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Ecological aspects of endemic plant populations on Klang Gates quartz ridge, a habitat island in Peninsular Malaysia

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Abstract The population characteristics of *Aleisanthia rupestris* (Rubiaceae), *Eulalia milsumii* (Poaceae) and *Ilex praetermissa* (Aquifoliaceae), endemic to the Klang Gates quartz ridge north-east of Kuala Lumpur, Malaysia were studied. Whereas their narrow, natural distribution within species-poor communities in drier, less fertile conditions on the ridge can be explained by the selection of adaptive traits and reduced plant competition compared to the more extensive, surrounding richer forest communities on more fertile soils, recent disturbances altering site conditions have diminished their populations. Populations were compared among various terrain and site conditions (ridge spine or rockface, exposed or sheltered) on less disturbed and very disturbed portions of the ridge. *A. rupestris* was scarce or absent in sites shaded by taller vegetation, probably an inability to establish in conditions associated with deeper soil development. *I. praetermissa* appeared specially adapted to rockfaces where unstable substrates and poor soil development may restrict competition with other plants. All three species were adversely affected to varying degrees by disturbance and altered site conditions; invasive, fast-spreading, thicket-forming, weeds in disturbed sites on gentler terrain on the ridge spine appear to be especially detrimental to *A. rupestris* and *E. milsumii* establishment. Although the larger plant size of *I. praetermissa* compared to the other two species could mean it is less likely to be shaded out by invading weedy species, residual adults as well as new regeneration may not adapt to changed site conditions following disturbance. Distinguishing between adaptation (of both adults and new regeneration) to changed environmental conditions following disturbance, and ability in competing for space and resources against invading weedy species, is relevant.

Keywords Conservation biology · Endemic plants · Habitat islands · Invasives · Malaysia · Rare plants · Quartz ridges · Tropical biodiversity

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Introduction

The Klang Gates quartz ridge system just outside the north-eastern part of the city of Kuala Lumpur and within the state of Selangor Darul Ehsan in Peninsular Malaysia, is over 14 km long and reaches up to about 380 m high. The narrow wall-like formation of this quartz reef (Figs. 1, 2) is due to crystallisation of the quartz solution that infilled a large fault in the Main Range granite, with the present feature revealed when the surrounding weathered material eroded away. This ridge is the most prominent of a series of such ridges in this part of Peninsular Malaysia.

Current collecting indicates that inventory of the plant life on this ridge remains incomplete since the earlier listings by Ridley (1922) (21 species) and Henderson (1928) (265 species), and a later enumeration by Kiew (1982) (175 species). Many records do not distinguish between an occurrence on the quartz ridge proper and one on the abutting (non-quartz) slopes. Five plant species are known only from the quartz ridge (Reid 1951, 1959; Kiew 1982): *Aleisanthia rupestris* (Ridl.) Ridl. (Rubiaceae) (Fig. 3a, b), *Borreria pilulifera* Ridl. (Rubiaceae), *Eulalia milsumii* Ridl. (Poaceae) (Fig. 3c), *Henckelia primulina* (Ridl.) A. Weber (Gesneriaceae), and *Ilex praetermissa* Kiew (Aquifoliaceae) (Fig. 3d).

Fig. 1 The Klang Gates quartz ridge, with regenerated lowland mixed dipterocarp forest to its north (*left* in the picture), part of the Klang Gates reservoir catchment forest, and cultivated land or young secondary forest to the right

Fig. 2 The precipitous south-facing rockface of the ridge, showing a portion much exposed by previous vegetation clearance for cultivation and housing development

Fig. 3 Endemic plant species of the Klang Gates quartz ridge investigated in the present study: *Aleisanthia rupestris*, habit (**a**) and leafy branch (**b**); *Eulalia milsumii* growing in wefts (**c**); *Ilex praetermissa*, fruiting branch (**d**)

