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Assessing the Influence of Bird's Nest Ferns (*Asplenium* spp.) on the Local Microclimate across a Range of Habitat Disturbances in Sabah, Malaysia

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Abstract. Epiphytes can influence their local microclimate by altering the evaporative water loss and temperature around them and therefore may affect the distribution and species composition of micro-fauna associated with them. In this study, the authors investigate for the first time the influence of epiphytes on microclimate across a range of habitat disturbances. Temperature and relative humidity were recorded during a 24-hour period at locations in the immediate vicinity of the epiphytic bird's nest fern (*Asplenium* spp.) and at control locations (with no ferns present) in areas of primary forest, logged forest, and oil palm plantation in Sabah, Malaysia. Bird's nest ferns reduced the temperature variation during a 24-hour period compared to control locations in all three habitats and also reduced the mean temperature in oil palm plantations. Control locations in oil palm plantations had a higher temperature variation during a 24-hour period compared to control locations in the primary and logged forests. This, however, was not the case at fern locations, where temperature variation was not significantly different in the three habitats. The role of bird's nest ferns in moderating the microclimate in their local area is discussed with reference to possible effects on the micro-fauna, the influence of accelerating habitat conversion, and predicted climate change in Southeast Asia.

Key words: bird's nest fern, *Asplenium,* epiphytes, microclimate, habitat change, oil palm

Introduction

Epiphytes alter their local microclimate by reducing the evaporative water loss and temperature variation of an area (Freiberg 2001, Stuntz et al. 2002a). Microclimate, important in determining the micro-fauna of a forest habitat, is one of the major factors that drive faunal changes following habitat disturbance (e.g., McNeely 1994, Murcia 1995, Ozanne et al. 1997, Didham 1997, Didham et al. 1998, Didham & Lawton 1999, Chung et al. 2000). The role of epiphytes as natural "air-conditioning units" (Stuntz et al. 2002a) therefore may be important in determining the distribution of micro-fauna in the environment. Such a role may be particularly marked in the forest canopy, where epiphytes could act as refuges for those species that are unequipped to deal with the surrounding harsh environmental conditions (Richardson 1999, Stuntz et al. 2002b, Madigosky 2004). The modifying effect of epiphytes on microclimate may be equally important in degraded habitats, where conditions normally associated with the canopy occur at ground level.

Southeast Asia has one of the highest rates of deforestation of any tropical biome (Sodhi et al. 2004). In Sabah, Malaysia, the reduction in forest cover has been largely the result of a rapid expansion of agricultural areas, particularly oil palm plantations, which now cover some 15.2% of the land area (Teoch et al. 2001). Research into management strategies that reduce some of the detrimental impacts of habitat change is therefore important, as man-managed habitats are likely to continue to expand at the expense of the remaining tracts of forest. Methods of habitat management that benefit arthropods may be particularly important, as arthropods include the most speciose groups of organisms and fulfill many important functions in the ecosystem (e.g., Janzen 1987, Didham et al. 1996).

In this study, we investigated the effect of epiphytic bird's nest ferns (*Asplenium nidus* L. and *Asplenium phyllitidis* D.Don (Holtt. Aspleniaceae)) on the microclimate in their immediate vicinity by comparing the temperature and relative humidity of an area of tree-trunk with a fern to a control area of trunk without a fern during 24-hour periods in primary forest, logged forest, and oil palm plantation. Both *A. nidus* and *A. phyllitidis* are common epiphytes of the Old-World tropics, can reach moderately high densities in the rain forest environment (Ellwood et al. 2002), and house a relatively high density of arthropods in primary forest, logged forest, and oil palm plantations (Ellwood & Foster 2004, Turner 2005). Both species form a cone-like structure of upward-facing leaves that acts to collect falling litter and other debris. The large and often damp root mass at their base is likely therefore to affect the temperature and relative humidity in their local area.

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We also investigated the effect of habitat degradation on microclimate by comparing the temperature and relative humidity in fern and control locations in the three habitats. Thus we were able to determine whether bird's nest ferns influence the changing temperature and humidity between habitats and whether they potentially could be used as management tools to provide refuges of favorable microclimate in plantations. We discuss the implications of our findings with particular reference to the micro-faunal community of oil palm plantations and to the predicted changes in land-use and climate in Southeast Asia.

