African Journal of Ecology

Notes and records

Tea breaks: how flower visitors can benefit from unplanned floral buffer strips in a Tanzanian tea plantation

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Introduction

Cultivation of commodity crops is altering tropical landscapes worldwide, with severe impacts on biodiversity. Forest conversion to intensive monoculture drives species loss, and over 30% of agricultural land in SE Asia is now covered by coconut, rubber and oil palm (Sodhi *et al.*, 2004); the latter is now thought to be the greatest threat to biodiversity globally (Wilcove & Koh, 2010). A meta-analysis by Donald (2004) assessed the biodiversity impacts of several tropical commodity crops, concluding that for cocoa, coffee, rice, palm oil and soybean, intensified production/increased crop area underpinned environmental destruction and biodiversity loss; insufficient data were available to evaluate two other monoculture crops, tea and rubber.

The Amani Nature Reserve, East Usambaras, Tanzania, comprises forest fragments, shambas (small farm plots) and tea plantations (Newmark, 2002). In Derema tea plantation, herbaceous vegetation has encroached from forest edges into the tea where plants grow along paths that connect villages and isolated forest blocks. Workers undertake manual clearance and use chemical applications, but their efforts have minimal effects and paths contain strips of flowering plants that attract visiting insects.

This is the first study to examine insects in Tanzanian tea plantations; through transect walks and focal watches, we assessed insect populations along the flower-rich path edges and the tea crop to establish the utilization of within-tea habitats by flower visitors and other insects. Our objective was to confirm initial observations that insects are more plentiful along paths than within the crop; a pattern that we examined by also assessing the availability of floral resources for pollinators such as bees and butterflies, key ecological components of the overall landscape.

Methods

This study took place in the Derema tea plantations, Amani Nature Reserve (5°6′S, 38°37′E). Transects, separated by at least 500 m, were surveyed at six randomly selected sites (Fig. 1) in tea fields of >5 ha from 16 to 24 August 2009. Three parallel sub-transects (75 × 2 m) perpendicular to the forest edge into the tea fields were established; one along the main path (up to 2 m wide for access on foot between villages) and two through the tea crop between rows of plants. Each transect was surveyed three times on a single day between 09.00 and 16.00 hours (the peak time period for general insect activity in this area in a pilot study), with observers walking from the forest edge into the plantation. All insects were recorded and identified in flight to species where possible, or to order and family.

Subsequently, 1 m^2 quadrats were randomly selected along each transect for floral and flower-visitor surveys, and 10-min focal watches were performed to determine visitation (insects either landing on or feeding at, flowers).

Statistical analyses were completed using R version 2.10.1 (R Project, 2010). We averaged tea transects to make a direct comparison between path and tea; abundances were summed across sampling dates to produce a single value per site.

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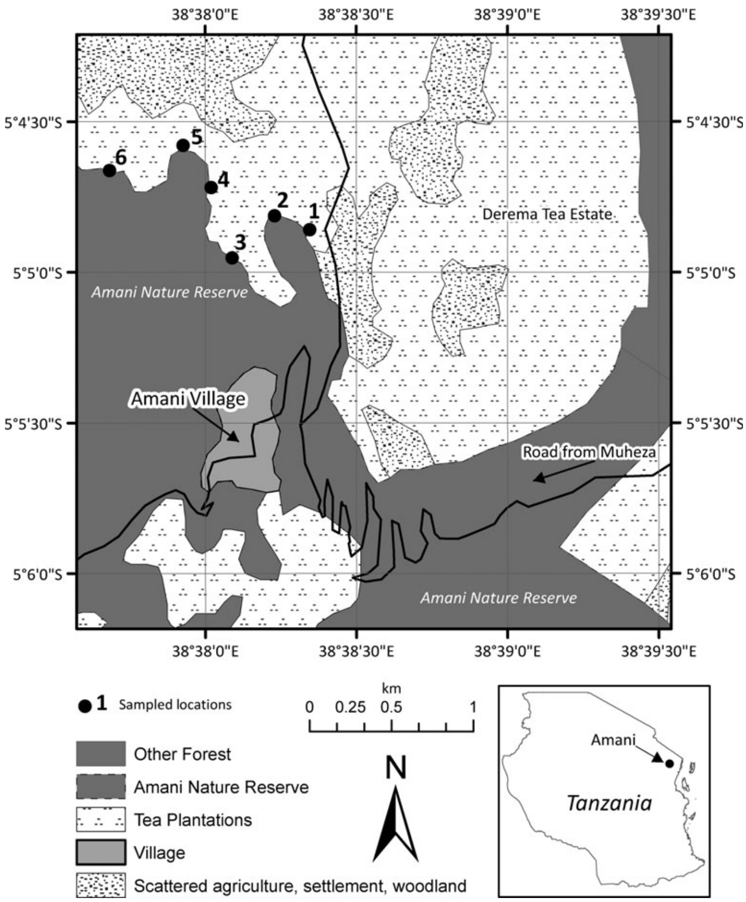

Fig 1 Location area of study and transect sample locations

Results and discussion

In transect surveys covering a total area of 2700 m^2, we recorded 2617 insects from ten orders. The most abundant orders were Hymenoptera (38%), Diptera (25%), Lepidoptera and Orthoptera (both 16%), with highest bee and butterfly abundance along paths (Fig. 2) and dipterans and orthopterans mainly within the tea.

