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NEWS AND PERSPECTIVES

Behavior of geladas and other endemic wildlife during a desert locust outbreak at Guassa, Ethiopia: ecological and conservation implications

Peter J. Fashing · Nga Nguyen · Norman J. Fashing

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Abstract Desert locust (*Schistocerca gregaria*) outbreaks have occurred repeatedly throughout recorded history in the Horn of Africa region, devastating crops and contributing to famines. In June 2009, a desert locust swarm invaded the Guassa Plateau, Ethiopia, a large and unusually intact Afroalpine tall-grass ecosystem, home to important populations of geladas (*Theropithecus gelada*), Ethiopian wolves (*Canis simensis*), thick-billed ravens (*Corvus crassirostris*), and other Ethiopian or Horn of Africa endemics. During the outbreak and its aftermath, we observed many animals, including geladas, ravens, and a wolf, feeding on locusts in large quantities. These observations suggest surprising flexibility in the normally highly specialized diets of geladas and wolves, including the potential for temporary but intensive insectivory during locust outbreaks. To our knowledge, Guassa is the highest elevation site (3,200–3,600 m) at which desert locusts, which require temperatures >20°C for sustained flight, have been reported. Continued monitoring will be necessary to determine whether the June 2009 outbreak was an isolated incident or part of an emerging pattern in the Ethiopian Highlands linked to global warming. The intensive consumption of desert locusts by geladas, wolves, and ravens during the outbreak at Guassa raises concerns about pesticide-based locust control strategies and potential unintended adverse effects on endemic and endangered wildlife.

Keywords Desert locust · Diet · Ethiopian wolf · Gelada · Global warming · Guassa · Locust control · Pesticide · Thick-billed raven

P. J. Fashing (✉) · N. Nguyen
Department of Anthropology, California State University Fullerton, 800 N. State College Boulevard, Fullerton, CA 92834, USA
e-mail: pfashing@fullerton.edu

N. J. Fashing
Department of Biology, College of William and Mary, Williamsburg, VA 23187, USA

Introduction

Desert locusts (*Schistocerca gregaria*) have a long history of devastating crops and contributing to famines across southwest Asia, the Middle East, and northern Africa (van Huis 1995). Generally solitary and occurring at low densities, desert locusts occasionally become gregarious following periods of high rainfall and form destructive swarms of millions or even billions (Krall 1995; Buhl et al. 2006). Though many bird taxa, including numerous raptors, storks, and passerines, have long been known to prey on and sometimes track desert locust swarms (Smith and Popov 1953; Sanchez-Zapata et al. 2007), little is known about the extent to which other vertebrates also feed opportunistically on these swarms (Ashall and Ellis 1962; Greathead 1966).

Major desert locust outbreaks have occurred repeatedly along the Red Sea coastal plains of Eritrea, Sudan, and Somalia (Showler 2002). Swarms forming in these arid coastal areas threaten lowland agricultural regions and, to a lesser extent, the rich agricultural lands of the densely populated Ethiopian Highlands (Rubenson 1991; Showler 2002). One severe desert locust outbreak in Ethiopia resulted in destruction of enough grain to feed 1 million people (Steedman 1988). Outbreaks are generally combatted with the intensive application of chemical pesticides, a technique whose efficacy has been widely debated

and has considerable environmental drawbacks (Krall 1995; Witkelius et al. 2003).

In June 2009, a desert locust swarm that had formed in northern Somalia (FAO 2009) reached the Guassa Plateau in Ethiopia's Menz Highlands where we have been conducting research on wild geladas (*Theropithecus gelada*) since 2005. Here we provide a detailed descriptive account of the behavior of geladas and two additional sympatric endemic species, Ethiopian wolves (*Canis simensis*) and thick-billed ravens (*Corvus crassirostris*), during the swarm and its aftermath and discuss the ecological and conservation implications of these observations in light of current desert locust management strategies in Africa.

