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# DIVERSITY OF ORTHOPTERA FROM NEO TIEW LANE 2, SINGAPORE

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***ABSTRACT.*** — The orthopteran community in a vacant site along Neo Tiew Lane 2 (NTL2), Singapore, was examined for 28 months. The objectives were to understand the abundance, species richness, diversity, evenness, and species composition of Orthoptera in NTL2. A total of 54 species of Orthoptera were recorded, with the suborder Ensifera having a greater richness, abundance, and diversity than Caelifera. Forty-five plant species were identified during the surveys, of which almost half of the species are classified as naturalised, and only a small proportion is native (16%). A clearance of vegetation also occurred during the monitoring, hence the impact and response of orthopterans to habitat change were investigated. Orthopteran diversity was found to be affected by the clearance but also recovered with vegetation succession to a lower diversity than pre-clearance. The diversity for Caelifera and Ensifera follows a similar trend but the impact of clearance on Caelifera is more significant.

***KEY WORDS.*** — Orthoptera, grassland, diversity, clearance response, Neo Tiew, Singapore

## INTRODUCTION

Insects from the order Orthoptera are important grassland species which fulfil key ecological niches (Gandar, 1982; Belovski & Slade, 1993; Ryszkowski et al., 1993). Some are keystone species of an ecological community while others may serve as good indicators of ecosystem health (Quinn et al., 1993; Lockwood, 1996; Samways, 1997; Armstrong & van Hensberen, 1999; Mahmood et al., 2007). Although there was an increase in orthopteran research in Singapore in recent years, greater emphasis was placed on taxonomic studies and species richness (Gorochov & Tan, 2012; Ingrisch & Tan, 2012; Tan, 2012a, 2012b; Tan & Robillard, 2012; Tan et al., 2012). There has been no long-term monitoring of populations of Orthoptera in Singapore.

In the present study, the orthopteran community in a vacant site along Neo Tiew Lane 2 (NTL2), a road approximately 1.09 km long, was surveyed over a period of 28 months. NTL2 was chosen owing to its close proximity to the Kranji Marshes, one of the 22 designated Nature Areas, and this area is well known for its birds and dragonfly diversity (Lim, 2010; Ngiam, 2011; R. W. J. Ngiam, pers. obs.). Sampling along NTL2 also offered ease of access as the surveys were conducted at night, and the road served as a ready-made transect.

In the past till the late 1980s, NTL2 used to be a residential village, populated mainly by a Chinese community who practised small-scale poultry and vegetable farming. The village was subsequently abandoned as the community was relocated to other parts of Singapore. The wild vegetation of NTL2 now consists of mainly grassland species and weedy herbaceous climbers. Hence, to enhance the existing biodiversity data for management purposes, Orthoptera, as predominant grassland insects, was selected. Through this study, we aim to understand the abundance, species richness, diversity, evenness, and species composition of Orthoptera in NTL2.

During the monitoring period, a major clearance of the vegetation occurred in the study area along some of the transects. It was unlike typical grass mowing but instead involved heavy machinery that removed tall grasses and shrubs, and upturned the ground. Although the reason for the vegetation clearance was not known, we investigated the impact of habitat change on orthopterans as well as their response to the recovery of vegetation.

## MATERIAL AND METHODS

***Study area.*** — Neo Tiew is located to the south of Kranji in the north-west of Singapore Island (Fig. 1). The study area is a vacant site that borders NTL2. Transects were established along NTL2 (Fig. 2) and were located beyond Kranji Farm Resort (1.420192N, 103.719252E), where vehicular movements are highly restricted (Fig. 1).


Fig. 1. Map of Neo Tiew Lane 2 (NTL2) labelled with the locations of the Kranji Farm Resort, PUB pump station, and transects (Google, 2013). Each transect was 20 m long. Each red dot represents the start of the respectively numbered transect.

***Sampling***. — Six line transects, each 20 m long, were demarcated and distributed at approximately equal distance from each other along NTL2. Orthopteran monitoring was conducted for 28 months from Jul.2010–Oct.2012. Nocturnal surveys on non-rainy evenings from 1930–2200 hours were conducted once every month, whenever possible. In total, 20 surveys were conducted. Each survey was conducted by two to five persons and lasted for 15 min, during which opportunistic collection of adult and nymph orthopterans was conducted up to 5 m into the study area along the transect, and up to 2 m above ground: searching vegetation, ground and tree felling; raking litter; sweeping vegetation; breaking off branches, and examining the interior; searching burrows; and locating calls. After 15 min, the orthopterans were identified by MKT, counted and released thereafter. Sampling was conducted by alternating the starting transect for each consecutive survey to account for human error owing to sampling fatigue and time differences.

An assessment of the floristic composition along the transects was also conducted. A preliminary inventory was created by visual consensus. In-situ plant identification was done mostly by HI. Specimens that required further determination were sent to the Singapore Botanic Gardens Herbarium for identification. The composition of the vegetation was also determined by quadrat sampling. Within each 20-m transect, five 1-$m^2$ quadrats were randomly sampled, in which the plant species were identified. Each 1-$m^2$ quadrat was divided into 100 grids. Within each grid, the dominant plant species were recorded. Hence, the vegetation composition within a 1 $m^2$ quadrat was represented to 100 %.