Conservation interest in the ridge (Wong et al. 2005) focusses on a number of aspects. The low, species-poor plant community that resembles *kerangas*-type vegetation on thin, poor sandy soils elsewhere in the peninsula (Wong et al. 1987) is here distinctive by the dominance of the trees *Baeckea frutescens* L. (a small tree often 2–4 m high, with 1-several stems and fine needle-leaves; Myrtaceae) and *Rhodoleia championii* Hook.f. (a small tree, commonly 4–8 m high; Hamamelidaceae). This was formerly surrounded by lowland mixed dipterocarp forest, much of which has been transformed by development (Fig. 2). The occurrence of five narrowly distributed endemics in a relatively small area along the ridge emphasises the special nature of habitat islands (Wong 1998), although the impacts of human activities have affected the integrity of the original vegetation after the 1970s (Kiew 1982). The quartz reef, with a craggy ridge spine, cutting through an otherwise low, undulating landscape presents a spectacular geological feature. Trending roughly southwest to northeast, this ridge also forms a natural boundary between the catchment forest for the Klang Gates reservoir to its north and the area transformed by tree plantations and other crops, and housing and road development to its south (Figs. 1, 2). Earlier, the ridge had been established as the Klang Gates Wildlife Sanctuary (130 ha) in 1936, primarily for conservation of the Serow *Naemorhedus sumatrensis* (Bechstein). Presently, the ridge is proposed for inclusion as a special part of the Taman Warisan Selangor (Selangor Heritage Park), declared in 2005, with the intention of better managing its conservation.

The most spectacular part of the ridge is the middle section, about 4–5 km long, just behind the Taman Melawati residential neighbourhood and near to the National Zoo. Here, access is easiest along the southwest part adjacent to a dip in the ridge where the Klang Gates Dam is situated; the northeast part is precipitous and not accessible and has a largely intact vegetation cover at the top. A preliminary survey in August, 2006 found that the

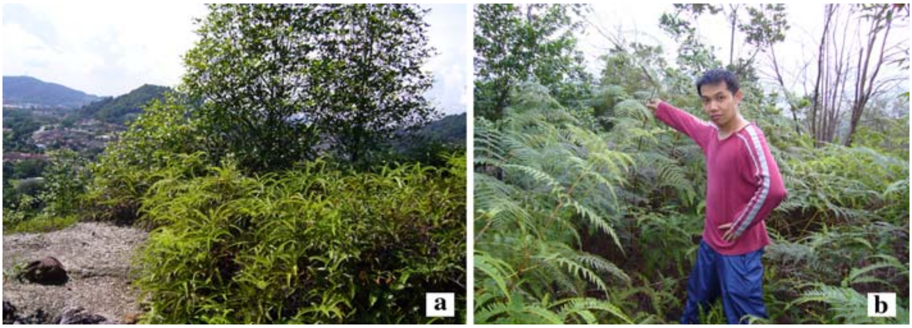

Fig. 4 Weedy species invading disturbed, open sites on the Klang Gates ridge spine: *Dicranopteris linearis*, the *resam* fern (**a**, *left*) and *Pteridium esculentum*, bracken (**b**)

immediate section of the ridge just southwest of the Dam was conspicuously more disturbed than the section farther southwest from this, which is less visited by people because of its distance. For convenience, these portions are simply referred to as the "very disturbed" and "less disturbed" parts of the ridge. Greater impacts on the vegetation in the very disturbed part are a result of trampling, woodcutting, site clearing and burning in the past. Many disturbed patches are colonized by weedy species, including the ferns *Dicranopteris linearis* J. Underw. (Gleicheniaceae) (Fig. 4a) and *Pteridium esculentum* (G. Forst.) Cockayne (Pteridaceae) (Fig. 4b); the grasses *Eriachne pallescens* R.Br., *Imperata cylindrica* L. and *Pennisetum purpureum* Schumach. (Poaceae); and the low woody dicots *Clidemia hirta* (L.) D.Don and *Melastoma malabathricum* L. (Melastomataceae), and *Eupatorium odoratum* L. (Asteraceae). This work considers various ecological aspects of plant conservation on the Klang Gates ridge by comparing some population characteristics of the endemic plants *A. rupestris*, *E. milsumii* and *I. praetermissa* in the very disturbed and less disturbed parts of the ridge.

From general observation, the distribution of *Aleisanthia* and *Eulalia* appeared to be different between the very disturbed and less disturbed portions of the ridge. It appeared that whereas *A. rupestris* still occurred on the very disturbed portion of the ridge, *E. milsumii* was difficult to sight on this portion and only became more conspicuous in the more remote, less disturbed part. Hence, it appears that *E. milsumii* may be highly sensitive to disturbance. In the preliminary survey, *I. praetermissa* was more frequently found in shaded sites along the northern rock face of the ridge, and less so in exposed sites. Thus, it could be expected that *I. praetermissa* prefers sheltered sites along the rock face.