METHODS

Study Sites

Fieldwork was carried out at Danum Valley Field Center (DVFC), Sabah, Malaysia, located at 4°58′N, 117°42′E, and ca. 170 m (for site details, see Marsh & Greer 1992). The work was conducted from March to April 2003. Primary forest sites were located within the Danum Valley Conservation Area, predominantly composed of lowland, evergreen dipterocarp rain forest (Marsh & Greer 1992). At DVFC, the average rainfall (2785.4 mm per year) is not strongly seasonal (Fox 1978, Walsh & Newbery 1999). Recorded temperatures at DVFC are typical of a wet equatorial climate (Marsh & Greer 1992), with a mean maximum temperature of 31.0°C and a mean minimum temperature of 22.5°C. The mean daily relative humidity for the site is 94.6% at 08:00 hours and 72.2% at 14:00 hours (courtesy of the DVFC Hydrology project). Logged forest sites were located within an area of forest that was logged in 1988 using a modified uniform system (Whitmore 1984). The site, located only 4 km east of DVFC, therefore has a very similar climate to that of the field center.

Oil palm plantation sites were located within Sebrang Estate (5°02′N, 118°35′E, altitude ca. 150 m), an area of oil palm plantation that is owned and managed by Borneo Samudera. This site is about 96 kilometers from DVFC and about four kilometers from the Tabin Wildlife Reserve. At Tabin the rainfall averages between 1500–3000 mm per year, and is not strongly seasonal. Recorded temperatures in the reserve range from a mean maximum temperature of 32.0°C to a mean minimum temperature of 22°C. Therefore the local climate at the oil palm sites is comparable with that of the primary and logged forest. It was necessary to choose sites so far from the field center, because oil palm plantations closer to DVFC were small in area with young trees and therefore not representative of a mature oil palm plantation.

Conversion to oil palm plantation involves clear felling of the existing forest, drying, and burning. Sebrang oil palm estate is a mosaic of areas of different aged palms, with planting dates ranging from 1974–2002. After establishment, oil palm plantations are intensively managed (Teo 2000) often including the removal of bird's nest ferns as they are thought to reduce harvest efficiency (Piggott 1996). However, this is not part of the management practice in Sebrang Estate (Sebrang Estate Manager pers. comm.), making it an excellent study site in which to investigate the effect of bird's nest ferns on the plantation ecosystem. To minimize heterogeneity and to ensure that sites were representative of a mature oil palm plantation, we chose sites which had been planted between 1984 and 1988.

Selection of Ferns

In each of these three habitat types, twenty transects of 100 meters by 20 meters were surveyed for ferns growing at heights of up to 15 m. In addition several of the existing trail systems in the primary and logged forest were walked and additional ferns recorded. Ferns were found to be abundant in all habitats with a mean of 90 ferns per hectare found in the primary forest, 53 ferns per hectare in the logged forest, and 117 ferns per hectare in the oil palm plantation. Ferns in the primary and logged forest were exclusively *A. phyllitidis* and those in the oil palm plantation exclusively *A. nidus.* However, as both species have a similar structure and form a comparable microhabitat, we decided that a comparison between them was valid. From all recorded ferns of intermediate size (60–90 cm maximum diameter of leaves), at an accessible height (less than 8 meters) and on large trees (30–60 cm diameter at breast height) a random subset of six were chosen from each habitat. These were selected to maximize the comparability between ferns and habitats and allow easy access with ladders to set up the recording apparatus. The sampling protocol thus represents a stratified-random design (Sokal and Rohlf 1995). At each sample site, we selected a nearby tree of a similar diameter, but with no fern, to act as a control.

Experimental Setup

We set up data loggers (LOGIT Data-Meter1000), one on the trunk with a fern and one on the control area of trunk without a fern, so that they were easily accessible by ladder.