***Data analysis***. — For both the orthopteran and vegetation surveys, the abundance (number of individuals of each species recorded) and species richness (number of species recorded) were determined. Species composition (specific assemblages of species) was illustrated by listing the species recorded in the Appendix. The diversity, which accounts for both species richness and evenness, was quantified using the Shannon-Weiner Index (H′), with this formula (where $p_i$ is the relative abundance of the $i^{th}$ species within $R$):

$$\mathrm{H}' = -\sum_{i=1}^{R} p_i \ln p_i$$

In the analysis, three stages were assigned: pre-clearance (Jul.2010–Jan.2011), clearance (Feb.2011–May 2011), and recovery (Jun.2011–Oct.2012). All statistical analyses and evaluations were performed using RExcel (RExcel, 2007).


Fig. 2. Habitats of the six line transects surveyed in NTL2: A–F, transects 1–6, respectively. (Photographs by: Robin Wen Jiang Ngiam).

## RESULTS AND DISCUSSION

From the 28 months of monitoring, 54 species of Orthoptera were recorded from NTL2 (see Appendix 1). Eighteen species were caeliferans (grasshoppers) and 36 species were ensiferans (crickets and katydids). Box plots were used to compare the species richness, abundance, and diversity (H′) between the suborders. There was graphical evidence to suggest that NTL2 supports a greater richness, abundance, and diversity of Ensifera than Caelifera (Fig. 3). The species

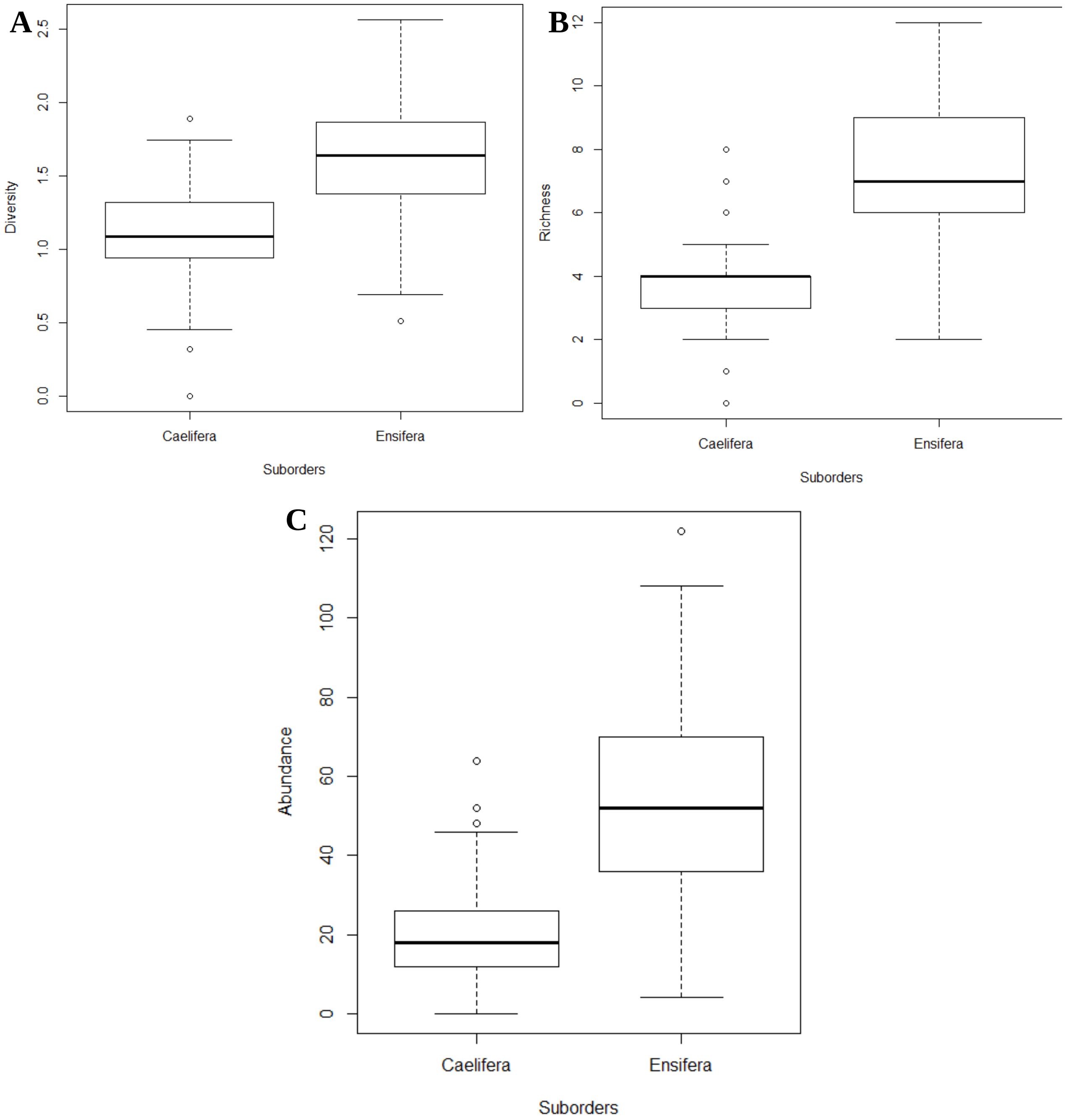


Fig. 3. Box plots with whiskers from minimum to maximum on the differences in: A, species richness; B, diversity; C, abundance; of the two suborders Caelifera and Ensifera. Non-overlapping box plots suggest that the abundance and diversity of Ensifera is greater than Caelifera in NTL2. The bold line within the box represents the median.

