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SHORT COMMUNICATION

Cooperative hunting in Brown-Necked Raven (*Corvus rufficollis*) on Egyptian Mastigure (*Uromastyx aegyptius*)

Reuven Yosef · Nufar Yosef

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Abstract We describe cooperative hunting by Brown-necked Raven (*Corvus ruficollis*) on Egyptian Mastigure (*Uromastyx aegyptius*) in the Arava Valley, Israel. At first, in all nine observed hunts, the ravens were observed to be in the vicinity and were seen simultaneously. The Mastigure was almost always at a distance from the burrow entrance and either foraging on the bushes or lying flattened on a bush sunning itself. The attack started when a circling pair of ravens flew in at high speed and landed on the entrance of the burrow, cutting off the escape route of the lizard. Following this maneuver, the other ravens attacked the lizard. The ravens pecked randomly at the most exposed part of the lizard, eventually causing its death. Only when the lizard was evidently dead did the two individuals that blocked the escape route join in the feeding ravens.

Keywords Brown-necked Raven · *Corvus ruficollis* · Egyptian Mastigure · *Uromastyx aegyptius* · Theory of mind · Cooperative hunting

Alternative common names in English for *Uromastyx* lizards are: Dabb or Dhubb lizards or Spiny-tailed lizards. In the literature, one can also find alternative spellings of the scientific specific names, such as *aegyptius* or *ornatus*. Here, we follow the scientific names in the CITES standard reference for the genus *Uromastyx*.

R. Yosef (✉)
International Birding and Research Centre in Eilat,
P.O. Box 774, Eilat, Israel
e-mail: ryosef@eilatcity.co.il

N. Yosef
Department of Education,
Tel Aviv University, Ramat Aviv, Israel

Introduction

Cooperative/tandem hunting occurs when two (usually a breeding pair) or more individuals (usually parents and offspring, sometimes also helpers) help each other to hunt a common prey (Hector 1986). The strategy involves one bird flushing the prey in a manner that the fleeing bird's flight path is anticipated by the mate, and increases the chances of a successful hunt. The success rate of tandem hunts is almost always higher than hunts by single birds, or compensates for fluctuations in prey populations (Ellis et al. 1993). Cooperative hunting has been observed mostly in falcons (e.g., *Falco biarmicus*, Yosef 1991, Leonardi 2002; *F. peregrinus*, Dekker and Taylor 2005; *F. cherrug*, Eakle et al. 2004; *F. femoralis*, Brown et al. 2004; *F. fasciinucha*, Hartley et al. 1993), Harris Hawk (*Parabuteo unicinctus*, Bednarz 1988), shrikes (*Lanius ludovicianus*, Frye and Gerhardt 2001; *L. excubitor*, Hannah 2005) and corvids (*Corvus corax*, Hendricks and Schlang 1998; *Aphelocoma coerulescens*, Bowman 2003).

In this paper, we describe cooperative hunting in Brown-necked Raven (*Corvus ruficollis*) in the Arava Rift valley of Israel at two separate locations which are ca. 40 km distant from each other.

Materials and methods

The studied phenomenon was brought to our attention by a ranger of the Israeli Nature Reserves and Parks Authority. In places where we observed ravens and Egyptian Mastigures (*Uromastyx aegyptius*) to occur in tandem, we sat in a parked vehicle at a distance of 35–50 m from the burrows of the lizards for ca. 2 h each. A total of 33 such observations were made, i.e., a total of 66 observational hours. All observations

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were made during the summer months of April–July, months when the Mastigure are active and known to forage at a greater radius from their burrows (personal observations).

Study species

The Egyptian Mastigure (*Uromastyx aegyptius*) is a large (males 328–2,146 g, $n = 61$; females 418–1,082 g, $n = 29$; Naldo et al. 2006) ground-dwelling herbivore distributed widely in extremely arid zones of the Middle East. It digs burrows in sandy soil and defends itself by striking predators with its heavy, spiked tail, which can easily draw blood from a human being (Cooper and Al-Johany 2002). The burrows are well excavated in these soils and can be 10 m in length with depths of 1.8 m and are in use for many years (Nemtzov 2005). The primary foods of adults are leaves, fruits, and flowers of annual plants, and most of the diet in the southern Arava region consists mainly of salty plants (Foley et al. 1992). In our study area, the major plant species used by the lizard for eating and sunbathing is the perennial shrub *Zygophyllum dumosum*. They appear to live in loose colonies with distances of 15–20 m between burrow entrances. They are difficult to dislodge or extract from their burrows because they wedge themselves by inflating their bodies and facing inwards. In this manner, they are not only difficult to access in the burrow but they are also able to defend themselves with their spiny tail (Cooper et al. 2000). The global range of the species is restricted to Sudan, Egypt (including Sinai), Arabia, Jordan, Israel, and Iraq. The species is listed as threatened in most of its distribution owing to extensive development of its habitats for human purposes and, because of its docile behavior, is in great demand in the wildlife pet trade (Knapp 2004) or in domestic utilization for food and traditional medicine (Walls 1996). Internationally, all *Uromastyx* species have been listed in Appendix II of the CITES Convention since 1977.

