Attacked from above and below, new observations of cooperative and solitary predators on roosting cave bats

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Abstract

Predation of bats in their roosts has previously only been attributed to a limited number of species such as various raptors, owls, and snakes. However, in situations where due to over-crowding and limited roost space, some individuals may be forced to roost in suboptimal conditions, such as around the entrances of caves and may thus be vulnerable to predation by species which would normally be unlikely to predate bats whilst roosting inside caves. Here, we describe the first documented cooperative hunting of the Large-billed Crow, *Corvus macrorhynchos* Wagler, 1827 (Passeriformes: Corvidae) and opportunistic predation by the Yellow-headed water monitor, *Varanus cumingi* Martin, 1839 (Squamata: Varanidae) in the world's largest colony of Geoffroy's Rousette, *Rousettus amplexicaudatus* (É. Geoffroy Saint-Hilaire, 1810) (Chiroptera: Pteropidae) in the Island of Samal, Mindanao, Philippines.

Keywords: bats, caves, Cooperative behaviour, *Corvus*, prey-predator, *Varanus*.

I. Introduction

Animal feeding behaviour i.e., to locate, acquire, and consume food resources shaped their characteristics, community interactions, and the development of their complex behaviour to efficiently obtain food and survive (Roberts, 1942; McFarland, 1981). While, the availability of resources and predation are among the most important biotic drivers that shape interactions across wildlife communities (Talbot, 1978; Hiltunen & Laakso, 2013; Glen & Dickman, 2014). Within an ecosystem, when the predator populations decline or are absent, the prey population may dramatically increase (Gese & Knowlton, 2001; Ritchie et al., 2013). This release of a species numbers may have negative implications especially when the prey is an invasive and out-compete native species for space and other resources (Ritchie et al., 2013) therefore, predator plays a crucial role to balance the prey population. Predation is a complex behaviour and can involve many different approaches, these include (1) 'cooperation' when hunting occurs in a pair or group, (2) 'cheating' when hunters spot prey but only join at the end of a hunt (3) 'scavenging' when hunters do not hunt but join whenever it has a chance to take food or when predators consume carrion (DeVault et al., 2003), and (4) 'solitary' where predator hunts alone (Packer & Ruttan, 1988).

Until a recent global review the extent of bird predation on bats was not widely known (Mikula et al., 2016). Diurnal birds particularly raptors prey on at least 124 species (11 families) of bats (Mikula et al., 2016). Hunting and predation by birds frequently occur

near caves and roosting areas where bats are abundant and predators can hunt bats at emergence and during foraging (Laycock, 1982; Lee & Kuo, 2001; Stimpson, 2009). Inside caves and underground ecosystems, reptiles particularly snakes are widely known predators for cave-dwelling bats while varanids (monitor lizards) have not previously been reported. In the Asian tropics, few bat predators have been documented and there may be more interactions unreported (Lima & O'Keefe, 2013; Mikula et al., 2016). In the Philippines, large Raptors (Family: Accipitridae) and pythons have been noted to prey on tree roosting flying fox *Acerodon jubatus* (van Weerd et al., 2003) nonetheless this is the first clearly documented and described observation of crow predation on cave-dwelling bats (Tanalgo & Hughes, 2018). In this paper, we investigated and offer potential reasons in the cooperative hunting behaviour in Large-billed Crow (*Corvus macrorhynchos*) and opportunistic hunting in Yellow-headed water monitor (*Varanus cumingi*) in Monfort bat cave, Mindanao, Philippines.

II. Methods and Results

Locale of the observation

We conducted field observation on the Island of Samal located within the Gulf of Davao in the southern part of the Philippine Archipelago at the world's largest colony of the Geoffroy's Rousette (*Rousettus amplexicaudatus,* Chiroptera: Pteropodidae) (estimated population at present 2 million) (Carpenter et al., 2014) in the Monfort Bat Cave (7°09’53’’N, 125°41’31’’). The rousette bat is a medium-sized cave-dwelling fruit bat native to Southeast Asia (Csorba et al. 2008) and widely distributed throughout the Philippines (Heaney et al. 2010). Monfort Bat Cave is located in the private Monfort Bat Sanctuary and was opened for external ecotourism in 2005. Scientific research is allowed and several studies have been made before. Monfort bat cave is a relatively small cave with an approximate size of 150-metre length with an average 3 metres high and 5 metres wide. The cave system can be accessed through its horizontal entrance (opening #1) and four vertical openings (Carpenter et al., 2014).