composition of NTL2 consists of seven families in the order Orthoptera and is dominated by families Gryllidae (18 species), Tettigoniidae (17 species), and Acrididae (13 species; Fig. 4). The monitoring in NTL2 also revealed some noteworthy species. Three species of orthopterans, *Velarifictorus* (?) species 2, *Kuzicus* species and *Mirollia* species, are currently known to be found only in NTL2 for Singapore (Fig. 5). These species were also recorded once, indicating that they may be rare. Additionally, *Pseudorhynchus minor* Redtenbacher, although not recorded during the survey, was also found only from Neo Tiew (Tan, 2011).

Based on the vegetation survey, 45 plant species were identified during the surveys, as listed in Appendix 2. A large proportion (87%) are grasses and herbaceous climbers. Only a small proportion of the species present are native (16%) despite almost half of the species being classified as naturalised (Chong et al., 2009). These findings highlight that the vegetation in NTL2, which consists mainly of non-native or exotic species, supports a rich diversity of orthopterans.

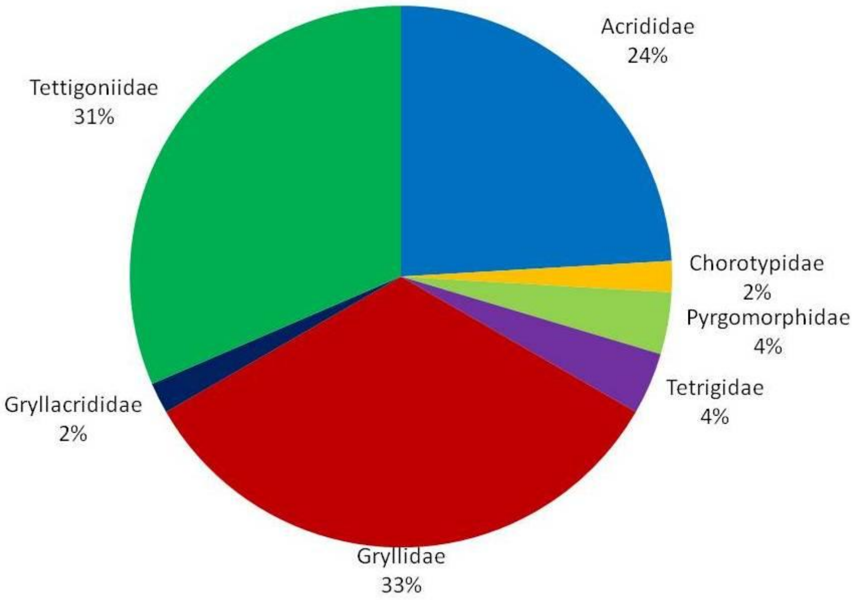


Fig. 4. Composition of Orthoptera families found in NTL2. Species recorded: 13 (Acrididae), 1 (Chorotypidae), 2 (Pyrgomorphidae), 2 (Tetrigidae), 18 (Gryllidae), 1 (Gryllacrididae), 17 (Tettigoniidae); 54 (total).

However, these non-native species should not be encouraged to proliferate for orthopteran conservation. This also does not imply that orthopterans have low conservation value owing to their ability to adapt to exotic habitats. Instead, grasslands are important orthopteran habitats even when they contain mainly exotic plants. Additionally, these grasslands are also important habitats that support other fauna such as birds, butterflies, and dragonflies. Further studies to identify native counterparts of these exotics will aid orthopteran conservation without compromising the aim of native faunal conservation in Singapore.

From the species accumulation curve, it is obvious that it appeared to plateau following the clearance, first observed in Feb.2011 (Fig. 6). However, the curve continued to rise from Sep.2011–Oct.2012 in a similar gradient as that for pre-clearance (Jul.2010–Jan.2011). Moreover, the orthopteran diversity (H′) also decreased (from Feb.2011–May 2011) before increasing (from Jun.2011–Aug.2011), and reached a plateau at a lower diversity than that of pre-clearance (Table 1; Fig. 7). Nevertheless, when the box plots comparing different stages were constructed, no conclusion could be made to show that these changes were statistically significant (Fig. 8A). As such, the diversity for each suborder was analysed further.

