Predation on insects on Tiwai, Sierra Leone

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Tiwai is a wooded island in the river Moa near the Gola rainforest in eastern Sierra Leone. A particular feature of the island is the lack of *Dorylus* driver ants, which are usually major predators in African forests, including of termites. Therefore termites are very abundant and this appears to result in efficient decomposition of dry leaves and perhaps leaves less room for other decomposers. Furthermore, arachnids catch the eye, including ferocious-looking whip spiders. Many butterflies and grasshoppers showed signs of predator attacks, especially also wing damage in the shape of a lizards maul. To gain better insight in predation on butterflies, caterpillars made from modeling clay (dummies) were used. Damage to the dummies suggests a daily predation pressure of 50%. Damage to dummies was mainly caused by ants and wasps, and not by birds. Although it was the dry season, many butterflies appeared to be young, and a good number and variety of caterpillars have been found, including a species for which no caterpillar records existed. In total, eighty butterfly species were observed, of the about 450 that may be expected locally. Hopefully, these scarce remnants of West-African forest will be conserved, so that nature lovers and entomologists can continue to benefit from the excellent facilities.

Introduction

A large part of West Africa would be covered by tropical forest if it weren't for the severe deforestation (Mayaux *et al.* 2013). Much remains to be learned about the ecology and biodiversity of these forests, including species discovery and, description of community dynamics and food-webs. In Sierra Leone, forest-like habitats can still be found on steep slopes in hilly country, in sacred forests, plantations (teak, rubber, eucalyptus), agro-forestry (cacao, coffee, palm) and as farm-bush, as well as in protected areas. Tiwai is an island of 12 km^2, isolated from the main land by the Moa river (figure 1). The habitat consists of lowland tropical forest and bits of swamp forest, with varying degrees of past human disturbance. It harbours a rich fauna (including many primates, pygmy hippopotamus *Choeropsis liberiensis* and red river hogs *Potamochoerus porcus*). Because the island lies only a few kilometres from the Gola Rainforest National Park, it is likely that many insect species can move easily between these forests. Tiwai is owned by two chiefdoms and co-managed by the Environment Foundation for Africa and Njala University as a reserve, supported by tourism and research, and provides excellent facilities. Sierra Leone is generally friendly and safe, and procedures for obtaining permits for research are reasonable.

The first author of this article has performed research on butterfly ecology and evolution in Uganda for the last fourteen years, and the second author did his PhD thesis on West-African butterflies, and has performed butterfly inventories in Gola Rainforest National Park (Sierra Leone), Gola Forest (Liberia), and elsewhere in the region. The first author visited Tiwai for nine days (12-16 and 20-23 February 2014), and the second author identified the observed butterflies.

What's missing

Driver ants

The absence of *Dorylus* driver ants on the island (abundant on mainland) offers the opportunity to investigate their possibly dominant ecological role on one hand, and may make this island less representative of West-African forest ecology on the other. In African forests, typically several species of driver ants are active, some hunting exclusively underground, a species hunting in the litter sphere and a species also climbing in vegetation (Schöning *et al.* 2008). Particular species of driver ants attack nests of other ant species and of termites in underground battles (Barth *et al.* 2013,Schöning 2007). Because driver ants proliferate by splitting their colony (queens don't fly), apparently they have not been able to cross the river recently to Tiwai or may have gone extinct due to inundation in the past. It appears that in the absence of their nemesis, termites flourish on the island, thus dominating decomposition and possibly contributing to less litter on the forest floor compared to Gola RNP. Termites do suffer predation (e.g. other ant species carrying off foraging termites, figure 2), but probably more rarely at the scale of whole nests. Perhaps termites leave little room for other decomposers of wood such as long-horn beetles (figure 2). With more forested islands in the area and Gola Rainforest National Park nearby, this could be a suitable system to

1. Tiwai as seen from the Moa river. Photo: Freerk Molleman
1. Tiwai gezien vanaf de rivier de Moa.

study the possibly dominant influence of driver ants on ecology, community composition and related evolutionary responses. On the other hand, it remains to be seen whether Tiwai can serve as a representative model for studying community structure of the wider region. For example, termites might redistribute nutrients more patchily and thus affect the spatial pattern of tree recruitment, and absence of driver ant raids may affect insect or spider communities.