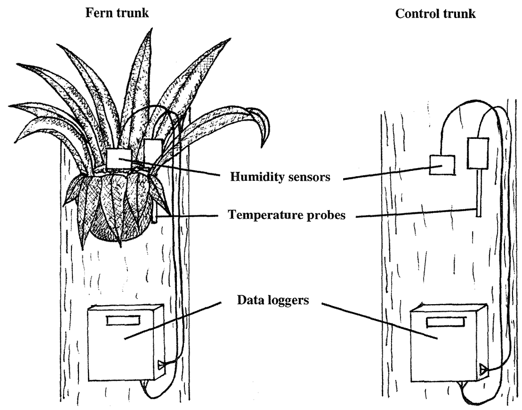

FIGURE 1. Temperature and humidity probes were placed as close to the base of the fern's leaves as possible and on a comparable area of a neighboring tree that did not contain a fern.

Each data logger bore separate sensors for measuring the temperature (HiTemp probe capable of measuring −10 to +110°C), and the relative humidity (HumiPro sensor covering a range 1–100% RH). We fixed the temperature probes so that they touched the side of the fern root mass or a comparable area of trunk on the control tree. We fixed the humidity sensors as close to the base of the fern's leaves as possible and on a comparable area of trunk on the control tree (FIGURE 1). Owing to a limited number of data loggers and logistic constraints, it was only possible to record for 24 hours at six different locations in each habitat. We consider this replicate size sufficient to determine the potential use of bird's nest ferns as management tools, a view that is substantiated by our clear results. Data loggers at fern and control locations were run concurrently at each site.

Owing to the sensitivity of the equipment, several of the relative humidity sensors failed to function properly so the number of replicates at each site was reduced from six to five for the relative humidity readings. From the recorded data we calculated four microclimatic parameters for each of the fern and control locations; the mean temperature over 24 hours, the temperature variation over 24 hours, the mean relative humidity over 24 hours, and the humidity variation over 24 hours.

Modes of Data Analysis

Paired *t*-tests were used to test for differences in the calculated parameters between fern and control locations within habitats. Significance levels were corrected for the number of tests carried out on each measured variable using sequential Bonferroni corrections. Repeated measures ANOVA, including an interaction term, were used to test whether the microclimate in fern and control locations changed in the same way as a result of habitat alteration. We found that there was a significant interaction in temperature between fern and control locations across the three habitats. Therefore one-way ANOVA were used to assess the effect of habitat change on the mean temperature and temperature variation for fern and control locations separately. There was no significant interaction for relative humidity between fern and control locations across the three habitats. Therefore repeated measures ANOVA were used to assess the effect of habitat change on the mean humidity and humidity variation for fern and control locations together. Fisher's Pairwise Comparisons (post hoc tests) were used to determine which pairs of habitats were significantly different from each other. Where necessary, data were transformed to meet assumptions of normality.

RESULTS

Ferns vs. Control Areas

Fern mean temperature was significantly lower than control mean temperature in the oil palm plantation but not significantly different in either the primary or logged forest. Fern temperature variation was significantly lower than control temperature variation in all three habitats (TABLE 1, FIGURE 2). Fern and control locations were not significantly different from each other in mean relative humidity or humidity variation in any of the habitat types (TABLE 1, FIGURE 3).

Microclimate Differences

Mean temperature was significantly higher at both fern and control locations in the oil palm plantation compared to the primary and logged forest. Temperature in the latter two habitats did not differ significantly from each other. Control temperature variation was also significantly higher in the oil palm plantation than in the primary and logged forest. Fern temperature variation, in contrast, was not significantly different across the three habitats (TABLE 2, FIGURE 2).

Mean relative humidity was significantly different across all three habitats, with the primary forest having the highest mean humidity, the logged forest the second highest, and the oil palm the lowest. Humidity variation was significantly higher in the oil palm plantation than in the primary and logged forest, which did not differ significantly from each other (TABLE 2, FIGURE 3).

TABLE 1. Paired *t*-tests of mean temperature, temperature variance, mean humidity, and humidity variance at fern and control locations across the three habitats. Significant differences after sequential Bonferroni correction are given in bold.

Habitat	Microclimatic parameter	*N*	*t*	*P*
Primary forest	Mean temperature	6	−0.18	0.864
	Temperature variance	6	20.56	**0.011**
	Mean humidity	5	−1.18	0.302
	Humidity variance	5	1.19	0.298
Logged forest	Mean temperature	6	−1.82	0.128
	Temperature variance	6	−3.26	**0.022**
	Mean humidity	5	0.38	0.721
	Humidity variance	5	−1.31	0.26
Oil palm plantation	Mean temperature	6	−5.63	**0.002**
	Temperature variance	6	−0.98	**<0.001**
	Mean humidity	5	−0.36	0.735
	Humidity variance	5	1.06	0.348

Note: N = number of replicates, t = t-value, P = P-value for test.