When the diversity (H′) for insects from the suborders Caelifera and Ensifera was examined, it was found that the response trend was similar to that of the order in general (Table 1). However, the change in diversity from pre-clearance to clearance was graphically significant for caeliferans, but not ensiferans (Table 1; Fig. 8B, C). This may be because of the diet of the different suborders. Caeliferans are mainly herbivorous whereas ensiferans range from being herbivorous to carnivorous (Rowell, 1978; Floren et al., 2001). This shows that insects from the suborder Caelifera may be more affected when their food sources are depleted owing to the clearance. For the order Orthoptera, the change in diversity from clearance to recovery is a small but graphically insignificant increase (Table 1; Fig. 8B, C).

Table 1. Statistical summary of the change in diversity (H′) of Orthoptera and its suborders during the three stages. N represents the number of samples collected.

| | | | **Diversity (H′)** | | | |
|---|---|---|---|---|---|---|
| | **Stage** | **N** | **Median** | **Minimum** | **Maximum** | **IQR** |
| Orthoptera | Pre-clearance | 30 | 2.123 | 1.557 | 2.565 | 0.254 |
| | Clearance | 18 | 1.853 | 1.378 | 2.545 | 0.365 |
| | Recovery | 72 | 1.989 | 0.964 | 2.573 | 0.339 |
| Caelifera | Pre-clearance | 30 | 1.260 | 0.562 | 1.633 | 0.336 |
| | Clearance | 18 | 1.003 | 0.000 | 1.359 | 0.401 |
| | Recovery | 72 | 1.070 | 0.000 | 1.887 | 0.458 |
| Ensifera | Pre-clearance | 30 | 1.735 | 0.963 | 2.565 | 0.362 |
| | Clearance | 18 | 1.557 | 0.693 | 2.393 | 0.370 |
| | Recovery | 72 | 1.570 | 0.509 | 2.528 | 0.578 |

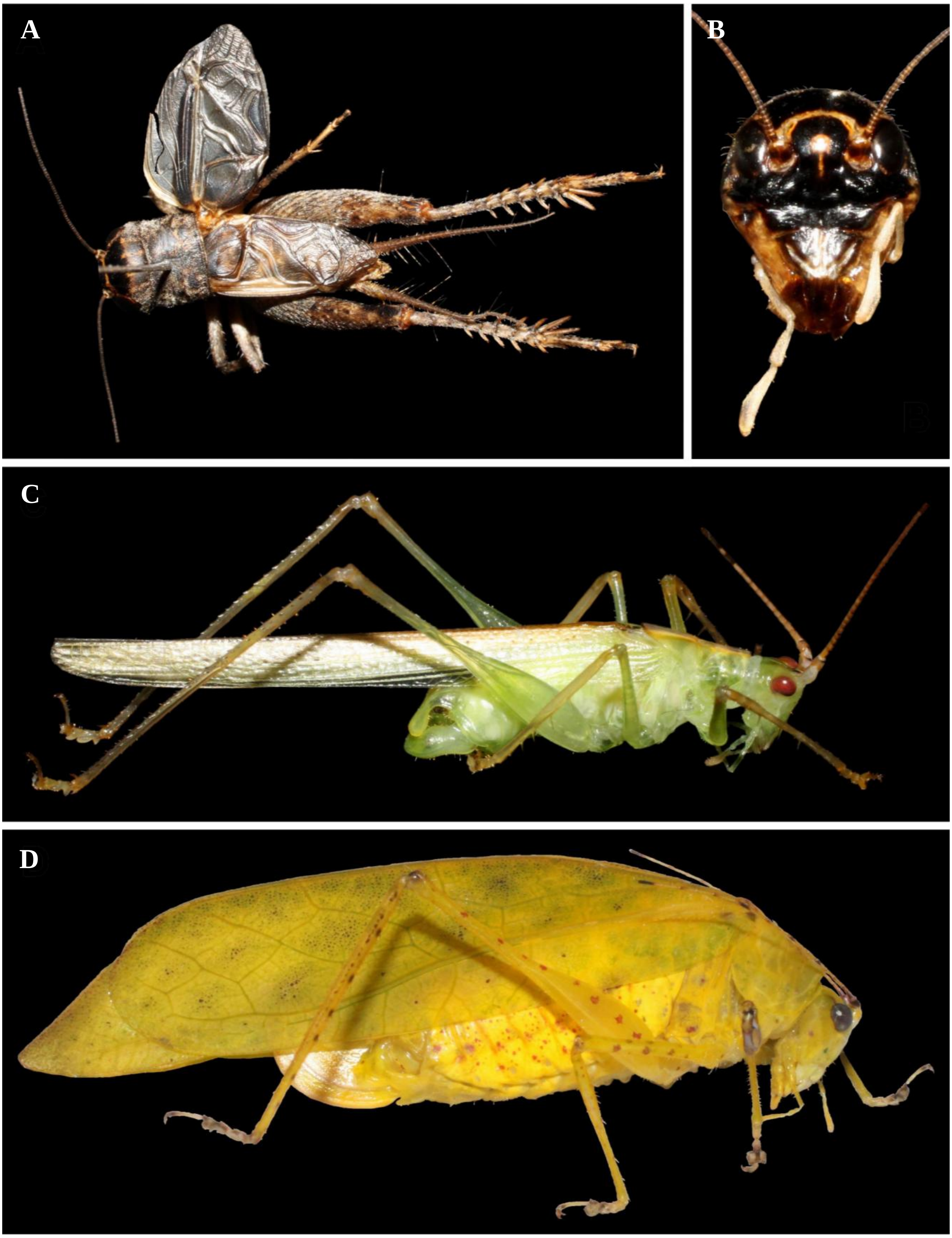


Fig. 5. Noteworthy species recorded from NTL2: A, B, *Velarifictorus* (?) species 2; C, *Kuzicus* species; D, *Mirollia* species. (Photographs by: Tan Ming Kai).