Predators appear to damage insects

Small lizards are numerous, and could be important predators of adult insects on Tiwai in addition to the usual suspects: birds. We have observed wing surface loss in the shape of lizard mauls on some butterflies, and grasshoppers with a leg missing (figure 3).

What can't be missed: spiders and whip spiders

The abundance of large spiders catches the eye on Tiwai (figure 4). Moreover, at night whip spiders can be spotted. These are not true spiders but members of the order Amblypygi, with large pinchers and with one of their four pairs of legs very long to serve as antennae. Even though they look dangerous to humans, they are not poisonous, and can even be social with each other (Hebets *et al.* 2014).

Marks of predation on dummy caterpillars

The use of dummy prey to assess relative predation rates and identify predators of insects is an emerging technique in ecology (Loh *et al.* 2014). Studies in Uganda have shown that the plant species on which caterpillar dummies are glued has a negligible effect on predation rates (Sam *et al.* in prep). Studies on Papua New Guinea showed that artificial leaf damage near such dummies increases predation rates by wasps and birds (Sam *et al.* 2014).

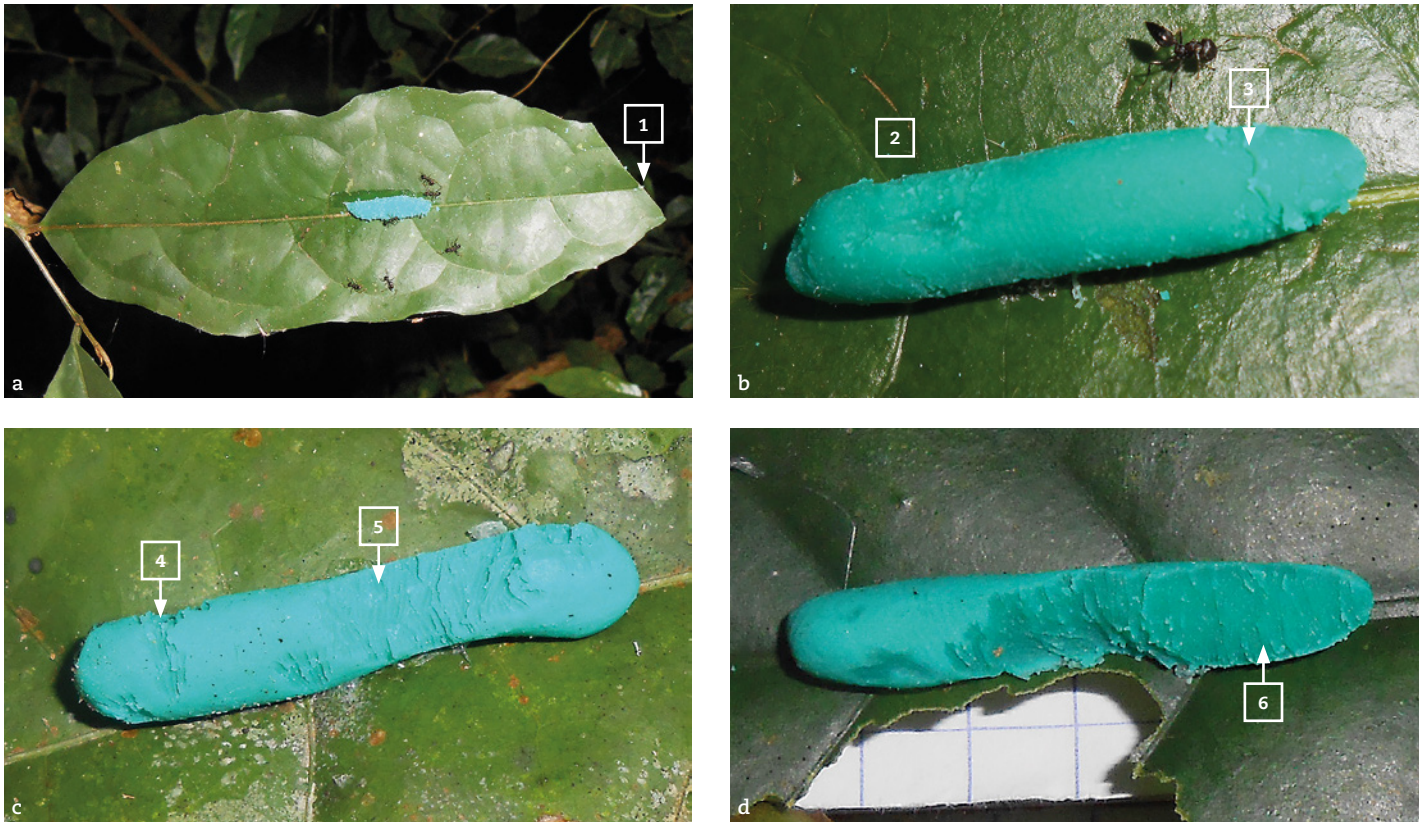
On Tiwai an experiment was performed using dummy caterpillars made of green modelling clay glued to the midrib of leaves of plants that are not ant-tended (figure 5). Leaf tips were cut with scissors. Dummies varied in length between 1.4 and 4.1 cm, and were placed at heights between 0.2 and 4.0 m. After 24 hours of exposure, out of 35 dummies, 8 appeared attacked by wasps, 15 by ants (6 by both wasps and ants) and at least one had been gnawed by a small mammal, totalling 50% survival rate in 24 hours. This predation rate was higher than in most other such studies, and very few caterpillars would be able to reach maturity at this rate. This high attack rate may in part be due to the cutting of the leaf tips on which dummies were placed, which may attract predators, and perhaps the color of the modelling clay. Survival of a dummy appeared to be unaffected by its size or height of placement (logistic regression: length Wald=0.73 & p=0.39, height Wald=0.54 & p=0.46).