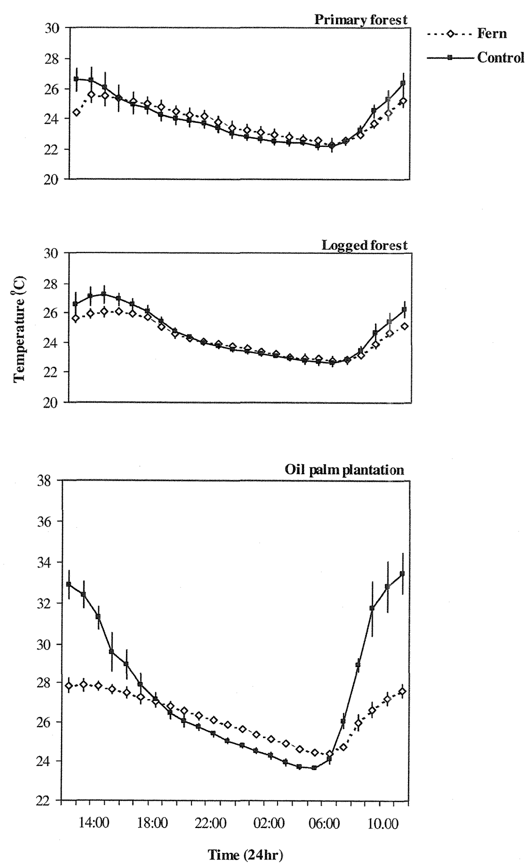

FIGURE 2. Mean hourly temperature (°C) during a 24-hour period at fern and control locations in primary forest, logged forest, and oil palm plantation. Standard error bars are shown (N = 6).

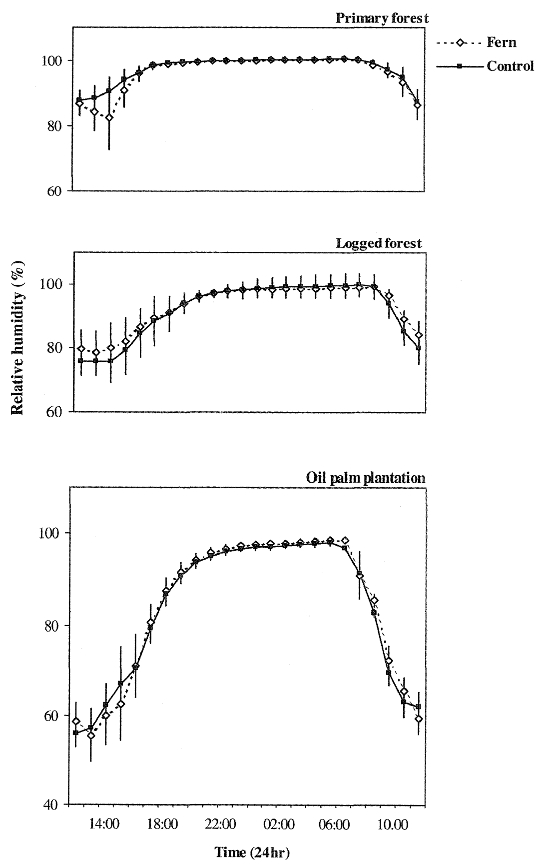

FIGURE 3. Mean hourly relative humidity (%) over a 24-hour period at fern and control locations in primary forest, logged forest, and oil palm plantation. Standard error bars are shown (N = 5).

TABLE 2. ANOVA for the calculated microclimatic variables across the three habitats. One-way ANOVA are presented for differences between habitats for mean temperature and temperature variance across the three habitats. Repeated measures ANOVA are presented for differences in mean relative humidity and humidity variance at fern and control locations across the three habitats. Significant differences are given in bold.