While these results are statistically insignificant, possibly as a result of insufficiently large sample size and/or replicate number, it is safe to suggest that those observations are biologically significant. It was also previously reported that mechanical clearance results in high direct mortality of orthopterans (Detzel, 1985; Gerstmeier & Lang, 1996; Gardiner, 2006; Gardiner & Hill, 2006; Humbert et al., 2009; Marini et al., 2009). From these analyses, it seems plausible that orthopteran diversity is affected by clearance but also recovers with vegetation succession, albeit to a lower diversity than the pre-clearance level. The analyses also suggest that insects from the suborder Caelifera may have an ecological indicator value. In Singapore, the vegetation in many manicured parks and even in nature parks and forest edges are subjected to regular grass maintenance. The significant impact on the caeliferan diversity due to clearance provide insights on the possible impact of such maintenance on the orthopterans, and also invertebrates with low mobility, in these manicured vegetation sites (Gardiner & Hill, 2006; Johst et al., 2006).

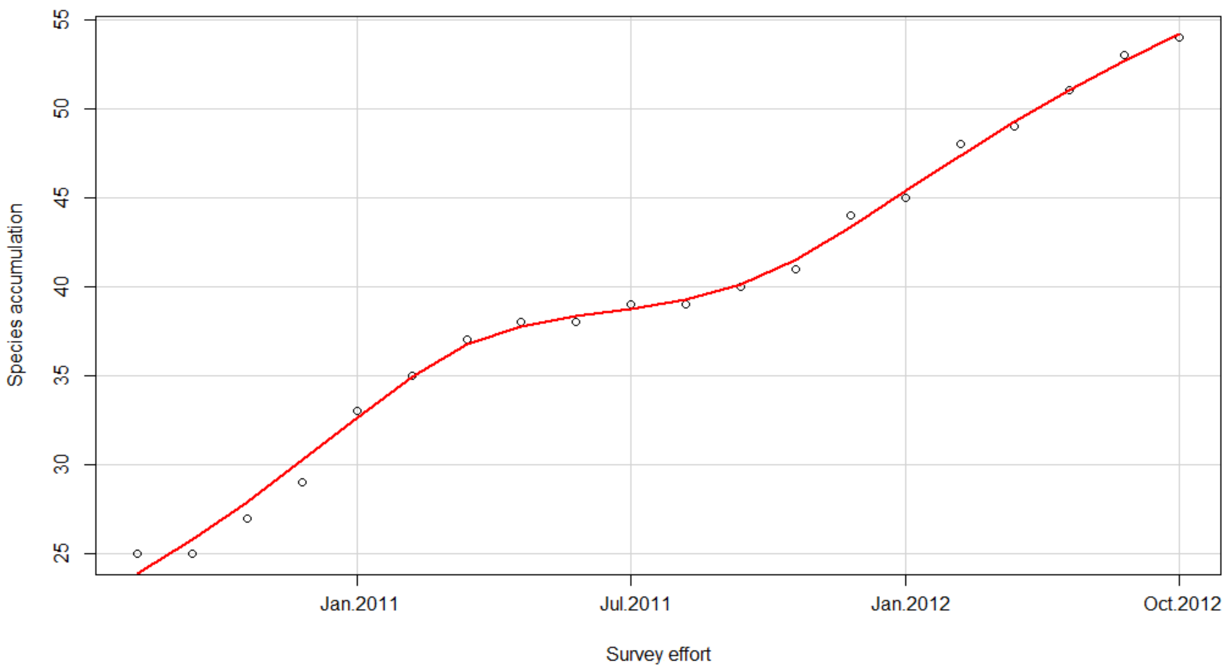


Fig. 6. Species accumulation curve for the Orthoptera in NTL2. The total number of orthopteran species recorded was 54.

