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Puddling in Elephant Dung by Lepidopterans in Wasgamuwa, Sri Lanka

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Abstract. We recorded puddling of lepidopterans on elephant dung in Wasgamuwa. In 148 days of observation, puddling was observed on nine days, on 9 of 978 dung piles examined, suggesting that the behaviour was uncommon. We identified 26 butterfly species from six families who engaged in this behaviour, indicating that elephant dung puddling was much more wide spread among butterfly species than recognized previously. All puddling occurred on fresh dung, was more in the wet season and male butterflies tended to puddle more than females, supporting the notion that dung puddling by butterflies is for obtaining minerals, especially sodium.

Introduction

Lepidopterans are mainly nectar feeders, yet they can have extremely diverse food habits especially in the tropics (Adler 1982; Sourakov *et al*. 2012). The diversity of food habits is related to ecological and biological differences within the group. Unlike the larvae which have specific food requirements, adult butterflies are opportunistic feeders and in addition to flower nectar, are capable of obtaining nutrients from a variety of substrates such as mud, carrion, rotten fruits, tree sap, perspiration and dung (Downes 1973; Boggs & Jackson 1991; Molleman 2010).

The phenomenon of feeding on non-nectar sources by lepidopterans is termed "puddling", presumably derived from reference to feeding on mud-puddles (Molleman 2010).

Puddling provides butterflies with nutrients, which are scarce in nectar (Molleman *et al*. 2005). Lepidopterans acquire a limited amount of minerals during the herbivorous caterpillar stage that is sequestered and used in subsequent life stages. Behavioural adaptations such as puddling enable them to obtain a balanced mineral intake, overcoming shortfalls in larval nutrition. One of the main minerals obtained through puddling is sodium, which is important for neuromuscular function and regulating fluid balance (Fraústo da Silva & Williams 2001) but also plays a role in the reproductive behaviour of some butterflies.

An important criteria in food selection by herbivores is the nitrogen content of plants (Ball *et al*. 2000) as it is required for protein synthesis. Animals excrete nitrogen metabolites to the environment through dung and urine (Ball *et al*. 2000). Obtaining nitrogenous compounds such as amino acids, albumin, and casein, is another reason for puddling (Boggs & Gilbert 1979; Beck *et al*. 1999).

Besides lepidopterans, different bee species also engage in puddling behaviour. For example, honey bees, sweat bees (Butler 1940) and stingless bees (Bänziger *et al*. 2009) are known to puddle on sweat and tears.

This paper presents observations of lepidopterans puddling on Asian elephant (*Elephas maximus*) dung, which has previously been recorded only in two species of butterflies; Malayan and Lesser Grass Blue (Hewavitharana *et al*. 2013).

Methodology

Study area

Our study area borders the south-western part of the Wasgamuwa National Park, Sri Lanka.

The area includes different habitat types such as chena (slash-and-burn cultivation), lake beds, agricultural fields, home gardens, scrub lands, secondary forests and dry-mixed evergreen forests.

The climate of the study area is tropical, with a dry season extending from March to September and a rainy season from October to February. From May to August the region experiences high winds. The mean temperature is 32˚C and the mean annual rainfall is 2250 mm, which occurs mostly during the northeast monsoon.

The region is situated in lowland Sri Lanka, and has an elevation gradient of 125–300 m a.s.l. The terrain of the study area is predominantly flat with some low-undulating areas and elevated rock outcrops.

Data collection

Dung–puddling was opportunistically recorded in 2013, 2014, and 2016, while conducting elephant dung transects. When puddling butterflies were encountered, the species, their numbers, and sex were recorded. Butterflies were photographed using a Nikon-Coolpix P510 camera and sexed using wing characteristics.

Habitat types were classified as reservoir bed grasslands, tall grass, scrublands, closed forests, agricultural fields and home gardens based on visual characteristics. The habitat type where dung piles were located was recorded.

Dung was categorized as "fresh" or "old" where dung piles deposited within an approximately 48-hour period was considered as "fresh". Characteristics used to identify fresh dung were; moist outer surface, distinct odour, lighter colour, and the presence of flies.

In order to assess seasonality of puddling in dry and wet seasons, we created a puddling index for each season by dividing the total number of puddling incidents by the total number of dung piles observed in each season, then averaged to a month.

Results

In a total of 148 days of observation, puddling was observed on nine days, on nine of 978 dung piles examined. A total of 26 species of butterflies from five families were observed puddling (Figs. 1, 2 & 3): Lycaenidae (9 species), Pieridae (7 species), Nymphalidae (4 species), Papilionidae (4 species) and Hesperiidae (2 species). Mean number of species recorded per dung pile was 3.78 ± 4.3 (range 1–15).