Methods

Our research was conducted on the Guassa Plateau, a large (111 km^2) and unusually intact Afroalpine tall-grass ecosystem located along the western edge of the Great Rift Valley (10°15′–10°27′N; 39°45′–39°49′E) at elevations between 3,200 and 3,600 m asl (see Ashenafi 2001 for further details). From 2007 to 2009 at Guassa, mean daily low temperatures were 4.1°C, mean daily highs were 17.0°C, and annual rainfall averaged 1,595 mm ($N = 36$ months; P. Fashing and N. Nguyen, unpublished data). Guassa is home to important populations of several large mammalian species endemic to Ethiopia, including over 1,000 geladas (P. Fashing and N. Nguyen, unpublished data) and 28–35 Ethiopian wolves (0.25–0.32 individuals/km^2: Z. Ashenafi, personal communication), an endangered species consisting of <450 remaining individuals (Stewart and Gordon 2009). At least 111 bird species also inhabit Guassa, including 14 endemic to Ethiopia, as well as numerous species endemic to the Horn of Africa, such as the thick-billed raven (Tilahun et al. 1996). We initiated a long-term study of a ~220-member gelada band at Guassa in December 2005 and have continued to monitor the band on a near-daily basis since November 2006. Geladas are unusual among primates in that they live in multi-tiered societies (consisting of many one-male units that together form a band), feed primarily on grass, and spend the night on cliffs (Dunbar and Dunbar 1975; Mori et al. 2003). Due to their limited geographical distribution, global warming, and conversion of their Afroalpine grassland habitat to farms by humans, geladas are at considerable conservation risk (Dunbar 1998; Beehner et al. 2008).

The *Desert Locust Bulletin* (FAO 2009) reported the June 2009 movement of locust swarms into eastern Ethiopia, and the locusts that invaded Guassa were verified as desert locusts based on their size, color, and presence of a tubercle between the head and thorax (Steedman 1988). Their pinkish-brown coloration indicated that the locusts were sexually immature adults (Uvarov 1966). Although feeding and ranging data are routinely collected on the gelada population at Guassa (Fashing and Nguyen 2009), during the locust outbreak, we were unable to collect systematic data on the diets of geladas (and other animals) due to the chaotic nature of the incident, which made it impossible to follow specific individuals (or one-male units) for long at the unusually high speeds the animals were traveling over the hilly terrain. On subsequent days, when geladas descended to the farms below their sleeping cliffs at Guassa, they could be observed through binoculars intensively chasing and capturing locusts, though at a distance of nearly 1 km away, again rendering it impossible to collect systematic dietary data.

Results

We first spotted desert locusts on 11 June 2009 when geladas were observed chasing, capturing, and eating scattered locusts (Fig. 1) that had blown up to Guassa along wind currents from farms in the Rift Valley 600–700 m below. Locust density at Guassa remained low over the next 2.5 weeks, and geladas encountered and consumed locusts only rarely over this period. However, on 28 June 2009 at 1355 h, a swarm consisting of millions of locusts moved up to Guassa from the farms below. The geladas, which were at ~3,500 m asl at the time the locusts first appeared, responded immediately by screaming repeatedly, vocalizations typically associated with intense fear (Dunbar and Dunbar 1975). Their alarmed reaction suggests that the geladas were not familiar with locust swarms; however, they soon overcame their fear and began running east toward the locust swarm, traveling 550 m and descending to ~3,300 m asl in <5 min.

During the ~30-min period when most of the swarm remained at Guassa, many locusts were airborne whereas others landed in large numbers on the eastern edge of the grassland. Gelada one-male units moved in an unusually chaotic manner, dispersing widely while chasing locusts. The geladas initially captured locusts by leaping into the air and grabbing them in flight but soon began pouncing on those that had already landed on the ground. Geladas varied widely in locust consumption technique. After first plucking the wings, adult males generally consumed entire locusts in one bite. In contrast, adult females and immatures tended to first bite off and spit out the head before plucking the wings and eating the remainder in one or more bites.

