioned the sex of their predator stimuli. It is possible that both the size of the species overall, and the sex of the threat influenced the subject's perception of threat. While Parids in the wild may consider multiple species equally as dangerous, or may not even be able to distinguish between male and female predators of the same species, these are major factors that could influence the results of each of the studies in this review.

The data we collected in our systematic literature review suggests that birds in the family Paridae likely perceive some level of risk when mobbing, but that risk changes rapidly with a multitude of factors. These results preliminarily support the idea that mobbing *does* carry risk that individuals in a mob must manage. These risk factors would be best separated out with meta-analytic techniques, and such an analysis would greatly improve our understanding of mobbing behavior as a whole. As it stands, why mobbing persists is largely based around four theories (physically removing the predator, disrupting the predator's hunting behavior, communicating with other potential prey, and benefits that are not related to the predator; Carlson & Griesser, 2022), with individual experiments testing said theories. A meta-analysis pending more literature as the next step of this systematic review would have a great impact on how we understand mobbing as a whole.

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