Methods

Site classification

Ridge spine and rockface were recognised as the two main terrain categories. On the ridge spine, exposed sites are those in which the ground is unshaded or scantily shaded by low bushes or herbs, whereas sheltered sites are those lightly shaded by tree cover mostly formed by *B. frutescens* and *R. championii*. For rockfaces, an especially contrasting feature was the largely sheer and less vegetated southern face (Fig. 2), a result of intense exposure

Table 1 Mean irradiance (klux), temperature (°C) and humidity (%) in different conditions on the Klang Gates quartz ridge

Site category	Mean irradiance (klux)	Mean temperature (°C)	Mean humidity (%)
A. Very disturbed exposed ridge spine	98.9	35.2	56.3
B. Less disturbed exposed ridge spine	90.6	36.0	53.0
C. Very disturbed sheltered ridge spine	17.9	33.8	57.5
D. Less disturbed sheltered ridge spine	10.6	29.8	65.0
E. Disturbed exposed rockface (south-facing)	*	35.8	50.2
F. Undisturbed sheltered rockface (north-facing)	**	30.1	57.6

Means are of three readings taken at different sites for each habitat category, obtained between 12.30 p.m. and 2.30 p.m. on a clear sunny afternoon (5 January 2007)

* not recorded but similar to conditions in habitat categories A and B

** not recorded but similar to conditions in habitat categories C and D

after clearance of the original forest on the slopes, as opposed to the shaded and more vegetated northern face, sheltered by intact forest on the slopes there (and which form part of the protected watershed of the Klang Gates reservoir) (Fig. 1). Site categories accessible for study on the ridge top or ridge spine include: (a) exposed sites on the very disturbed ridge portion; (b) exposed sites on the less disturbed ridge portion; (c) sheltered sites on the very disturbed ridge portion; (d) sheltered sites on the less disturbed ridge portion. Rockfaces were distinguished as (e) the disturbed, exposed south-facing side, and (f) the undisturbed, sheltered north-facing side. Conditions present in these sites are represented in Table 1.

Sampling

Reference transects were used for the terrain categories ridge top (along both very and less disturbed portions of the ridge) and rockface (along the south-facing and north-facing sides). For *A. rupestris* (a small shrub) and *E. milsumii* (a grass), 10 replicate 1 × 1 m quadrats were randomly selected for each site category along the transect. In the quadrats, the density and cover of plant species were recorded. The occurrence of *I. praetermissa* (a small tree mostly 3–6 m high) on the rockfaces rather than flatter sites on the ridge spine implied that quadrats could not be used efficiently, so a transect survey was adopted. A 250-m survey transect was followed along the ridge spine, enumerating the number of *Ilex* individuals seen within 50-m intervals, at the uppermost 5-m zone of both the north-facing and south-facing rock faces.

Results

Table 2 summarises the frequency, mean cover and mean density of *A. rupestris*, as well as mean relative cover of *A. rupestris* and other plant species in the different site categories. *A. rupestris* is reasonably common (60% frequency) on both types of rock faces (site categories E and F) compared to all ridge spine categories. On the ridge spine, there was a higher frequency in exposed (A and B) than in the sheltered sites, in which no *A. rupestris* was

Table 2 Frequency, mean cover per quadrat, mean density per quadrat, and mean relative cover (%) of *Alesanthia rupestris* and other plant species in different site categories studied on the Klang Gates quartz ridge

Site category	Frequency of *A. rupestris* (%)	Mean cover per quadrat[a] (%) of *A. rupestris*	Mean density per quadrat[a] of *A. rupestris*	Mean relative cover (%) of *A. rupestris*	Mean relative cover (%) of other plant species
A. Very disturbed exposed ridge spine	20	1.0	0.2	3.2	96.8
B. Less disturbed exposed ridge spine	30	3.3	0.4	9.8	90.2
C. Very disturbed sheltered ridge spine	0	0	0	0	100
D. Less disturbed sheltered ridge spine	0	0	0	0	100
E. Disturbed exposed rockface	60	9.1	0.7	34.4	65.6
F. Undisturbed sheltered rockface	60	6.6	0.8	20.6	79.4