Shortly after the swarm arrived, the geladas were joined by large flocks of birds, including many raptors and thick-billed ravens, as well as by an Ethiopian wolf. The birds circled above, feeding on airborne locusts, whereas the

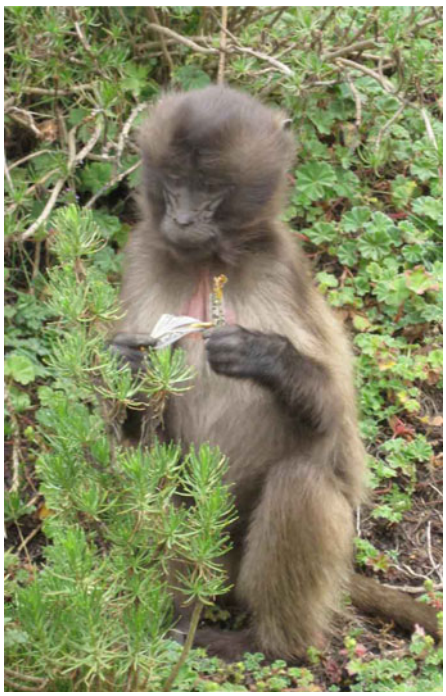

Fig. 1 Juvenile gelada at Guassa plucking wings from desert locust before feeding on it. Photo by C. Barret Goodale

wolf foraged for locusts on the ground amidst the geladas. Unlike when foraging for rodents, the wolf did not dash forward or leap into the air before pouncing on its prey (Morris and Malcolm 1977) but thrust its head forward quickly to snatch nearby locusts off the ground. By ~1425 h, most of the swarm had descended to the farms in the valley below. Still, many thousands of locusts remained on the ground at Guassa and, for the rest of the afternoon, geladas continued to feed more intensively on locusts than on their normal dietary staples of grass blades and herb leaves, which combined typically account for ~80% of their annual diet at Guassa (Fashing and Nguyen 2009). Feeding on locusts appeared to have no ill effect on the gelada gastrointestinal system, as no major changes were noted in the consistency of their feces following intensive locust feeding.

The next two mornings, rather than ascending to the plateau to feed on grass and herbs as usual, the geladas descended from their sleeping cliffs to the farms in the valley below where they fed intensively on locusts. Though the vast majority of locusts remained on the farms during this period, much smaller swarms intermittently blew up to Guassa. On several occasions during this period, we observed flocks of ≥16 thick-billed ravens feeding on airborne locusts above Guassa. On 2 July 2009, with most of the locusts having departed the area, the geladas finally returned from feeding on locusts on the farms and resumed their normal ranging and feeding patterns upon the Guassa Plateau.

Discussion

A wide variety of vertebrate species, including Ethiopian or Horn of Africa endemics such as geladas, Ethiopian wolves, and thick-billed ravens, fed extensively on desert locusts during the outbreak. Though geladas have long been regarded as highly specialized primates whose diets consist almost entirely of grass (Dunbar 1977; Iwamoto 1979), our observations suggest that the large quantities of easily accessible protein available in locust swarms (Uvarov 1966) are enough to convert geladas to temporary though intensive insectivory. Indeed, during the locust outbreak, the geladas' focus on locusts as food items was so great that they descended to the farms below their sleeping cliffs to feed on them for 2 full days before resuming their normal ranging patterns on the plateau at Guassa. Intriguingly, at least two previous incidents of insect feeding (flying ants and termites) have been reported for geladas at other sites, though the intensity and duration of this insectivory was not described (Crook and Aldrich-Blake 1968; Iwamoto 1993). Among primates, to our knowledge, only hamadryas baboons in the Ethiopian desert have also been reported to consume desert locusts, though over a period of only several hours rather than days, as in the case of geladas at Guassa (Kummer 1968).