Cooperative hunting by Large-billed crows Corvus macrorhynchos

C. macrorhyncus is a common crow species widely distributed throughout the Asian region and are territorial and monogamous birds, often found in forested areas, coastal areas, plantations, and highly common in urban areas and co-exist with human settlements (Tanalgo & Achondo, in-review). These species are documented as omnivorous but they appear to be carnivorous in areas where animal prey are abundantly available (Goodwin, 1982; Richardson & Verbeek, 1997; Tanalgo et al., 2015). In Southeast Asia, *C. macrorhyncus* has previously been recorded to prey on *Cynopterus sphinx* while the co-occurring species *C. enca* is known to prey on *Tadarida plicata* (as accounted by Mikula et al., 2016). Other documented crow prey from Asian region include young of domestic cats (*Felis catus*), murids, rock doves (*Columba livia*), Grey Starlings (*Sturnus cineraceus*), and Tree Sparrows (*Passer montanus*) (Kurosawa et al., 2003). Previous records of bat predation of *Myotis lucifugus* by the American Crow (*Corvus brachyrhynchos*) in North America largely focuses on crow attacks on bats during flight and do not enter caves to hunt (Lefevre, 2005; Henandez et al., 2007; Flaspohler, 2017).

In Monfort cave, crows have been known to predate bats since 2006 but their behaviour not recorded in depth. In late 2018 (September to December) *R. amplexicaudatus* approximately 5-10 metres away from the entrances of five chambers of the cave. Further, we

repeatedly observed crows perching on the trees surrounding the cave and flying into the cave preying upon the bats. In the succeeding months, we evaluated the patterns of predation by strategically installing a single wireless microcamera (TT microcamera™, P.R. China coupled with TT Android-based application support) combined with actual distant observation at the first and third cave openings from 0700 H to 1700 H. Over 60 observational hours were made in the study site.

We observed 10 to 15 crows (*Corvus macrorhyncus*) flocking on trees 10 metres away from the caves. Two groups then form with group A is on standby (~9 to 10 individuals), perching on tree branches around the caves while group B (~2-7 individuals) perch on the fence or vines near the opening strategizing the population it will attack to initiate the hunting. Coordinated hunting begins with surveillance behaviour, which is the longest phase that occasionally lasted up to an estimated 10-15 minutes. Crows are occasionally observed producing loud calls whilst they remained near the cave openings taking advantage of perching on tree branches or canopy vines. The third stage or the 'hunting' begins when the crow hunters (group B) flew rapidly towards the cave entrance, hover, and mob the roosting bats to distract the clumping population in the uppermost to mid-part part of the cave openings causing the population to dilute that makes it easier for the hunters to capture bats. The hunting group will then forcefully capture the bats using their beaks and emerge from the cave. This stage takes a maximum time of 8.78 minutes with an average of 2.20 minutes. The hunting phase is not always successful in the 1st attempt and takes another 2nd to 3rd attempts for the same hunters to successfully capture a prey. The fourth and last stage is when hunting group (group B) emerge from the cave where the group A are waiting and will fight with the murder until they rip up the bat individuals then fly off away from the cave. Typically, during hunting 2-3 crows can successfully single bat individual (graphically described in Figure 1). Sometimes a bat escapes and flies outside the cave, group A that is on stand-by will follow and attack the bats and rip them apart. This activity recurs throughout the day and each hunting phases are variable but the relative length is consistent. This is due to the human presence in the vicinity of the cave as crows may disappear and pause bat hunting when tourists or the observers are noticeably present (e.g., numerous groups of tourist are present and noisy). In addition, because the exact population of crows we observed in the study is not certain we cannot determine if the same individuals perform the same role. The hunting success rate of crows are frequently successful but the distribution of food (e.g., amount of meat) varies and mostly favours the group B (hunters).

Opportunistic Hunting by Varanus cumingi

In addition to coordinated hunting by large-billed crows, we also documented solitary opportunistic predation by *V. cumingi* on *R. amplexicaudatus.* Unlike other Philippine endemic varanids (e.g., *Varanus olivaceus, V. mabitang*, and *V. bitatawa*) that are frugivorous, whereas *V. cumingi* is chiefly carnivorous and common in mangroves, fishponds, and tropical forests (Losos and Greene 1988, Koch et al. 2007; Sy et al. 2009), though some are frugivorous, for example, which are endemic to the Philippines (Koch et al., 2010; Law et al., 2018). According to historical accounts (Tata Albeti, pers. comm.), *V. cumingi* are resident cave dweller in the and chiefly remained inside, rarely venturing out where they are vulnerable to hunting. We observed two large *V. cumingi* preying solitarily on roosting bats in the lower part of the cave where less active (adult, sleeping, or ill) bats are located. *V. cumingi* predation is swift and more efficient compared to crow predation. The predation mode of *V. cumingi* is solitary and it starts with surveillance, which takes only a few minutes (~2 to 3 minutes). Once a lizard finds its potential prey, it swallows the whole bat (taking 5-8 minutes). After swallowing the prey it hides and rests under the boulders