Ten quadrats were sampled for each site category. Mean relative cover of *A. rupestris* is calculated by $[C_A/(C_A + C_N)] \times 100$ where C_A is mean percent cover of *A. rupestris* for all the quadrats sampled in a category and C_N is mean percent cover of all other plant species. This value subtracted from 100 then gives the mean percent relative cover of all other species

[a] Comparisons by *t*-tests indicated that mean covers and mean densities of *A. rupestris* in each of the categories A, B, E and F were significantly higher ($P = 0.05$) than in C or D

recorded. Both mean cover and mean density values were significantly higher (*t*-test, $P = 0.05$) on rockfaces and exposed ridge spine sites compared to sheltered ridge spine sites. A similar relative establishment success in the various sites is reflected in the mean relative cover of *A. rupestris* compared to that of other plant species (Table 2).

The mean density and cover of weedy species per quadrat, and the total number of plant species found in the different site categories is shown in Table 3. The highest number of plant species (34) was found in category A (very disturbed, exposed ridge spine). Mean density and mean cover of weedy species were not significantly different (*t*-test, $P = 0.05$) between A and C (very disturbed, exposed or sheltered ridge spine), B and D (less disturbed, exposed or sheltered ridge spine), or E and F (exposed and sheltered rockfaces). Ridge spine sites and rockfaces also did not necessarily have significantly different weed densities or cover (compare B, D, E and F). However, mean cover of weeds, indicating intense smothering of ground area, was significantly higher in A than in B and D (the less disturbed ridge spine sites), or E (disturbed, exposed rockface).

The frequency, mean cover and mean density of *E. milsumii*, and the mean relative cover of *E. milsumii* and other plant species in the various sites is shown in Table 4. Frequency is highest on the less disturbed exposed ridge spine (site category B), moderately common in the less disturbed sheltered ridge spine (D) and both rockfaces (E, F), and the species was not encountered in very disturbed sites on the ridge spine, whether exposed or sheltered. Its mean relative cover is also highest in site B, the only site where other plant cover is not greater.

The frequency of *I. praetermissa* along the north-facing and south-facing rockfaces is shown in Table 5. The northern face of the ridge had clearly more individuals (19 stems), compared to the southern face (only 1 stem).

Table 3 Mean values of density and cover per quadrat of weedy species and total number of plant species recorded in different site categories on the Klang Gates quartz ridge

Site category	Mean density per quadrat of weedy species	Mean cover per quadrat (%) of weedy species	Total number of plant species recorded
A. Very disturbed exposed ridge spine	1.6	34.1	34
B. Less disturbed exposed ridge spine	0.3	4.9	23
C. Very disturbed sheltered ridge spine	1.2	23.7	26
D. Less disturbed sheltered ridge spine	0.4	5.3	22
E. Disturbed exposed rockface	0.3	2.3	24
F. Undisturbed sheltered rockface	0.7	13.0	26

'Weedy species' are exotic species or those known to spread quickly following disturbances such as fires

Comparisons by *t*-tests indicated that the mean density of weedy species in category A was significantly higher ($P = 0.05$) than in B, D, E or F, and higher in C than E. The mean cover of weedy species in A was also significantly higher than in B, D and E

Discussion

Ecological distribution of *Aleisanthia rupestris*

The similar and relatively high cover and density on both disturbed, exposed and undisturbed, sheltered rockfaces (Table 2: E and F) suggest that neither disturbance nor shading per se could account for significant diminishment in *A. rupestris* populations. On the other hand, the differential distribution (or survival) of this species between exposed sites (whether less or more disturbed) compared to sheltered sites suggests that other factors could be important in discouraging its establishment or commonness within sheltered sites on the ridge spine, that were absent or less severe on the sheltered rockface.