The most frequently observed species were Common Hedge Blue and Lesser Grass Blue both lycaenids, which were recorded on four occasions. The lycaenids, Indian Cupid and Lime Blue, and the pierid, Common Grass Yellow were recorded on two occasions. All other species were observed only once (Table 1). The number of individuals per dung pile varied from 45 to 1 (mean 8.57 ± 5.9). The most number of individuals of a single species recorded from a dung pile was the Lemon Emigrant (n = 45) followed by the Common Gull (n = 21), both pierids, and the Common Jay (n = 17) a papilionid. The highest number of species recorded on a single dung pile was 12 and represented all five families.

Of 169 individual butterflies observed puddling across all species, 91% were males and 9% females. Recorded females were of Common Albatross, Common Gull, Common Pierrot and Lemon Emigrant.

All the puddling in dung piles occurred in scrubland (56%) and in reservoir grass beds (44%). No puddling incidents were observed in tall grass, closed forest, home gardens and agricultural fields. Puddling incidents in the wet

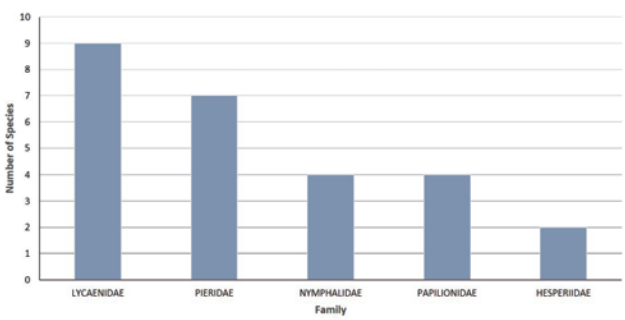

Figure 1. Number of butterfly species recorded in each family.