below the cave. We did not observe this behaviour frequently. Based on cave morphology, patterns of bats roosting in the cave, and likely behaviour of *V. cumingi*, we believe the lizard preys upon bats roosting on the lower cave walls as well as on and underneath the rock breakdown in a cave. They are likely more successful preying upon vulnerable bats that are injured, sick, older, or younger. There are instances of smaller varanids attempting to capture bats in the upper part walls but these frequently fail.

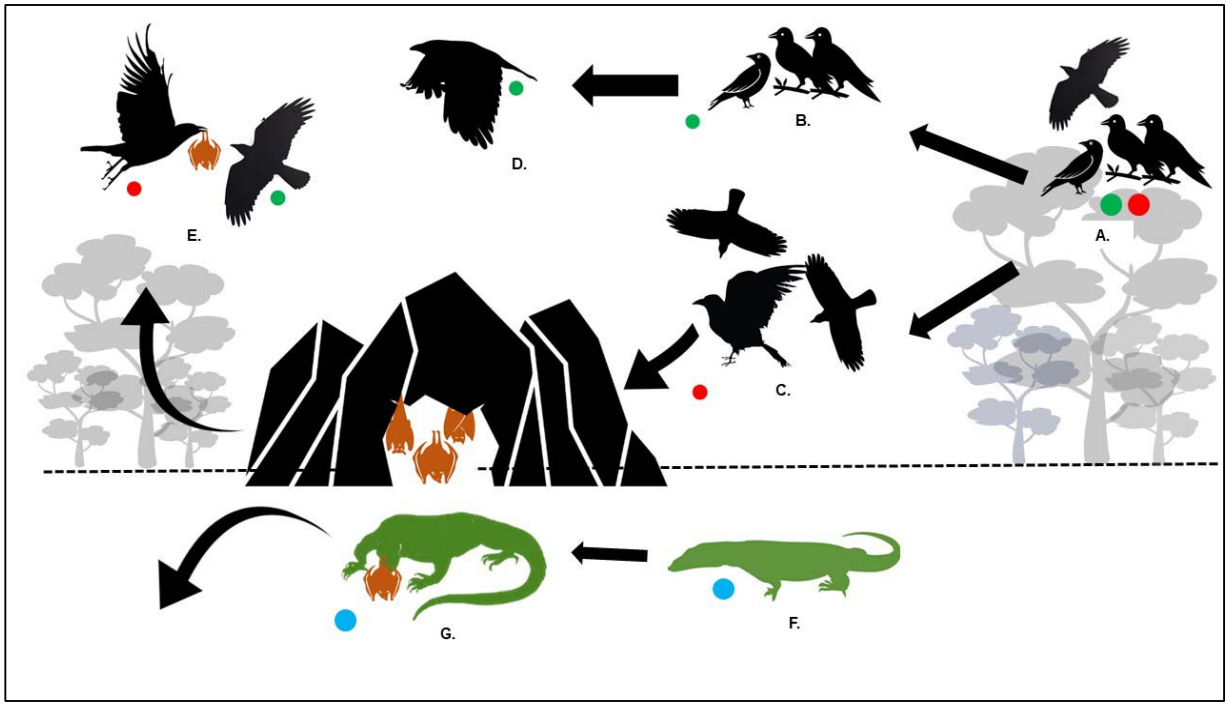

Figure 1. A diagram illustrating the cooperative hunting in crows *(C. macrorrhyncos*) (A-E) and solitary hunting of water monitor *V. cumingi* on cave-dwelling bat *Rousettus amplexicaudatus* in Samal Island, Philippines.