Microclimatic variable	*N*	F	*P*
Fern mean temperature	6	29.21	**<0.001**
Control mean temperature	6	48.76	**<0.001**
Fern temperature variance	6	0.31	0.737
Control temperature variance	6	12.91	**0.001**
Mean relative humidity	5	9.123	**0.004**
Humidity variance	5	11.05	**0.002**

Note: N = number of replicates, F = degrees of freedom, P = P-value for test.

DISCUSSION

Bird's nest ferns reduced the temperature variation during a 24-hour period in their immediate vicinity in all three habitats. In the oil palm plantation, they also reduced the mean temperature compared to control locations. Ferns did not, however, appear to have any effect on the relative humidity of their local area, as this was not significantly different between fern and control locations in any of the three habitats. Conversion of forest to plantation had dramatic effects on all aspects of microclimate at control locations. The mean temperature and temperature variation was higher, the mean humidity lower, and the humidity variation higher in oil palm plantations compared to primary and logged forest. Owing to the effect of fern presence, however, no significant difference occurred in temperature variation across the three habitats in the immediate vicinity of bird's nest ferns.

The effect of bird's nest ferns on the temperature regime may influence the resident micro-faunal community in and around ferns as well as migration into and out of ferns. In oil palm plantations, this effect may be particularly dramatic, as the microclimate is relatively hot, dry, and unstable compared to microclimate in the primary and logged forest, thus creating an unfavorable environment for micro-fauna. For this reason, ferns possibly may act as refuges for micro-fauna that would be otherwise unable to survive in plantations. Another possibility is that microfauna might actively migrate into the epiphytes to avoid high temperatures (Richardson 1999) that are found in plantations during mid-day (FIGURE 2). Such a beneficial effect may explain the relatively high density of arthropods found in bird's nest ferns in the upper canopy of primary forest (Ellwood & Foster 2004) and in the lower canopy across all three habitats (Turner 2005).

The role of bird's nest ferns in providing a relatively stable temperature regime may render them important management tools in plantations and other degraded landscapes. By leaving ferns or by actively introducing them into plantations, managers could provide a potential refuge for vulnerable arthropod species and therefore may increase the numbers of arthropods present in an area. Such a strategy may have beneficial impacts on biodiversity as well as on the successful functioning of the ecosystem (depending on the particular species and functional guilds occupying the ferns and their level of migration into the surrounding ecosystem). In Sebrang Estate, the ferns were present at an extremely high density (a mean of 117 plants per ha) suggesting that such a management strategy would be easy to implement, as ferns appear to establish readily and survive easily in plantations.

Deforestation continues at an unprecedented rate both in Malaysia and the rest of the tropics (Sodhi et al. 2004), which means that developing management strategies to maintain biodiversity and ecosystem function in degraded landscapes has never been more important. Furthermore, in the future it is likely that the effects of habitat conversion will be compounded by changes in the world's climate. In Southeast Asia the climate is generally predicted to get hotter (IPCC 2005). Diurnal fluctuations in the temperature regime, therefore, are likely to become more severe. This may be especially the case in landscapes such as oil palm plantations, where the natural buffering capacity provided by the forest canopy no longer exists. The function of bird's nest ferns to provide pockets of stable temperature in oil palm plantations may take on an increasingly important role in maintaining arthropod populations in the future. This study represents a preliminary attempt to assess the role of bird's nest ferns in controlling their local microclimate, yet results demonstrate that ferns have a potentially important part to play in plantation management.

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Literature Cited

Chung, A.Y.C., P. Eggleton, M.R. Speight, P.M. Hammond, and V.K. Chey. 2000. The diversity of beetle assemblages in different habitat types in Sabah, Malaysia. Bulletin of Entomological Research 90: 475–496.

Didham, R.K. 1997. An overview of invertebrate responses to forest fragmentation. Pp. 303–320 *in* A.D. Watt, N.E. Stork, and M.D. Hunter, eds. Forests and Insects. Chapman and Hall, London.

Didham, R.K. and J.H. Lawton. 1999. Edge structure determines the magnitude of changes in microclimate and vegetation structure in tropical forest fragments. Biotropica 31(1): 17–30.

Didham, R.K., J. Ghazoul, N.E. Stork, and A.J. Davis. 1996. Insects in fragmented forests: a functional approach. Trends Ecol. Evol. 11(6): 255–260.