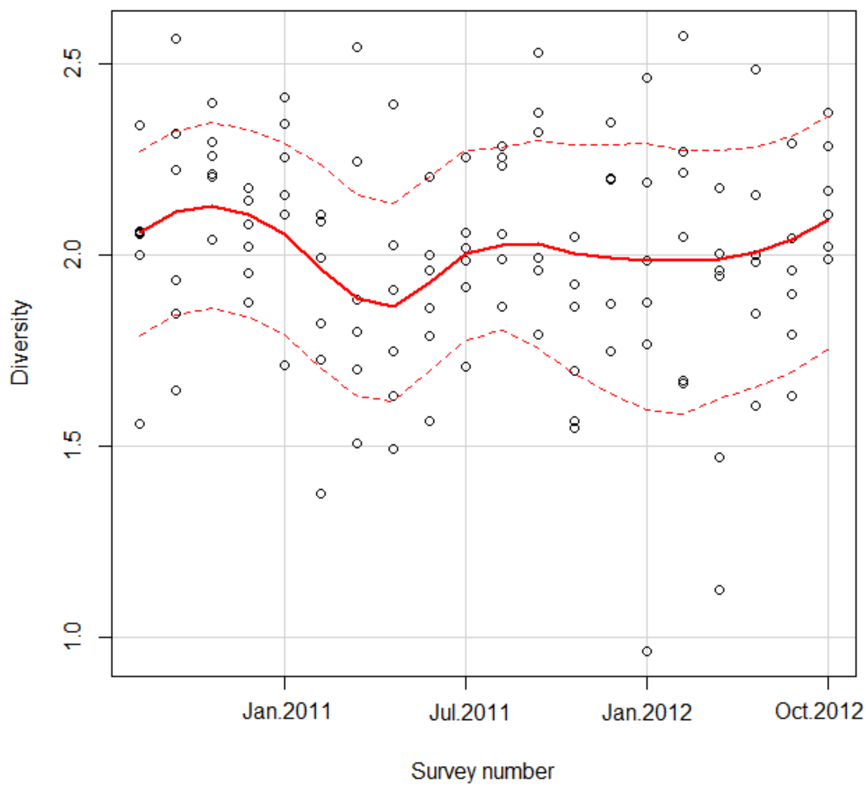


Fig. 7. Scatter plots showing the variation of the diversity of the Orthoptera over 20 surveys. The red line indicates the trend. The dotted lines indicate the spread.

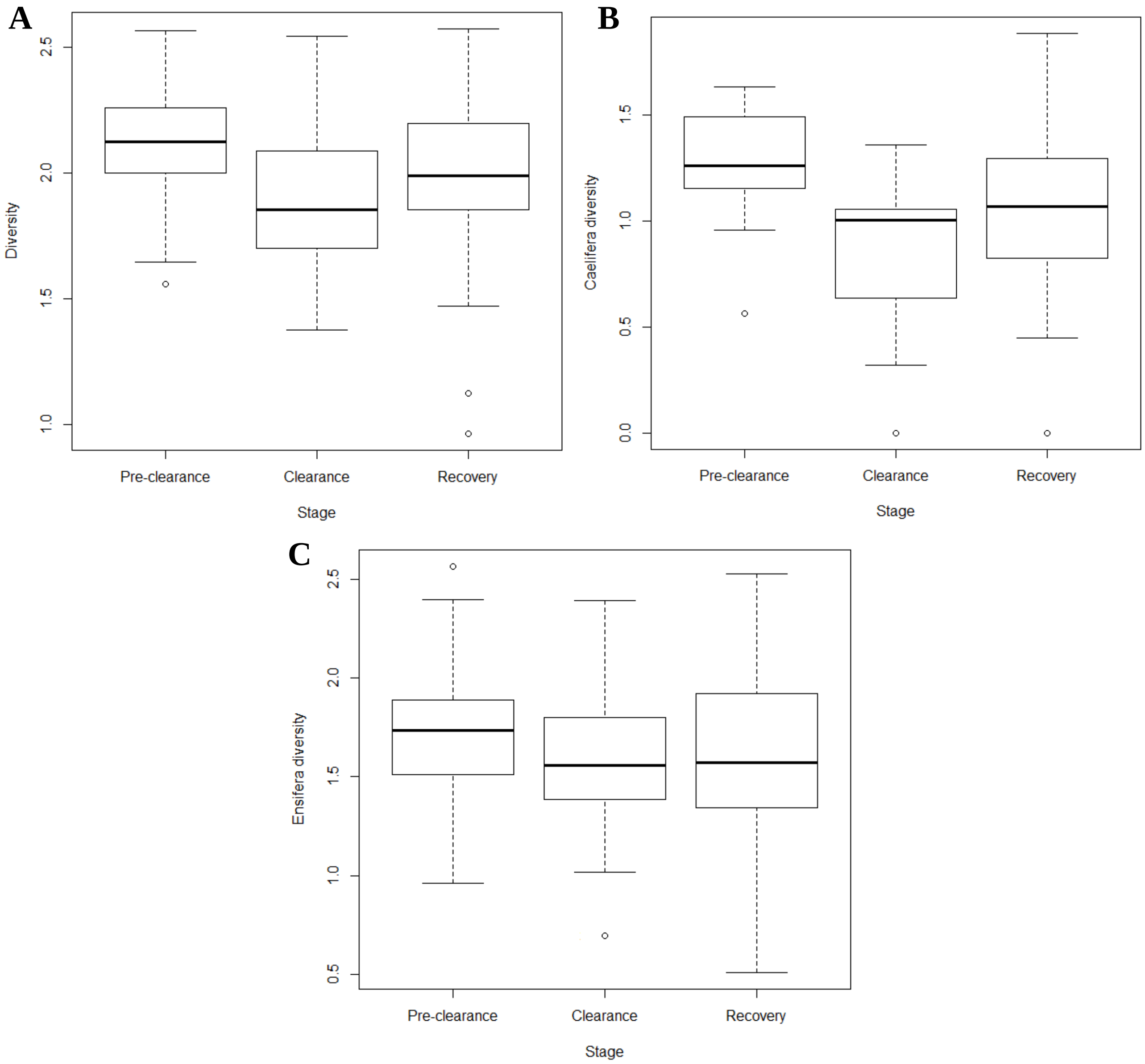


Fig. 8. Box plots with whiskers from minimum to maximum on the differences in the diversity for the three stages, pre-clearance, clearance, and recovery: A, Orthoptera; B, Caelifera; C, Ensifera. The bold line within each box represents the median.