That invertebrates appeared the most prevalent caterpillar predators seems typical for the understory of lowland tropical forest (Tvardikova & Novotny 2012), including sub-montane forest in Uganda (Molleman *et al.* submitted). In contrast, birds are dominant caterpillar predators in temperate regions and montane tropical forest (Remmel *et al.* 2009,Tvardikova & Novotny 2012). The relative contributions of predator classes to adult mortality is harder to compare.

2. Decomposer fauna: (a) termite mount, (b), termite mount (c), the only long-horned beetle observed, (d) ant attacking a termite, (e) termites gathering dry leaves, (f) (tenebrionid?) beetles and (g) millipedes grazing fungus from a dead log. Photos: Freerk Molleman
2. Afbraakfauna: (a) termieten heuvel, (b) termieten heuvel (c), de enige waargenomen boktor, (d) mier die een termiet aanvalt, (e) termieten die droge bladeren verzamalen, (f) kevers (Tenebrionidae?) en (g) miljoenpoten die schimmel grazen van een dode boomstam.

3. Damaged insects. (a) *Euriphene coerulea/simplex* (underside would be needed for identification) and (b) *Euphaedra harpalyce* with wing surface missing in a shape that suggests lizard attack and (c) a grasshopper with one of its jumping legs missing. Photos: Freerk Molleman
3. Beschadigde insecten. (a) *Euriphene coerulea/simplex* (onderzijde nodig voor determinatie) en (b) *Euphaedra harpalyce* die vleugeloppervlak missen in de vorm van de bek van een hagedis, en (c) een sprinkhaan die een achterpoot mist.

4. (a) Whip spider (*Damon medius* (Herbst)?) eating a winged termite, and large true spiders, (b) *Nephila* sp. and (c) *Argiope* sp. Photos: Freerk Molleman
4. (a) Zweepspin (*Damon medius* (Herbst)?) die een gevleugelde termiet eet, en grote echte spinnen (b) *Nephila* sp. en (c) *Argiope* sp.