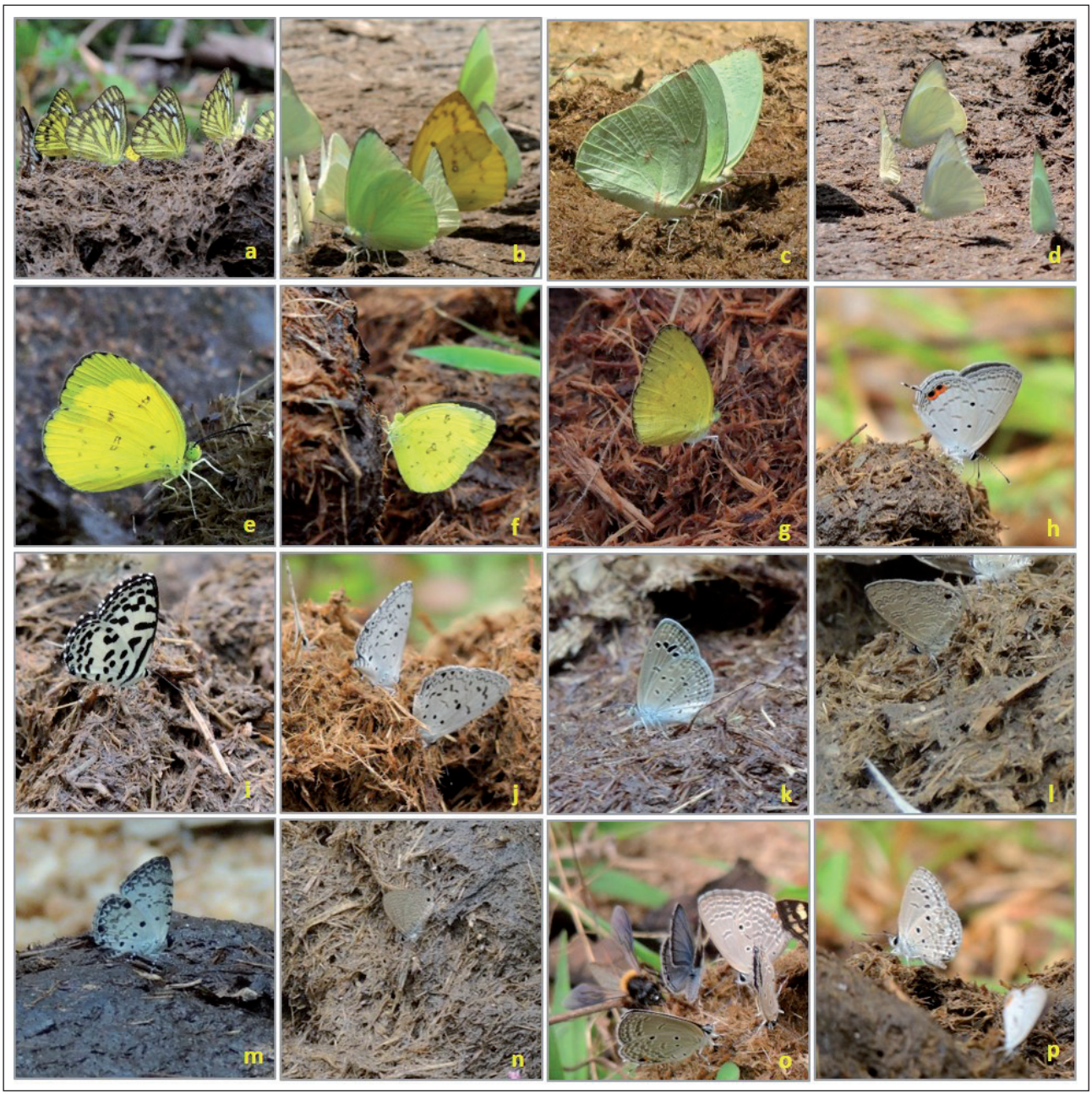

Figure 2. Butterfly species that were recorded in family Pieridae (a–g) and Lycaenidae (h–p). a = Common Gull; b = Lemon Emigrant; c = Mottled Emigrant; d = Common Albatross, e = One-spot Grass Yellow; f = Common Grass Yellow; g = Small Grass Yellow; h = Indian Cupid; i = Common Pierrot; j = Common Hedge Blue; k = Lesser Grass Blue; l = Common Lineblue; m = Malayan; n = Tailless Lineblue; o = Plains Cupid; p = Lime Blue.

season was 0.3 incidents per month whereas in the dry season it was 0.09 incidents per month. All observations were from fresh dung piles with no puddling events being observed on old dung piles.

Discussion

In the observation of 978 individual dung piles over 148 days, we only observed puddling on nine dung piles on nine days. This suggests that puddling on elephant dung, and its use as a food substrate by butterflies is not common.

All the butterfly species we recorded on elephant dung mainly feed on nectar. Of these, 35% belonged to Lycaenidae, which also has the highest representation among butterflies in Sri Lanka with 34% of species. Lycaenids in general, utilize a variety of food sources (Krenn 2008). Of

Figure 3. Butterfly species that were recorded in family Nymphalidae (q–t), Papilionidae (u–x) and Hesperiidae (y–z). q = Great Eggfly; r = Lemon Pansy; s = Chocolate Soldier; t = White Four-ring; u = Common Jay; v = Common Mormon; w = Lime Butterfly; x = Spot Swordtail; y = Golden Angle; z = Indian Skipper.

the nine lycaenids observed puddling on elephant dung by us, only the Lesser Grass Blue and the Malayan have been previously reported to do so (Hewavitharana *et al*. 2013). Among the others, the Common Hedge Blue, Common Lineblue and Tailless Lineblue have been reported to feed on scat and bird droppings (van der Poorten & van der Poorten 2016). The Common Pierrort was thought to seldom feed on dung (Rima *et al*. 2016; van der Poorten & van der Poorten 2016). The Indian Cupid, Lime Blue and Plains Cupid have been reported to puddle on mud (van der Poorten & van der Poorten 2016) but not on other substrates.

While pierids are known for mud sipping, they were not previously reported to feed on elephant dung. Pierids congregate in large numbers in wet soil (van der Poorten & van der Poorten 2016). We also observed the Common Albatross, Common Gull, Lemon Emigrant and Mottled Emigrant congregating on elephant dung, displaying greater gregariousness than other butterflies in dung puddling also.

The four species of papilionids that we recorded on elephant dung have been observed to mud sip especially during dry and hot weather (Rima *et al*. 2016; van der Poorten & van der Poorten 2016), but no previous records were found on the use of other substrates as food sources by them.

Amongst the recorded nymphalids, the Great Eggfly and Chocolate Soldier are known to feed on tree sap and fruits (van der Poorten & van der Poorten 2016). Although the Lemon Pansy imbibes liquids from the soil, they have not been recorded to feed on mammalian dung previously. The White Four-ring has been reported to feed on bear faeces (Hewavitharana *et al*. 2013).

Table 1. Butterfly species and their frequency of occurrence (N) in elephant dung in Wasgamuwa.