Towards the end of the monitoring period (Aug.2012–Oct.2012), it appeared that the orthopteran diversity was increasing after a plateau period. It is unclear if the change is merely a random fluctuation or of a particular trend. At such, it would be erroneous to extrapolate the change and suggest any explanation without further investigation. Moreover, the species accumulation curve in NTL2 indicates that the species richness has not reached a plateau. Continued monitoring would reveal more species in NTL2, as well as some understanding on the temporal variation owing to seasonal or environmental variations.

## CONCLUSIONS

The study of insects from the order Orthoptera in NTL2 over a relatively long time period of 28 months allowed the understanding on the impact of clearance on orthopterans in Singapore. Results showed that orthopterans were affected by clearance but also recovered with vegetation succession. But, it appears that caeliferans were more affected than the ensiferans. Additionally, the results also suggested that vacant sites may still hold rich biodiversity despite holding little conservation value and possessing many exotic plant species. Therefore, in this paper, we hope to document the existence of the orthopterans and offer naturalists and conservation managers in Singapore a means to understand and appreciate the biodiversity that natural grassland habitats in Singapore may hold.

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## APPENDIX 1

Checklist of the Orthoptera in Neo Tiew Lane 2. Given that the species accumulation curve did not reach a plateau, this list is not an exhaustive compilation of all the species within the site.

| S/No. | Suborder | Superfamily | Family | Subfamily | Species |
|---|---|---|---|---|---|
| 1. | Caelifera | Acridomorpha | Acrididae | Acridinae | *Phlaeoba antennata* |
| 2. | | | | | *Phlaeoba infumata* |
| 3. | | | | Catantopinae | *Apalacris varicornis* |
| 4. | | | | | *Traulia azureipennis* |
| 5. | | | | | *Xenocatantops humilis* |
| 6. | | | | Coptacridinae | *Epistaurus aberrans* |
| 7. | | | | Oedipodinae | *Aiolopus thalassinus tumulus* |
| 8. | | | | | *Trilophidia annulata* |
| 9. | | | | Oxyinae | *Gesonula mundata* |
| 10. | | | | | *Oxya japonica japonica* |
| 11. | | | | | *Oxya hyla intricata* |
| 12. | | | | | *Pseudoxya diminuta* |
| 13. | | | | Spathosterninae | *Spathosternum prasiniferum* |
| 14. | | | Chorotypidae | Erianthinae | *Erianthus* sp. |
| 15. | | | Pyrgomorphidae | Pyrgomorphinae | *Atractomorpha* sp. |
| 16. | | | | | *Tagasta marginella* |
| 17. | | Tetrigoidea | Tetrigidae | Scelimeninae | Scelimeninae sp. |
| 18. | | | | Tetriginae | Tetriginae sp. |
| 19. | Ensifera | Grylloidea | Gryllidae | Eneopterinae | *Nisitrus vittatus* |
| 20. | | | | Euscyrtinae | *Euscyrtus concinnus* |
| 21. | | | | | *Euscyrtus hemelytrus* |
| 22. | | | | | *Patiscus* sp. |
| 23. | | | | Gryllinae | *Loxoblemmus* sp. |
| 24. | | | | | *Teleogryllus* sp. |
| 25. | | | | | *Velarifictorus* sp. |
| 26. | | | | | *Velarifictorus* (?) sp. 2 |
| 27. | | | | Nemobiinae | *Pteronemobius* sp. 1 |
| 28. | | | | | *Pteronemobius* sp. 2 |
| 29. | | | | Sclerogryllinae | *Sclerogryllus* sp. |
| 30. | | | | Trigonidiinae | *Anaxipha* sp. 1 |
| 31. | | | | | *Anaxipha* sp. 2 |
| 32. | | | | | *Anaxipha* sp. 3 |
| 33. | | | | | *Anaxipha* sp. 4 |
| 34. | | | | | *Amusurgus* sp. |
| 35. | | | | | *Homoeoxipha lycoides* |