Our findings show higher overall insect abundance on paths, with some differences between taxa (Table 1). Obligate flower visitors, bees and butterflies, were plentiful on the paths, with the number of bees being associated with higher floral densities. In contrast, ants and dipterans occurred mainly within the tea. For ants, there was no association with floral density, and abundance patterns are likely to be explained by the proximity to nest position/recruitment of individuals; dipterans showed a negative correlation with floral density (as the majority of flies were Muscidae, other resources probably drive this pattern). Obligate herbivores, orthopterans, showed no

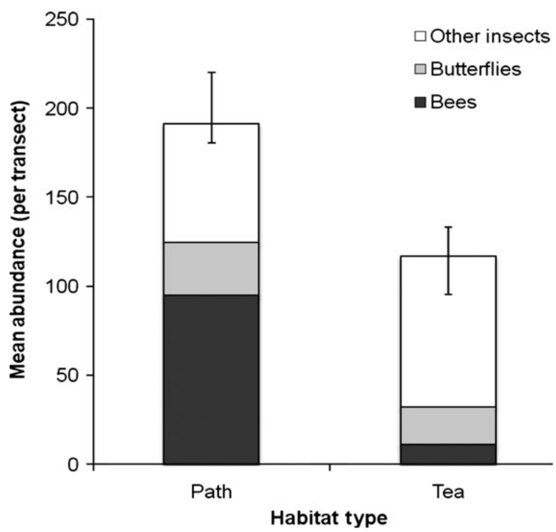

Fig 2 Mean abundance of main insect groups recorded per transect in path and tea habitats

Table 1 Habitat type effect on arthropod abundance (per 75 × 2 m transect). Generalized mixed effects models [*lmer* function of *lme4* package (Bates, 2005)] were used to evaluate insect abundance using Poisson distributions and Laplace approximations. The response variables were abundance of (i) total arthropods; (ii) bees; (iii) butterflies; (iv) dipterans; (v) orthopterans; (vi) ants; and (vii) other insects. Habitat treatment (path or tea), floral density and the corresponding floral visitation rate were used as the explanatory fixed factors, and site ($N = 6$) was included as a random effect factor to account for spatial variance (Crawley, 2007). Model justifications were based on AIC values, and the significance of the fixed effects was determined with Wald *z*-tests. Estimate represents the average difference in the response factor (path – tea) as estimated by the model

	Mean (per transect) ± SEM		lmer model outputs				
Response factor (abundance)	Path	Tea	Fixed effect factor	Estimate	Z	*P*-value	AIC
Arthropods	195.83 ± 28.9	122.33 ± 16.5	Habitat type	0.293 ± 0.071	4.15	**0.001**	40.24
			Floral density	0.004 ± 0.001	2.78	**0.005**	40.24
			Total visitation rate	0.062 ± 0.028	2.16	**0.031**	40.24
Bees	94.83 ± 28.1	10.67 ± 5.0	Habitat type	1.633 ± 0.31	8.83	**0.001**	54.85
			Floral density	0.014 ± 0.004	3.59	**0.001**	54.85
			Visitation rate	0.314 ± 0.14	2.194	**0.028**	54.85
Butterflies	29.67 ± 6.6	21.33 ± 5.2	Habitat type	0.330 ± 0.12	2.84	**0.004**	35.46
			Floral density	*ns*			
			Visitation rate	*ns*			
Dipterans	27.00 ± 11.6	40.83 ± 5.9	Habitat type	−0.598 ± 0.14	−4.31	**0.001**	51.85
			Floral density	−0.007 ± 0.003	2.13	**0.033**	51.85
			Visitation rate	−13.615 ± 2.96	4.58	**0.001**	51.85
Ants	8.00 ± 1.8	15.67 ± 8.6	Habitat type	−0.672 ± 0.18	3.78	**0.001**	66.53
			Floral density	*ns*			
			Visitation rate	*ns*			
Orthopterans	25.50 ± 9.1	22.83 ± 3.9	Habitat type	−0.111 ± 0.12	0.94	0.348	84.24
			Floral density	ns			
Others	6.00 ± 3.1	5.5 ± 1.1	Habitat Type	−0.087 ± 0.24	0.36	0.719	41.58
			Floral density	*ns*			

P-values significant at 0.05 in bold; ns denotes a nonsignificant fixed effect factor that was not included in the final model (model selection based on lowest AIC values).

difference between transects or association with floral density.