Didham, R.K., P.M. Hammond, J.H. Lawton, P. Eggleton, and N.E. Stork. 1998. Beetle responses to tropical forest fragmentation. Ecol. Monogr. 68 (3): 255–260.

Ellwood, M.D.F. and W.A. Foster. 2004. Doubling the estimate of invertebrate biomass in a rainforest canopy. Nature 429: 549–551.

Ellwood, M.D.F., D.T. Jones, and W.A. Foster. 2002. Canopy ferns in lowland dipterocarp forest support a prolific abundance of ants, termites, and other invertebrates. Biotropica 34(4): 575–583.

Fox, J. 1978. The natural vegetation of Sabah, Malaysia. 1. The physical environment and classification. Trop. Ecol. 19(2): 218–239.

Freiberg, M. 2001. The influence of epiphyte cover on branch temperature in a tropical tree. Pl. Ecol. 153(2): 241–250.

IPCC (Intergovernmental Panel on Climate Change). 2005. The Regional Impacts of Climate Change: An Assessment of Vulnerability. An IPCC Special Report. Online access August 2005. http://www.grida.no/climate/ipcc/regional/289.htm

Janzen, D.H. 1987. Insect diversity of a Costa Rican dry forest: why keep it and how? Biol. J. Linn. Soc. 30: 343–356.

Marsh, C.W. and A.G. Greer. 1992. Forest land use in Sabah, Malaysia: an introduction to Danum Valley. Philos. Trans. Roy. Soc. B 335: 331–339.

McNeely, J.A. 1994. Lessons from the past—forests and biodiversity. Biodivers. Conserv. 3(1): 3–20.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. TREE. 10(2): 58–62.

Ozanne, C., C. Hambler, A. Foggo, and M.R. Speight. 1997. The significance of edge effects in the management of forest for invertebrate biodiversity. Pp. 534–550 *in* N.E. Stork, J. Adis, and R.K. Didham, eds. Canopy Arthropods. Chapman and Hall, London.

Piggott, A. 1996. Ferns of Malaysia in Colour. Tropical Press, Sdn Bhd, Malaysia.

Richardson, B.A. 1999. The bromeliad microcosm and the assessment of faunal diversity in a neotropical forest. Biotropica 31(2): 321–336.

Sodhi, N., L. Koh, B. Brook, and P. Ng. 2004. Southeast Asian biodiversity: an impending disaster. Trends Ecol. Evol. 19(12): 654–660.

Sokal, R. and F. Rohlf. 1995. Biometry: The Principles and Practice of Statistics in Research. W.H. Freeman and Company, 3rd ed. New York.

Stuntz, S., U. Simon, and G. Zotz. 2002a. Rainforest air-conditioning: the moderating influence of epiphytes on the microclimate in tropical tree crowns. Int. J. Biometeorol. 46(2): 53–59.

Stuntz, S., C. Ziegler, U. Simon, and G. Zotz. 2002b. Diversity and structure of the arthropod fauna within three canopy epiphyte species in central Panama. J. Trop. Ecol. 18: 161–176.

Teo, L. 2000. Mechanization in oil palm plantations: achievements and challenges. Oils and Fats International Congress and Exhibition 2000, Putra World Trade Centre, Kuala Lumpur, Malaysia.

Teoch, C.H., A. Ng, C. Prudente, C. Pang, and J. Tek Choon Yee. 2001. Balancing the need for sustainable oil palm development and conservation: the Lower Kinabatangan Floodplains experience. Strategic Directions for the Sustainability of the Oil Palm Industry, Incorporated Society of Plantations National Seminar, Kota Kinabalu, Sabah, Malaysia.

Turner, E.C. 2005. "The ecology of the Bird's Nest Fern (*Asplenium* spp.) in unlogged and managed habitats in Sabah, Malaysia." Ph.D. diss., Univ. Cambridge, Cambridge, UK.

Walsh, R. and D. Newbery. 1999. The ecoclimatology of Danum, Sabah, in the context of the world's rainforest regions, with particular reference to dry periods and their impacts. Philos. Trans. Roy. Soc. B. 354: 1869–1883.

Whitmore, T.C. 1984. Tropical Rain Forests of the Far East, 2nd ed. Clarendon Press, Oxford, UK.