Family	Common name	Scientific name	N
Papilionidae	Lime Butterfly	*Papilio demoleus*	1
	Common Mormon	*Papiliyo polytes*	1
	Common Jay	*Graphium doson*	1
	Spot Swordtail	*Graphium nomius*	1
Pieridae	Common Gull	*Cepora nerissa*	1
	Common Albatross	*Appias albina*	1
	Lemon Emigrant	*Catospilla pomona*	1
	Mottled Emigrant	*Catospilla pyranthe*	1
	Small Grass Yellow	*Eurema brigitta*	1
	Common Grass Yellow	*Eurema hecabe*	2
	One-spot Grass Yellow	*Eurema ormistoni*	1
Nymphalidae	Lemon Pansy	*Junonia lemonias*	1
	Chocolate Soldier	*Junonia iphita*	1
	Great Eggfly	*Hypolimnas bolina*	1
	White Four-ring	*Ypthima ceylonica*	1
Lycaenidae	Common Hedge Blue	*Acytolepis puspa*	4
	Common Pierrot	*Castalius rosimon*	1
	Lime Blue	*Chilades lajus*	2
	Indian Cupid	*Everes lacturnus*	2
	Malayan	*Megisba malaya*	1
	Tailless Lineblue	*Prosotas dubiosa*	1
	Common Lineblue	*Prosotas nora*	1
	Lesser Grass Blue	*Zizina otis*	4
	Plains Cupid	*Chilades pandava*	1
Hesperiidae	Indian Skipper	*Spialia galba*	1
	Golden Angle	*Caprona ransonnettii*	1

Hesperiids are known to feed on substrates such as tree-sap, bird droppings and dung in addition to nectar. The hesperids we observed puddling on elephant dung, the Indian Skipper and the Golden Angle have previously not been recorded to feed on mammalian dung.

Hewavitharana *et al*. (2013) recorded five species of lepidopterans puddling on bear faeces in Wasgamuwa National Park. These species also occur in our study area. Among them, we observed only the White Four-ring on elephant dung. The other four species recorded by Hewavitharana *et al*. (2013), the Common Evening Brown (*Melanitics leda*), Tamil Yeoman (*Cirrochora thais*), Large Four Lineblue (*Nacaduba pactolus*) and Common Cerulean (*Jamides celeno*) could be potential puddlers on elephant dung, as butterflies tend to be non-species specific in feeding on dung.

A majority of the puddling incidents occurred during the wet season. This implies that butterflies were not feeding on elephant dung to obtain moisture. In the tropics, the reproductive season of butterflies coincides with rainfall (Braby 1995; Kemp 2001; Jones 2011). In seasonal habitats such as Wasgamuwa, butterflies arrest their breeding activities during the dry season as most of the larval food plants either cease their growth, are deciduous or seasonal. Butterflies start their breeding activities with the onset of the monsoon. During the breeding season, nutrient requirements of butterflies are high, especially for males, which may explain the relative increase in puddling. Another possibility is that it was related to seasonal differences in nutrient availability in elephant dung, as elephant diet varies seasonally.

It has been suggested that acquiring sodium is the main trigger for puddling (Braby 1995; Beck

et al. 1999; Boggs & Dau 2004; Krenn 2008). Elephant dung is a good source of sodium, as it is one of the minerals that determine elephant diet (Dougall 1963; Weir 1972). As nectar is low in sodium, male butterflies collect sodium from non-floral substrates such as mud, carrion, rotten fruits, sweat and bird droppings (Molleman *et al*. 2005; Ravenscraft & Boggs 2016). They transfer a significant amount of collected sodium to females through spermatophores, as a nuptial gift to increase mating success (Sculley & Boggs 1996; Beck *et al*. 1999; Molleman *et al*. 2005). Therefore, it is predominantly young males that engage in puddling (Boggs & Jackson 1991). Male biased sex differentials in our study support this assertion.

All the puddling incidents observed by us were in relatively open habitats, such as reservoir-bed grasslands and scrublands. This is probably linked with the habitat preferences of the butterfly species observed puddling, as they inhabit relatively open and sunlit habitats during the breeding season.

We only recorded puddling on fresh dung piles. The outer surface of elephant dung desiccates within about 48 hours after defecation, eliminating the surface moisture in which nutrients and other chemicals are dissolved. This may provide an explanation as to why butterflies were not recorded on dry (old) dung piles. It also suggests that butterflies are unable to penetrate into elephant dung when it is dry and feed on the nutrients inside, and why butterflies are not specialized puddlers on elephant dung.

Butterflies locate their food sources using both olfactory and visual cues. According to Beck *et al*. (1999), pierids and papilionids mainly depend on visual cues to discover food sources whereas nymphalids, hesperiids and lycaenids rely on olfactory cues. It is likely that olfaction may assist butterflies in locating elephant dung more than visual cues, as it provides a wider zone of detection. Fresh elephant dung has a strong smell that fades away within a day or two after defecation, which may also be a reason for our observation of butterflies puddling only on fresh dung (Fig. 4).

In the tropics, studies on foraging behaviour of lepidopterans have mainly focused on food preferences in terms of nectar and fruits and the use of other substrates including mammalian dung has received little attention. Our findings show that a variety of butterfly species use elephant dung for supplementary foraging, indicating the importance of assessing the foraging ecology of lepidopterans on other foraging substrates.

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Figure 4. Common Gulls puddling on a fresh elephant dung pile.

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