As with geladas, Ethiopian wolves exhibit highly specialized diets, focusing almost entirely on rodents, though they occasionally consume hares, antelopes, or sheep (Sillero-Zubiri and Gottelli 1995; Malcolm 1997; Ashenafi et al. 2005). Although only one wolf was observed amidst our gelada study band during the locust outbreak, the wolf was feeding intensively on locusts. Due to the extremely low density of wolves and their typically solitary hunting habits at Guassa (Ashenafi et al. 2005), we did not have the opportunity to determine whether other wolves fed on locusts in different parts of Guassa during the outbreak or whether they did not come across the outbreak at all. Our observation represents the first report of an Ethiopian wolf feeding on invertebrates and suggests that, as with geladas, wolves will prey opportunistically on large numbers of locusts during outbreaks. Furthermore, though many birds have been reported to prey upon desert locusts (Hudleston 1958; Sanchez-Zapata et al. 2007), we provide the first report of this behavior for the thick-billed raven, a little-studied species. During our studies at Guassa, we noted that thick-billed ravens typically occur in pairs, an observation consistent with observations elsewhere (Madge and Burn 1994). On several occasions during the locust outbreak and its aftermath, however, we observed ravens in flocks of ≥16 individuals while feeding on locusts.

Most desert locust outbreaks take place in arid low-elevation regions (Showler 2009). Indeed, to our knowledge, Guassa is the highest elevation site at which a desert

locust outbreak has been reported. Because desert locusts are generally incapable of sustained flight at temperatures <20°C (Symmons and Cressman 2001), many agriculturally rich highland areas of Ethiopia have rarely been invaded by locusts. However, given global warming trends, desert locust incursions into the Ethiopian Highlands, which support both a large human population and a rich and unique assemblage of animals, may increase markedly in the future. Continued monitoring will be necessary to determine whether the locust outbreak at Guassa in June 2009 was an isolated incident or part of an emerging pattern.

Our observations echo recent concerns about the potential adverse impacts of locust management strategies on the health and survival of wildlife and wild habitats (Peveling et al. 2003; Sanchez-Zapata et al. 2007). Whereas efforts have been made in recent decades to reduce negative environmental effects of treatments used to manage locust outbreaks (Lomer et al. 2001), insecticides are still the primary means of combating them (Witkelius et al. 2003; Peveling 2005) despite the mixed record of success (Krall 1995; Witkelius et al. 2003). Some pesticides are toxic not only to locusts but also to other invertebrates, as well as fish, reptiles, birds, and mammals (Tingle et al. 2003; Witkelius et al. 2003). Furthermore, not all locusts exposed to insecticides die (Rainey et al. 1979; Peveling 2001). Indeed, increasing chemical pesticide resistance has become a major obstacle to migratory locust control in recent years (Yang et al. 2009). During an outbreak in Australia in which locusts were sprayed with organophosphorous insecticides, locusts in weakened or dying states were the primary food item for several bird species (Story and Cox 2001). In fact, due to concerns about insecticide toxicity, humans are discouraged from eating locusts in outbreaks that have been treated with insecticides (Showler 2009).

Whereas pesticide spraying for locust control generally takes place in desert regions of Ethiopia to the east and north (FAO 2009), our observations suggest the potential exists for surviving treated locusts to reach neighboring highland regions where they may be consumed in large quantities by some of Ethiopia's most endangered and spectacular endemic animals. Assessment of pesticide concentrations (e.g., Rainwater et al. 2009) in geladas and other locust-eating fauna would help evaluate the extent to which the health and survival of these species are threatened by current locust management strategies. Our observations during the Guassa outbreak reinforce recent concerns regarding the potential environmental effects of locust control using traditional chemical insecticides and highlight the importance of increased emphasis on the development and use of biological agents for locust management (Lomer et al. 2001; Hunter 2005).

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