It is not easy to confirm if competition with other plants is an important factor although the mean density and cover of weedy species (Table 3) indicate that weedy species are not less likely to establish well on the rockface or in sheltered sites. An observed physical difference between the sheltered ridge spine sites and the exposed ridge spine sites or rockfaces was the accumulation of organic material and development of a thin soil over the rocks in the former, due to the presence of taller plants (that provide shade and organic material) and a more level terrain (that discourages rapid erosion of accumulated substrate). This implies that rooting characteristics, such as intolerance to a deeper, moister substrate, or increased activity of soil organisms, or root competition with other plants, could restrict *A. rupestris* establishment. These were not specifically investigated, but the inability of *A. rupestris* to spread into the adjacent forest on earth slopes and the limited growth and subsequent death of rooted cuttings in moist sandy or clayey substrates in the botanic garden of the University of Malaya (Zahid 1998) may be indications that such factors operate. However, weedy growth was significant in sites on the very disturbed, exposed ridge spine (Table 3: site category A) and fast-spreading, smothering thickets of *resam* fern (*D. linearis*) or bracken (*P. esculentum*) were found to be common only in disturbed, exposed patches on more level terrain on the ridge spine (Fig. 4). This could help explain the much lower mean relative cover of *A. rupestris* there (Table 2).

Table 4 Frequency, mean cover per quadrat, mean density per quadrat, and mean relative cover (%) of *Eulalia milsumii* and other plant species in the different site categories studied on the Klang Gates quartz ridge

Site category	Frequency of *E. milsumii* (%)	Mean cover per quadrat[a] (%) of *E. milsumii*	Mean density per quadrat[a] of *E. milsumii*	Mean relative cover (%) of *E. milsumii*	Mean relative cover (%) of other plant species
A. Very disturbed exposed ridge spine	0	0	0	0	100
B. Less disturbed exposed ridge spine	80	22.7	1.2	52.6	47.4
C. Very disturbed sheltered ridge spine	0	0	0	0	100
D. Less disturbed sheltered ridge spine	30	12.1	0.5	23.1	76.9
E. Disturbed exposed rockface	30	6.9	0.3	18.7	81.3
F. Undisturbed sheltered rockface	40	23.7	0.4	30.9	69.1

Ten quadrats were sampled for each habitat category. Mean percent relative cover of *E. milsumii* is calculated by $[C_E/(C_E + C_N)] \times 100$ where C_E is mean percent cover of *E. milsumii* for all the quadrats sampled in a category and C_N is mean percent cover of all other plant species. This value subtracted from 100 then gives the mean percent relative cover of all other species

[a] Comparisons by *t*-tests indicated that mean covers of *E. milsumii* in each of the categories B, D, E and F were significantly higher ($P = 0.05$) than in A or C, and higher in B than E. For mean densities, values in B, D, E and F were significantly higher than in A or C, and higher in B than in either E or F

Table 5 Frequency of *Ilex praetermissa* along a 250-m transect sampling the uppermost 5-m zone of rock-faces (both north-facing and south-facing) on the Klang Gates quartz ridge

50-m intervals from origin	North-facing rockface	South-facing rockface
0–50 m	0	1
51–100 m	5	0
101–150 m	5	0
151–200 m	8	0
201–250 m	1	0
	Total 19	Total 1

The north-facing side is adjacent to good regenerated lowland forest and so is more sheltered and possibly less disturbed, compared to the south-facing side, which has little shelter from adjacent vegetation and overlooks orchards established in land formerly cleared of forest

Disturbance and *Eulalia milsumii*

Eulalia milsumii was reasonably common in the less disturbed habitats (whether exposed or sheltered ridge spine (Table 4: site categories B and D) and both rockfaces (E, F), and absent in very disturbed sites. This suggests that it may be, like *A. rupestris*, unable to establish or survive on very disturbed, more gentle terrain where very aggressive smothering weeds are common. Indeed, the mean cover per quadrat of weedy species (Table 3) is highest in the very disturbed sites on the ridge spine (A, C). Unlike *A. rupestris*, *E. milsumii* occurs in sheltered sites, but only in the less disturbed or undisturbed areas. This is also reflected in the mean relative cover of *E. milsumii* compared to other plant species (Table 4).

Ilex praetermissa along the disturbed and undisturbed rockfaces

Ilex praetermissa was surveyed along both (undisturbed, sheltered) north-facing and (disturbed, exposed) south-facing rock faces, the only site categories available for study of this species, an understory small tree not found on the main ridge spine. Its higher frequency along the northern face of the ridge (Table 5), where conditions are cooler and slightly more humid (Table 1), suggests that *I. praetermissa* either preferred conditions along the northern part for establishment, or survived better there (i.e. failed to establish or survive along the south-facing rock face).