| S/No. | Suborder | Superfamily | Family | Subfamily | Species |
|---|---|---|---|---|---|
| 36. | | | | | *Metioche pallipes* |
| 37. | | Stenopelmatoidea | Gryllacrididae | ? | Gryllacrididae sp. |
| 38. | | Tettigonioidea | Tettigoniidae | Conocephalinae | *Conocephalus cognatus* |
| 39. | | | | | *Conocephalus maculatus* |
| 40. | | | | | *Conocephalus melaenus* |
| 41. | | | | | *Conocephalus longipennis* |
| 42. | | | | | Copiphorini spp. |
| 43. | | | | | *Euconocephalus nasutus* |
| 44. | | | | | *Euconocephalus picteti* |
| 45. | | | | Hexacentrinae | *Hexacentrus unicolor* |
| 46. | | | | Meconematinae | *Alloteratura* sp. |
| 47. | | | | | *Xiphidiopsis* sp. |
| 48. | | | | | *Kuzicus* sp. |
| 49. | | | | Mecopodinae | *Mecopoda elongata* |
| 50. | | | | Phaneropterinae | *Ducetia japonica* |
| 51. | | | | | *Elimaea subcarinata* |
| 52. | | | | | *Holochlora* cf. *obtusa* |
| 53. | | | | | *Phaneroptera brevis* |
| 54. | | | | | *Mirollia* sp. |

## APPENDIX 2

Checklist of the plant species identified at NTL2. This list is by no means to suggest an exhaustive list of all the plant species within the survey plots. But it does cover a comprehensive listing of the plants that can be found there. The conservation status of each species as well as whether they are native or introduced (hence exotic) is based on Chong et al. (2009).

| S/No. | Species | Family | Habit | Conservation Status |
|---|---|---|---|---|
| 1. | *Asystasia gangetica* | Acanthaceae | Herb | Exotic |
| 2. | *Axonopus compressus* | Poaceae | Herb | Exotic |
| 3. | *Cassytha filiformis* | Lauraceae | Creeper or climber | Common |
| 4. | *Cleome rutidosperma* | Cleomaceae | Herb | Exotic |
| 5. | *Coccinia grandis* | Cucurbitaceae | Creeper or climber | Exotic |
| 6. | *Commelina diffusa* | Commelinaceae | Creeper or climber | Exotic |
| 7. | *Cyperus rotundus* | Cyperaceae | Herb | Exotic |
| 8. | *Desmodium triflorum* | Fabaceae | Creeper or climber | Exotic |
| 9. | *Dieffenbachia* hybrid | Araceae | Herb | Exotic |
| 10. | *Dillenia suffruticosa* | Dilleniaceae | Tree | Common |
| 11. | *Eclipta prostrata* | Asteraceae | Herb | Exotic |
| 12. | *Eleusine indica* | Poaceae | Herb | Exotic |
| 13. | *Eragrostis amabilis* | Poaceae | Herb | Exotic |
| 14. | *Fimbristylis complanata* | Cyperaceae | Herb | Common |
| 15. | *Heliconia* hybrid | Heliconiaceae | Herb | Exotic |
| 16. | *Hyptis capitata* | Lamiaceae | Herb | Exotic |
| 17. | *Ipomoea aquatica* | Convolvulaceae | Creeper or climber | Exotic |
| 18. | *Ipomoea cairica* | Convolvulaceae | Creeper or climber | Exotic |
| 19. | *Ipomoea triloba* | Convolvulaceae | Creeper or climber | Exotic |
| 20. | *Ischaemum muticum* | Poaceae | Herb | Common |
| 21. | *Kyllinga brevifolia* | Cyperaceae | Herb | Exotic |

| S/No. | Species | Family | Habit | Conservation Status |
|---|---|---|---|---|
| 22. | *Kyllinga nemoralis* | Cypeaceae | Herb | Exotic |
| 23. | *Kyllinga polyphylla* | Cyperaceae | Herb | Exotic |
| 24. | *Lindernia antipoda* | Linderniaceae | Herb | Common |
| 25. | *Lindernia crustacea* | Linderniaceae | Herb | Exotic |
| 26. | *Ludwigia hyssopifolia* | Onagraceae | Herb | Exotic |
| 27. | *Manihot carthagenesis* subsp. *glaziovii* | Euphorbiaceae | Tree | Exotic |
| 28. | *Mikania micrantha* | Asteraceae | Creeper or climber | Exotic |
| 29. | *Mimosa pudica* | Fabaceae | Creeper or climber | Exotic |
| 30. | *Nephrolepis exaltata* | Oleandraceae | Fern | Exotic |
| 31. | *Paederia foetida* | Rubiaceae | Creeper or climber | Common |
| 32. | *Panicum maximum* | Poaceae | Herb | Exotic |
| 33. | *Paspalum conjugatum* | Poaceae | Herb | Exotic |
| 34. | *Passiflora foetida* | Passifloraceae | Creeper or climber | Exotic |
| 35. | *Pipturus argenteus* | Urticaceae | Shrub | Exotic |
| 36. | *Solanum torvum* | Solanaceae | Shrub | Exotic |
| 37. | *Spermacoce latifolia* | Rubiaceae | Herb | Exotic |
| 38. | *Spermacoce ocymoides* | Rubiaceae | Herb | Exotic |
| 39. | *Stenochlaena palustris* | Blechnaceae | Fern | Common |
| 40. | *Synedrella nodiflora* | Asteraceae | Herb | Exotic |
| 41. | *Terminalia catappa* | Combretaceae | Tree | Common |
| 42. | *Urochloa mutica* | Poaceae | Herb | Exotic |
| 43. | *Vernonia cinerea* | Asteraceae | Herb | Exotic |