5. Examples of dummy caterpillars with inferences on predator identity. (a) Dummy habitus with ants (1=the cut tip of the leaf), (b) dummy with damage by both ants and a wasp (2=the fussy damage of ants, 3 = the paired wasp mandible prints at the characteristic position), (c) dummy probably attacked by a wasp (4 = paired marks in the typical position and 5 = further sculpting work by the wasp or perhaps a small mammal), and (d) dummy attacked by small mammal (6 = incisor marks). Photos: Freerk Molleman
5. Voorbeelden van neprupsen met interpretatie. (a) Dummy habitus met mieren (1=het afgeknipte puntje), (b) neprups met schade door mieren en een wesp (2=de wollige schade van mieren, 3 = de gepaarde kaak-indrukken van en wesp op de karakterstieke positie, (c) neprups die waarschijnlijk was aangevallen door een wesp (4 = gepaarde indrukken op de karakterestieke positie, en 5 = verdere schade door een wesp of wellicht een klein zoogdier), en (d) neprups waaraan een klein zoogdier geknaagt heeft (6 = voortand sporen).

Butterflies during the dry season

The abundance of butterflies was fair given the timing of the visit (dry season) which may coincide with low butterfly abundance and species richness in West Africa (Aduse-Poku *et al.* 2012). At least some species were breeding: many individuals were freshly eclosed, a mating pair was observed, and caterpillars of butterfly species of the genera *Cymothoe*, *Pseudoneptis*, *Acraea* s.l., and an Adoliadine (*Euphaedra* c.s.) were found, including *Cymothoe althea* (Cramer) for which no caterpillar observations have been published before (figure 6). In addition, there were caterpillars of moths of the families Geometridae, Noctuidae, and a Lymantriidae. This indicates that at least some Lepidoptera continue breeding (and thus have no reproductive diapause) despite the lack of rain during the dry season. Perhaps on Tiwai, water reserves in the soil connected to the river and from the permanent evaporation-condensation from the river permit plants to continue growing during the dry season. Partly due to a lack of diapause, butterfly abundance could well be only mildly seasonal in this region as in other tropical forests (Grøtan *et al.* 2014, Grøtan *et al.* 2012, Valtonen *et al.* 2013), despite a very wet and a very dry season each year.

6. Butterflies reproducing during the dry season. (a) *Cymothoe jodutta* caterpillar on an Achariaceae, (b) *C. althea* caterpillars on an Achariaceae (new to science), (c) mating *C. althea*, (d) *Pseudoneptis bugandensis* caterpillar, (e) Acraeid caterpillar, and (f) eclosing *Acraea camaena*. Photos: Freerk Molleman

6. Vlinders die zich voortplanten tijdens het droge seizoen. (a) *Cymothoe jodutta*-rups op een Achariaceae, (b) ruspen van *C. althea* op een Achariaceae (nieuw voor de wetenschap), (c) parende *C. althea*, (d) rups van *Pseudoneptis bugandensis*, (e) rups van Acraeid, en (f) een net ontpopte *Acraea camaena*.

7. Examples of butterfly species. (a) *Acraea camaena*, (b) *Hallelesis halyma*, (c) *Cymothoe hartigi* Belcastro female, (d) *Tagiades flesus*, (e) *Bebearia mandinga/oxione* (underside would be needed for identification) male, (f) *Euriphene veronica* male. Photos: Freerk Molleman

7. Voorbeelden van vlindersoorten. (a) *Acraea camaena*, (b) *Hallelesis halyma*, (c) vrouwtje van *Cymothoe hartigi*, (d) *Tagiades flesus*, (e) mannetje van *Bebearia mandinga/oxione* (onderzijde nodig voor determinatie), (f) mannetje van *Euriphene veronica*.

Table 1. Species list of butterfly species encountered on Tiwai, Sierra Leone, 12-16 and 20-23 February 2014.
Tabel 1. Soortenlijst van dagvlinders die zijn waargenomen op Tiwai, Sierra Leone, 12-16 en 20-23 februari 2014.