Distribution of three endemic species compared

As *A. rupestris* is a small woody shrub, *E. milsumii* is a grass, and *I. praetermissa* a small understorey tree, their possible similarities and differences in distribution are of interest. The restriction of these species to the quartz ridge system here is probably most easily understood in terms of the contrasting environment on such ridges (drier conditions, poorer soil development and site fertility on a rocky outcrop) compared to the original surrounding lowland mixed dipterocarp forest (moister conditions, better soil development and fertility), where there would have been a more intense competition with a greater number of plant species. Plant communities on the quartz ridge are indeed simpler, with fewer species than in mixed dipterocarp forest (Reid 1959; Kiew 1982; Whitmore 1984). The relative intolerance of *A. rupestris* and *E. milsumii* for moister, better developed soils and its ability to thrive in hot, dry, exposed rock crevices appear to be well-selected adaptations for life on a quartz ridge. The apparent preference of *I. praetermissa* for rockfaces and rocky slopes may also be related to reduced competition, as relative slope instability and a rocky substrate present problems for plant establishment, as is also probably true of plants (rheophytes) restricted to the banks and flood zone of swift-flowing streams, where a similar substrate instability exists and the specialized plant diversity is reduced to a suite of well-selected species (Wong 1999).

Apart from their narrow endemism, disturbance (notably clearing, fire and trampling) seems to be the major factor that has impacted the distribution of all three species. *A. rupestris* grows well on both exposed and sheltered rock faces, where it had the highest frequencies recorded. On the ridge spine, *A. rupestris* seems to establish well only in the exposed sites. It appears to be sensitive to weedy growth in very disturbed, less steep sites, and unable to establish well on moister, better developed substrates in tree-sheltered sites. Unlike *A. rupestris*, which persisted in at least some very disturbed sites, *E. milsumii* was absent from all such sites and appears to establish and maintain itself best in less disturbed or undisturbed rock face and ridge spine sites, where the growth of weedy species was relatively less aggressive. *Ilex praetermissa* is more common along the less disturbed and more sheltered north-facing rock face and did not establish well along the disturbed, exposed south-facing rock face.

Generally, the population decline of the three endemic species on very disturbed sites could be due to at least two possible factors. The altered conditions after disturbance could be no longer suitable for the establishment, optimal growth or continued survival of these species. Alternatively, or additionally, these changed conditions favoured the colonisation or invasion by other (more weedy) species, which were superior competitors for space and resources. This study has established that fast-growing, smothering weedy growth of other species was important where *A. rupestris* and *E. milsumii* were either reduced in occurrence or absent, notably on the very disturbed, exposed ridge spine (site category A). In the case of *I. praetermissa*, limited comparisons here (restricted to two site categories) suggest that competition from weedy growth was not of overriding importance, as the extent of growth of weedy plant species was in fact greater along the undisturbed north-facing rockface (where there were more individuals of *I. praetermissa*) than the disturbed, south face (Table 3). Thus, it is possible that the more altered environment of the south face was unsuitable for establishment and continued survival of *I. praetermissa*. Unlike *E. milsumii* and *A. rupestris*, existing *I. praetermissa* are bigger plants not easily shaded out by the invading weedy species present; furthermore, its occurrence in the shade of taller trees suggests an extent of shade tolerance. A woody dicot tree, *I. praetermissa* develops a deeper and more extensive rooting system, and thus has potentially better survival against competition from smaller, invading weedy plants.

Plant size and other factors affecting survival of rare or endemic species in changed environments

The survival probability for rare or endemic species in disturbed environments could be influenced by plant size. Plant size can be categorized into small-sized plants (such as *A. rupestris* or *E. milsumii*) and bigger plants (e.g. *I. praetermissa*). Table 6 shows the various postulates for survival probability, with size. This shows the most likely adaptation of residual adults (either small plants or bigger plants) and new regeneration (essentially newly germinating or small plants) and their expected ability to compete with invading weedy species. For small-sized plants, remaining adults may not adapt to the new environmental

Table 6 The possible effect of plant size (considering residual adults versus new regeneration on site) on the ability of rare or endemic plants to adapt to changed site conditions following disturbance and ability to compete against other invading weedy species

Adult size	Generation	Adaptation to new/changed environmental conditions	Ability to resist competition from invading weedy species
Small-sized plants	Remaining adults	May not adapt	May not resist
	New regeneration in the changed environment	May not adapt	May not resist
Bigger plants	Remaining adults	May not adapt	Likely to resist
	New regeneration in the changed environment	May not adapt	May not resist

See text for Discussion

conditions and also may not compete well with invading weedy species. For bigger plants, such as *Ilex*, the remaining adults are more likely to resist competition from invading weedy species (which are typically smaller ferns, grasses, or shrubs), but may not adapt to the changed new environment and so decline in performance. New regeneration of both small-sized and big-sized plants lack a size advantage in resisting competition from invading weedy species, and also may not adapt to the changed environmental conditions.