Although species overlap was noticeable, floral species richness per quadrat was significantly higher along the path ($n = 23$) than within the tea ($n = 53$) (Mann–Whitney: $U = 1606.5$, $P < 0.001$), as was floral density ($U = 1564.5$, $P < 0.001$) (mean 270 ± 38.4 flowers per m^2 path plots and 117 ± 21.1 flowers per m^2 within tea) (Fig. 3a). Currently, ruderal plants dominate the study site, some of which are alien to the region, such as the super-abundant *Ageratum conyzoides* L. (Asteraceae) and *Bidens pilosa* L. (Asteraceae), forming what amount to 'accidental' floral buffer strips. In path quadrats, 157 visitors comprised mainly solitary bees (48%) and *Apis mellifera* (45%); 78 visitors were recorded in tea quadrats with solitary bees (28%) and *Apis mellifera* (26%) most numerous, and ants (25%) were always visiting the few available tea flowers (none on path quadrats). Visitation was significantly higher on path quadrats ($U = 1184.0$, $P < 0.001$) (mean visits: path = 6.83 ± 1.66; tea = 1.50 ± 0.33) (Fig. 3b).

The link between insects and floral resources is well studied, and we now confirm a connection between bee abundance and flowers within tea plantations. In Mediterranean ecosystems, pollinators (chiefly bees) are linked with floral resources provided by plant assemblages (Petanidou & Ellis, 1996; Potts *et al.*, 2003). Here, although there was no significant association with floral abundance or visitation rates, butterfly abundance was also greater on paths. Other tropical studies show that shade and host–plant availability within Indian coffee regions influence butterfly habitat usage in the study by Dolia *et al.* (2008); in oil palm plantations, increased

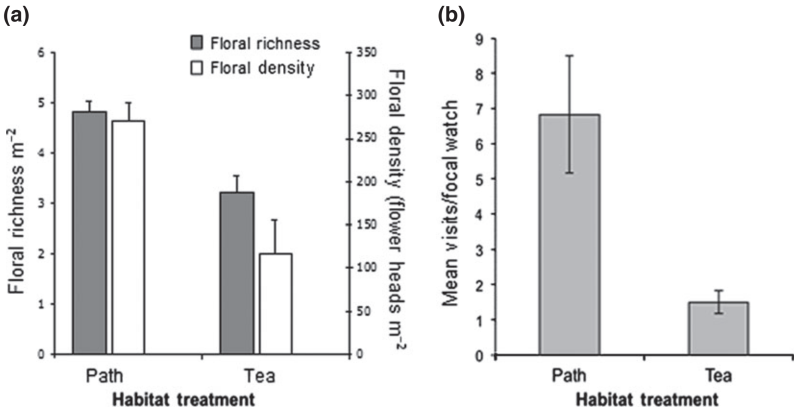

Fig 3 (a) Mean floral richness and mean floral density for path (N = 25) and tea quadrats (N = 50); and (b) Mean visitation rate (per 10 min focal watch) on path (N = 23) versus tea (N = 53) habitat. Data sets were tested for normality using the Anderson–Darling test where not normally distributed, and Mann–Whitney U-tests were used to compare median values for flower visits, floral density and floral diversity between the path and the tea

weedy plant ground cover impacted positively on forest butterfly diversity (Koh, 2008). Here, key pollinators such as bees and butterflies were the main floral visitors and are exploiting sources of nectar and pollen otherwise absent in the tea, as well as presumably promoting maintenance of the floral community.

In Amani, the seventeen plant species we recorded represent a small proportion of the 3246 vascular plants indigenous to the East Usambara forests (Pohjonen, 2012), indicating an impoverished plantation floral community. Multiple studies have demonstrated the crucial value of buffer strips and hedges for plants (Bart *et al.*, 2005) and insects (Croxton *et al.*, 2002; Kwaiser & Hendrix, 2008). This is the first study to show the importance of floral strips in tea estates. Although restricted to one location, our findings indicate a potential management practice that could aid insect conservation in a ubiquitous tropical agro-ecosystem; reduced herbicide use/manual clearance along paths could encourage insect biodiversity within plantations. Such a measure could have a vital impact on pollination services through increased numbers of key ecological groups including bees and butterflies.

Despite the pan-tropical scale of the tea industry, little attention has been paid to finding environmentally sensitive methods of cultivation; the monoculture practice in East Africa is particularly inhospitable to flower-visiting insects. This preliminary study shows encroachment of wild flowers on paths (where they do not compete with tea) drives a larger, more diverse community of flower visitors. This raises the possibility that a cost-neutral, within-crop conservation measure could be recommended to plantation owners.

Acknowledgements

With thanks to TBA, BES and BATBP for funding; EUTEACO for permission to work on their land; the staff at ANR field centre; and Ruth Swetnam (map of Amani), John Hall (plants) and Connal Eardley (bees) for species identifications.

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(*Manuscript accepted 18 September 2012*)

doi: 10.1111/aje.12039