1. *Papilio chrapkowskoides nurettini* Koçak, 1983
2. *Papilio cyproeofila* Butler, 1868
3. *Papilio cynorta* Fabricius, 1793
4. *Leptosia alcesta* (Stoll, [1782])
5. *Leptosia medusa* (Cramer, 1777)
6. *Eurema hecabe solifera* (Butler, 1875)
7. *Belenois calypso* (Drury, 1773)
8. *Mylothris chloris* (Fabricius, 1775)
9. *Pentila petreia* Hewitson, 1874
10. *Telipna acraea* (Westwood, [1851])
11. *Tetrarhanis symplocus* Clench, 1965
12. *Epitolina melissa* (Druce, 1888)
13. *Oxylides faunus* (Drury, 1773)
14. *Hypolycaena clenchi* Larsen, 1997
15. *Deudorix galathea* (Swainson, 1821)
16. *Euchrysops malathana* (Boisduval, 1833)
17. *Euchrysops osiris* (Hopffer, 1855)
18. *Thermoniphas micylus* (Cramer, 1780)
19. *Amauris niavius* (Linnaeus, 1758)
20. *Melanitis leda* (Linnaeus, 1758)
21. *Bicyclus evadne* (Cramer, 1779)
22. *Bicyclus dorothea* (Cramer, 1779)
23. *Bicyclus sandace* (Hewitson, 1877)
24. *Bicyclus martius* (Fabricius, 1793)
25. *Hallelesis halyma* (Fabricius, 1793)
26. *Charaxes lycurgus* (Fabricius, 1793)
27. *Junonia sophia* (Fabricius, 1793)
28. *Junonia terea* (Drury, 1773)
29. *Kallimoides rumia* (Westwood 1850)
30. *Hypolimnas anthedon* (Doubleday, 1845)
31. *Hypolimnas dinarcha* (Hewitson, 1865)
32. *Hypolimnas misippus* (Linnaeus, 1764)
33. *Hypolimnas salmacis* (Druce, 1773)
34. *Protogoniomorpha parhassus* (Drury, 1782)
35. *Pseudacraea eurytus* (Linnaeus, 1758)
36. *Pseudacraea semire* (Cramer, 1779)
37. *Pseudoneptis bugandensis ianthe* Hemming, 1964
38. *Mesoxantha ethosea* (Drury, 1782)
39. *Harma theobene* Doubleday, 1848
40. *Cymothoe jodutta* (Westwood, 1850)
41. *Cymothoe althea* (Cramer, 1776)
42. *Cymothoe hartigi* Belcastro, 1990
43. *Neptis nemetes* Hewitson, 1868
44. *Neptis alta* Overlaet, 1955
45. *Neptis troundi* Pierre-Baltus, 1978
46. *Catuna angustatum* (Felder & Felder, 1867)
47. *Euryphura chalcis* (Felder & Felder, 1860)
48. *Euriphene veronica* (Stoll, 1780)
49. *Euriphene coerulea* Boisduval, 1847
50. *Euriphene simplex* (Staudinger, 1891)
51. *Euriphene amicia gola* Fox, 1965
52. *Euriphene doriclea* (Drury, 1782)
53. *Bebearia zonara* (Butler, 1871)
54. *Bebearia cocalia* (Fabricius, 1793)
55. *Bebearia phantasina* (Staudinger, 1891)
56. *Bebearia maledicta* (Strand, 1912)
57. *Bebearia laetitia* (Plötz, 1880)
58. *Bebearia cutteri harleyi* (Fox, 1968)
59. *Euphaedra medon* (Linnaeus, 1763)
60. *Euphaedra xypete* (Hewitson, 1865)
61. *Euphaedra diffusa albocoerulea* Hecq, 1976
62. *Euphaedra ceres* (Fabricius, 1775)
63. *Euphaedra phaethusa aurea* Hecq, 1983
64. *Euphaedra harpalyce* (Cramer, 1777)
65. *Euptera zowa* Fox, 1965
66. *Acraea bonasia* (Fabricius, 1775)
67. *Acraea serena* (Fabricius, 1775)
68. *Acraea egina* (Cramer, 1775)
69. *Acraea camaena* (Drury, 1773)
70. *Acraea quirina* (Fabricius, 1781)
71. *Acraea alcinoe* Felder & Felder, 1865
72. *Acraea epaea* (Cramer, 1779)
73. *Tagiades flesus* (Fabricius, 1781)
74. *Celaenorrhinus leona* Berger, 1975
75. *Calleagris lacteus* (Mabille, 1877)
76. *Cerathrichia phocion* (Fabricius, 1781)
77. *Teniorhinus ignita* (Mabille, 1877)
78. *Pardaleodes incerta* (Aurivillius, 1912)
79. *Osmodes laronia* (Hewitson, 1868)
80. *Melphina malthina* (Hewitson, 1876)