It was obvious that a number of species establishing in the disturbed sites on the Klang Gates quartz ridge were introduced species, e.g. *Clidemia hirta* and *Pennisetum purpureum*. Many biological invasions, i.e. the establishment of organisms in habitats where they are not native, with negative effects on the population already there, have been caused by invasive introduced species (Alpert 2006). Invading weedy species may affect the performance of residual plant populations in various ways. Thomson (2005), studying *Oenothera deltoidea* Torrey & Frém. ssp. *howellii* (Munz) W.Klein (Onagraceae) at the Antioch Dunes National Wildlife Refuge, California, found that the strongest impact of invasive weedy plants on this endemic was most likely the effect of invasive species thatch (accumulation of poorly decomposed leaf litter) that reduced soil disturbance (necessary for germination of the endemic plant seed in this case). As such, endemic plant recruitment, rather than superior resource competition on the part of the invasive, could be more important. She noted that many studies have generally presumed resource competition was the main impact of invasive plants on rare or endemic species. For *A. rupestris*, we have discussed the possibility that taller or fast-invading vegetation may alter substrate conditions, besides imposing greater competition for space and resources. There is thus a need to distinguish between adaptation of both remaining adults and new regeneration to changed environmental conditions following disturbance, and the ability of the resident species to compete for resources against invading weedy species.

It should be emphasized that although optimal habitat may be important in sustaining populations of such endemic species on site, still other possible factors need to be considered. For example, a required critical population size, from which some populations can expand into suboptimal habitats through continued subsidy from a core population (Primack and Miao 1992; Pulliam 1998), could also be important. Further work, especially experimental studies, are needed to demonstrate the factors operating in the potential diminishment of populations of *A. rupestris*, *E. milsumii* and *I. praetermissa* on the Klang Gates quartz ridge. In particular, the reproductive and physiological ecology of these species would repay further study. At a basic level, these could investigate the reproductive success of individuals and population samples, modes and efficacy of dispersal, comparative establishment success (both between sites and on different substrates), and the genetic diversity of populations in different habitat conditions.

Conservation importance of the Klang Gates quartz ridge

The Klang Gates ridge is the main feature in a series of quartz ridges around the city of Kuala Lumpur, and includes others such as in the Kanching, Kuang, South Ulu Gombak and Sungai Tua areas (Reid 1959, 1961). Although several of these ridges carried vegetation similar to that found on the Klang Gates quartz ridge, the one at Klang Gates is among the best developed and most important, and some of the others have already been adversely affected by development.

The present study demonstrates that populations of rare, endemic plant species such as *A. rupestris*, *E. milsumii* and *I. praetermissa* are unable to tolerate severe changes in the environment, especially that which encourages weedy, fast-smothering species invading disturbed sites. There are many other rare plant species found at Klang Gates that have not been adequately studied, including *Acrymia ajugiflora* Prain (Lamiaceae), *Anerincleistus pauciflorus* Ridl. (Melastomataceae), *Begonia clivalis* Ridl. (Begoniaceae), *Capparis larutensis* King (Capparaceae), *Carallia suffruticosa* Ridl. (described by Ridley as *C. euryoides* Ridl.) (Rhizophoraceae), *Licuala kiahii* Furtado (Arecaceae) and *Mesua elegans* (King) Kosterm. (Clusiaceae) (Kiew 1982, 1983).

The Klang Gates quartz ridge is a remarkable natural feature with unique plant communities, including a suite of endemic species that are best protected on site (Wise and Zahid 1999; also highlighted in the local press by Tan 1998; Cheang 2004). Its adequate conservation management requires good legislation and enforcement, appropriate regulation of visitation on site, careful restoration of severely transformed sites, and provision of sufficient interpretation and information to encourage public awareness for the special features of the ridge.

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