The Brown-necked Raven is a little-studied species but, owing to its ability to exploit human intrusions and settlements in the desert, it has expanded its range extensively and populations have reached pest dimensions in the desert regions of Israel. The breeding distribution of the species is widespread and stretches across north and central Africa to southwest and central Asia. It is a fairly common resident in deserts, and in Israel breeds in the Negev, Arava Valley, Judea, and Samaria, and the southern Jordan River valley (Shirihai 1996).

Results

During 2007 and 2008, we observed nine cooperative attempts by ravens, of these seven were successful, a hunting success of 78% (Table 1). On two occasions, the Mastigure successfully escaped into an unguarded neighboring burrow. The hunting attempts were on a loess plain at the entrance to Moshav Faran (30°21′44″N, 35°09′18″E) and three in a desert canyon 34 km to the north (30°38′50″N, 35°11′79″E), i.e., at km 144 on the Arava highway.

We separate the sequential occurrence of the hunt into five distinct stages:

At first, in all nine observed hunts, the ravens were observed to be in the vicinity in pairs or as individuals with no apparent flocking behaviors. We heard an occasional call but all participating ravens could be observed simultaneously, suggesting that there was communication among them and that they had commonly targeted the active burrow of an Egyptian Mastigure and remained in eye-contact with the potential prey. The Mastigure was almost always at a distance from the burrow entrance and either foraging on the bushes or lying flattened on a bush sunning itself.

The second stage was when a circling pair of ravens flew in at high speed and landed on the burrow entrance effectively cutting off the escape route of the lizard.

The third stage was the targeting of the Mastigure by the remaining ravens. They flew at the lizard, which either remained motionless or tried to get back to its burrow, or, when attacked by the ravens, to find shelter in an adjacent burrow or under a bush.

The fourth stage was the physical attack of the Mastigure by the ravens. They pecked almost randomly at any part of the lizard that was most exposed, eventually causing its death. The ravens then picked at the body, attempting to cut off pieces to swallow.

In the fifth and final stage of the hunt, only when the lizard stopped trying to escape and was evidently dead, did the two individuals that blocked the escape route join in to feed. No antagonism was observed between conspecifics when feeding on the Mastigure.

In the nine attacks observed, the raven flocks comprised of six birds on four occasions, five birds on two, and four birds on three (Table 1). In all nine attempts, two ravens blocked the burrow entrance prior to the subsequent attack on the Mastigure by the remaining members of the flock. The latency between when we first observed the presence of the raven flock to the initiation of the attack was 10.4 min (±2.8 SD).

Discussion

During 2007 and 2008, we observed seven successful attempts by two geographically-disjunct groups of Brown-necked Ravens. Hence, we assume that the flocks observed

Table 1 Cooperative hunting attempts of Brown-necked Raven (*Corvus rufficollis*) on Egyptian Mastigure (*Uromastyx aegyptius*) in the Arava Valley, Israel

Date	Time (24-h clock)	Location	Latency	Number of ravens			Success
				In flock	Block entrance	Attack	
06 April 2007	1320	Faran	8	6	2	4	Yes
22 April 2007	1445	Faran	13	4	2	2	No
30 May 2007	1445	Km 144	15	4	2	2	Yes
22 June 2007	1415	Km 144	11	5	2	3	Yes
07 July 2007	1330	Faran	13	6	2	4	Yes
13 April 2008	1430	Faran	6	6	2	4	Yes
21 May 2008	1330	Faran	9	5	2	3	No
14 June 2008	1400	Km 144	10	4	2	2	Yes
19 July 2008	1330	Faran	9	6	2	4	Yes

Latency (in min) is the time between the observations of the raven flock until the blocking of the burrow entrance by two ravens following which the rest attacked the foraging Mastigure

at the two locations, which are ca. 40 km apart, comprised of different individuals. Also, the fact that we did not color-band the individuals makes us unsure if each individual has a fixed role to play in the hunt and its subsequent success.