Butterfly biodiversity

West-Africa basically covers the Guinean biogeographical sub-region of the Congolian region (Linder *et al.* 2012) with many West-African endemic butterflies at specific and sub-specific level (Larsen 2005). The butterfly fauna of Gola Rainforest National Park and the wider Gola forest area, including that of Gola National Forest in Liberia recently has been assessed, leading to a prediction of more than 700 species, and hosting almost 50% of all butterfly species endemic to the area west of the Dahomey Gap (Safian 2009, 2012). Therefore, it is reasonable to expect that 400-500 species also occur on Tiwai. With limited time and equipment, only a small proportion of the butterfly fauna was encountered (80 species, tabel 1). Even *Cymothoe hartigi* (figure 7) a Liberian sub-region endemic butterfly described from Tiwai in 1990 was observed, but none of the butterfly species recently described from Gola Rainforest National Park was observed (*Pseudopontia gola* Safian & Mitter, *Neurellipes gola* Safian, and *Euriphene taigola* Sáfián & Warren-Gash). There are probably still new butterfly species awaiting discovery on Tiwai. Widely distributed species were also observed (e.g. *Melanitis leda*, *Harma theobene* and *Kallimoides rumia*), including some that look very different from East African populations but are regarded as the same species (e.g. *Euphaedra harpalyce*).

Conclusion

Tiwai is a dangerous place for insects, but a heaven for entomologists. We hope that the rare pieces of natural habitat in West Africa such as on Tiwai will be conserved together with their rich fauna, and we recommend you to visit to admire or study it.

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Samenvatting

Predatie op insecten op Tiwai, Sierra Leone

Tiwai is een bebost eiland in de rivier de Moa in het oosten van Sierra Leone, vlakbij het Gola regenwoud. Een bijzonder aspect van het eiland is het ontbreken van *Dorylus*-soorten, oftewel safarimieren, die doorgaans belangrijke predatoren zijn, zeker van termieten. Die laatste zijn door het ontbreken van de mieren dan ook zeer algemeen en zorgen voor snelle afbraak van droge bladeren. Verder sprongen de spinachtigen in het oog, waaronder vervaarlijk ogende zweepspinnen (Amblypygi). Veel vlinders en sprinkhanen vertoonden sporen van predatie, met name in de vorm van een hagedissenbek. Rupsen gemaakt van modelklei (neprupsen) werden gebruikt om inzicht te krijgen in predatie ter plekke. Schade aan de neprupsen suggereert een dagelijkse predatiedruk van wel 50%. Dit werd voornamelijk veroorzaakt door mieren en wespen, en niet door vogels. Ondanks dat het de droge tijd was, maakten veel vlinders een jonge indruk en er zijn ook rupsen waargenomen, waaronder de nog niet bekende ruspen van *Cymothoe althea*. Er zijn 80 vlinder dagvlindersoorten waargenomen, van de ongeveer 450 die lokaal verwacht mogen worden. Hopelijk kan dit rijke gebied behouden blijven en kunnen natuurliefhebbers en entomologen nog vaak van de aanwezige faciliteiten profiteren.

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