Discussion

This is the first description and documentation of cooperative hunting and solitary opportunistic hunting by large-billed crow *C. macrorrhyncos* and *V. cumingi* respectively on the cave-dwelling bat species *R. amplexicaudatus*. Cooperative hunting is uncommon but has been widely documented in a few vertebrate groups and it is described as opportunistic or individually simultaneous hunt (Bernarz, 1988; Packer & Ruttan, 1988;Dinets 2017). This behaviour occurs when two or more individuals cooperate to hunt larger or more active prey to improve hunting success and reduce energy expenditure (Hector, 1986; Bernarz, 1988; Bowman et al., 2003). In our present observation, we observed members of the hunting murders mob and disturb prey groups to become more vulnerable and easier for other members to hunt, eventually when hunting succeeds hunters will ascend from the cave carrying a dead prey for other to rip apart and consume. This observed behaviour provides evidence of cooperative hunting among crows within the same group (hunters) and other groups (non-hunting). In this hunting strategy as best identified and described based on apparently observed coordination of the group or flocks, for example, each member attacks prey sequentially, which the hunters allow others groups to take advantage situation and benefit from it (Dinet, 2015). For example, in the case of Cuban, boas they block cave bats in the passage to increase hunting efficacy giving an advantage to other groups (Dinets et al.,

2017). Cooperation is widely known for corvids and has been documented in many species of crows in the wild (e.g., Bowman, 2003; Yosef & Yosef, 2010). Our present observation on *C. macrorhyncus* shared a similar pattern of intelligent cooperative hunting behaviour of *C. rufficollins* on Egyptian mastigure *Uromastyx aegypticus*, where crows divide into groups to perform coordinated hunting of the prey and are aware of their roles (see Yosef & Yosef, 2009). In addition, although not described in the present study, the cooperation success among *Corvus* depends on inter-individual tolerance, and they cease cooperation if other group members cheat (Massen et al., 2015).

However, cooperative hunting strategy does not always assure higher food intake (e.g., Mech & Boitani, 2003 demonstrated on grey wolf) or if the prey is smaller only those successful predators can take advantage (Packer & Ruttan, 1988). In our present observation, in cooperative hunting in crows, we observed that food intake mostly favours those groups that do the hunting actively (e.g., group B) compared to those in standby and waiting. While *Varanus cumingi* hunting strategy is solitary and opportunistic hunting, where it avoids conspecifics and therefore hunts solitarily. Most Varanus species prey on smaller vertebrates such as frogs and birds, but larger species can eat large animals as big as deer (Losos & Green, 1988). Archaeological evidence shows large monitor lizards dwelling in caves (Price et al. 2015) but contemporary evidence on varanid feeding on caves bats has not previously been recorded.

Two plausible explanations we can offer at present to explain potential drivers that may have influenced predator behaviour towards the cave bats. First, the 'doomed surplus paradigm', which predators take advantage and hunt the overcrowded population (Errington, 1946). In this concept, it is often assumed that preyed upon individuals were low-quality populations, and the predators play a role to assure check and balance in the health of the population. Our observation on *V. cumingi* solely predates vulnerable individuals (i.e., weak or presumably sick, old, or injured) while *C. macrorhynchos* hunts on individuals that roost in abundant clumps. Secondly, the population 'spillover effects' may have influenced the increase in bat biomass and predator influx in the cave. Although this concept is widely discussed and applied in marine reserves where no-take reserves increase and enhance the community complexity (e.g., species diversity and functional groups) due to the improvement of habitat quality and abundance of the prey availability and recruit predators (Russ & Alcala, 2011). In the case of Monfort bat cave, predator recruitment is driven by the steady increase of *R. amplexicaudatus* population due to absent of disturbances such as hunting and cave intrusion. Predators in Monfort Bat Cave are likely important to help maintain the ecological balance of the large aggregation of *R. amplexicaudatus* in the cave system. In addition to our documentation of predation by *C. macrorhynchos* and *V. cumingi*, pythons and large numbers of rats also live in the cave and have been observed to prey upon the bats. Moreover, we speculate another hypothesis that the presence of these predators may explain and shed light on the 'anecdotally abnormal' behaviour of *R. amplexicaudatus* in the cave in addition to overcrowding.

What is more, the predation of two predators on a cave-dwelling bat *R. amplexicaudatus* offers another understanding of ecological interactions present within caves and underground habitats. Although this is not the first time for corvids to be documented and described to perform cooperative hunting, our study has provided additional insight to support the capacity of crows to perform such complex behaviour on a different prey and ecological instances (e.g., caves) and that this behaviour is common rather than rare. In addition, we have also shown here modes of predation influence animal behaviour (e.g., the frequency of hunting and food intake). Therefore, corvids and varanids are interesting model taxa to explore and elucidate the comparative evolution and mechanism of cooperation in the animal kingdom.

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Supplementary

Crow hunting on cave bats
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Varanid predation
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