Packer and Ruttan (1988) suggested that cooperative hunting resulted in a higher hunting success rate than that of individual hunts and claimed that when individual hunting success is high, little improvement can be achieved by joining a group. Similarly, in a desert environment with limited food resources, cooperative hunting allows the ravens to access a prey that is otherwise impossible for the individual. This is substantiated by the fact that the ravens had a hunting success of 78%, which can be considered high in a desert environment. Also, even though there were additional ravens in the general area, the hunting group size of 4–6 ravens appears to be the optimal cooperative hunting flock in the desert. However, the lack of any foraging studies on the Brown-necked Ravens prevents comparisons.

Robinson (1995) found that the feeding rate to maintain energy balance is ca. 4.0 g dry weight per day, and that the approximate feeding rates of Egyptian Mastigure in the Negev Desert are almost triple this, suggesting that much of the annual energy requirement is acquired and stored during the brief period of annual plant productivity in the desert regions. In our study, conducted during the hot months of the year and when vegetation above the surface is minimal, the Mastigures are required to forage at greater distances from their burrows. This conforms to Packer (1988) who thought that cooperation between animals would only evolve under 'special circumstances'. He suggested that "pure" cooperation can evolve when each individual gains more from mutual cooperation than either would receive from exploiting the partner's cooperative behavior.

It is of interest that the ravens exhibit what appears to be a self-cognitive capability. The ravens recognize their individual physical size and limitations as compared to the potential prey. They showed this in the field by recognizing that a single bird is incapable of taking on and killing a Mastigure, and that it takes a minimum of two to successfully handle such a large lizard. This is reinforced by the fact that a minimum of two ravens are required not only to guard the burrow entrance but also a minimum of two to dispatch the Mastigure.

This leads to the second evidence for the understanding that cooperation between a minimum of four ravens is essential for success which is in the attack. Our observations suggest that the participating ravens have either communicated and formulated a strategy or have previously practised it to perfection. The evidence for the communal understanding amongst the members of the flock lies in the fact that the first pair flies in and blocks the Mastigure's escape path suggesting that they are highly aware of the exact attack pattern of the flock. This maneuver also suggests that they anticipate the Mastigure's reaction to try and escape to the safety of its' burrow. Whether either of these self-awareness characteristics is learned from previous experience remains unclear.

In addition to each bird's awareness of its own limitations, our observations also illustrate that the other members of the team are aware of the role of each of the other individuals and with whom they pair up to bring the attack to a successful conclusion. This is exhibited by the fact that at least one pair stays back and recognizes that the first pair has initiated the attack by passively blocking the entrance to the Mastigure's burrow. They are also well aware of the very different and aggressive role they will play in the attack strategy and that timing is of the essence—the more they delay, the greater the chances that the Mastigure will discover their intentions and find a safe refuge in a neighboring burrow or a large bush.

At all the seven cooperative hunts observed, the Mastigure was consumed at the kill site by the ravens. This is in contrast to studies wherein ravens are known to cache parts of the prey during cases of excess (e.g., Bugnyar and Heinrich 2003). This suggests that the available food resource in the desert affects their consumption habits, and

in areas with a low prey base they consume a maximum possible of the prey at each feeding session.

It is of interest that this specific behavior is limited to only two locations in the Arava Valley. This raises the question as to whether the participating individuals are long-term neighbors who have a good and profitable working relationship, or this is the result of epimeletic behavior (Greek: care-giving) and that these are young that have learned the tactics from their parents. The lack of any foraging and dispersal studies of the species prevents us from making any further interpretations.

Another possibility is that the cooperative hunting strategy described by us is a relatively recent development and is still in the early evolutionary stages. It is possible that cooperative hunting has been facilitated by the establishment of agricultural settlements along the Arava Valley since the 1950s. This has created areas of irruptive food abundance in a deprived environment and, in the early years, Mastigure were able to capitalize on the agricultural produce and so breeding aggregations were established around these plots reaching pest proportions (Moran and Keidar 1993).

The above is also true for the Brown-necked Ravens. The species distribution, and population densities, have increased greatly owing to their ability to exploit human settlements, agricultural practises, and the subsequent increase in food sources in their desert regions. We consider it safe to assume that the aggregations of Mastigures around agricultural areas resulted in an interaction between the two species leading to the ravens developing a hunting strategy that is still localized and could spread to the neighboring populations in the future.

We assume that the sporadic nature of reports of observations of predation of adult Mastigures (e.g., Golden Eagle, *Aquila chrysaetos*; Yosef 1996) suggests that the behavior reported in this paper is the first ever documented for the species—be it for the Brown-necked Ravens or for the Egyptian Mastigure.

It will be of great interest to focus future studies on the survival capabilities of the Egyptian Mastigures in the face of the evolutionary arms race against its predators that are evolving new hunting techniques. Also of interest is how the continued development of the arid regions by humans will affect the populations of the Mastigures that have limited tolerance to the disturbance of their habitats.

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