Tables 1 and 2 were corrected in a separate corrigenda dated 13 Jan.2014.
See http://rmbr.nus.edu.sg/nis/bulletin2013/2013nis289-300-corrigenda.pdf

NATURE IN SINGAPORE 2013 **6**: 289–300
Date of Publication: 2 December 2013

ORTHOPTERA IN THE MANGROVE FORESTS OF SINGAPORE

Ming Kai Tan
Department of Biological Sciences, National University of Singapore
14 Science Drive 4, Singapore 117543, Republic of Singapore
(Email: orthoptera.mingkai@gmail.com)

ABSTRACT. — Mangrove forests are unique habitats and have important ecosystem functions. While the biodiversity of mangrove forests in Singapore is well studied, its entomofauna is poorly known. As such, the mangrove forests in Sungei Buloh Wetland Reserve (SBWR), Pasir Ris Park (PRP), both on Singapore Island, and Chek Jawa (CJ), Pulau Ubin were surveyed for Orthoptera. The objectives were: 1) to examine the orthopteran species richness and abundance in mangrove forests of Singapore, in particular the populations of presumably mangrove-restricted orthopterans; 2) to compare the orthopteran diversity between the three mangrove forest patches; and 3) to compare the orthopteran diversity between mangrove forest patches and adjacent vegetation. Thirty-three species of Orthoptera were recorded from the three sites. The number of species recorded is highest in CJ, followed by PRP and then SBWR. CJ also supports greater abundance, species richness, and diversity (H') of Orthoptera than PRP and SBWR. *Svistella chekjawa* was also recorded in great abundance in CJ. The abundance, species richness, and diversity (H') of Orthoptera were also compared between different dominant plant species within transects and were found to be highest in *Bruguiera*-dominated transects and lowest in *Rhizophora*-dominated transects. *Svistella chekjawa* abundance is also significantly higher in *Bruguiera*-dominated transects and absent in other vegetation types. Orthopteran diversity was also significantly different between the mangrove and adjacent non-mangrove habitats. Therefore, the study provides a different understanding of our mangrove forests as well as an alternate perspective of the conservation status and value of different mangrove patches.

KEY WORDS. — Orthoptera, mangrove forests, diversity, inventory, Singapore

INTRODUCTION

Mangrove forests, globally distributed on tropical shores, consist of trees, shrubs, climbers, and ferns adapted to saline and anoxic habitats (Tomlinson, 1986; Duke et al., 1998). These morphological and ecophysiological adaptations make mangrove plants structurally and functionally unique (Alongi, 2002). Mangrove forests have important ecosystem functions but are also being exploited worldwide (Chong & Sasekumar, 1994; Duarte & Cebrain, 1996). The losses to pond aquaculture and development encroachment are some of the greatest threats (Alongi, 2002). Owing to these anthropogenic impacts, mangrove forests are in decline globally (Clough, 1993; Hong & San, 1993; Spalding et al., 1997).

The coasts of Singapore, like those around Southeast Asia, were historically occupied by mangrove forests (Aksornkoae, 1993; Yee et al., 2010). There are currently about 6.59 km^2 of mangrove forests along the coasts and rivers in Singapore (Yee et al., 2010). The mangrove forests in Sungei Buloh Wetland Reserve (SBWR) are gazetted as a nature reserve while those in Pasir Ris Park (PRP) and Chek Jawa (CJ), Pulau Ubin are designated parkland and natural area, respectively. However, mangrove forests are expected to shrink further with development projects such as the damming of Sungei Punggol and Sungei Serangoon, and land reclamation in Pulau Ubin and Pulau Tekong (Urban Redevelopment Authority, 2008). This is in spite of the lack of thorough understanding of the mangrove forest habitat and their associated biodiversity in Singapore.

Studies on the entomofauna of mangrove forests have been undertaken around the region (Robertson & Duke, 1987; Robertson et al., 1990; Veenakumari & Prashanth, 2009). However, while the biodiversity of mangrove forests in Singapore is generally relatively well documented, studies on its entomofauna, in particular of the order Orthoptera, are rare and brief (Murphy, 1990; Tan et al., 2012). Recently, two new species of Orthoptera were described from the mangrove forests of Singapore: *Svistella chekjawa* Tan & Robillard and *Ornebius tampines* Tan & Robillard (see Tan & Robillard, 2012). These two endemic species appear to be associated or stenotopic to the mangrove forests of Singapore but these claims require confirmation based on further studies on their autecology. Such research would also be helpful in understanding the overall orthopteran diversity in the mangrove forests of Singapore.

In the current study, three mangrove forest patches in Singapore were sampled: 1) SBWR; 2) PRP; and 3) CJ. In particular, the orthopteran diversity in the mangrove canopy and subcanopy was examined. The study of arboreal entomofauna has been of great interest but difficult (Roberts, 1973; Stork, 1991). Fogging would have provided a more representative diversity and population structure of entomofauna but the destructive nature of this method is not cost-effective or feasible in the small mangrove forest patches of Singapore (Paarmann & Stork, 1987). As such, the boardwalks raised above ground were used as a means to survey the mangrove forest in a non-destructive manner. Additionally, Orthoptera are considered to have a minimal ecological niche in mangrove forests (Robertson & Duke, 1987; Robertson et al., 1992). As such, little is known about how the orthopteran diversity may differ between mangrove forests and adjacent habitats (Burrows, 2003). Because of the dearth in knowledge in the mentioned field, the objectives of this study were: 1) to examine the orthopteran species richness and abundance in mangrove forests of Singapore, in particular the orthopterans presumed to be mangrove obligates; 2) to compare the orthopteran diversity between the three mangrove forest sites; and 3) to compare the orthopteran diversity between mangrove forest patches and adjacent vegetation.

MATERIAL AND METHODS

Study area. — Three mangrove forest sites in Singapore were studied: 1) Sungei Buloh Wetland Reserve (SBWR; 01.44702N, 103.7293E); 2) Pasir Ris Park (PRP; 01.37823N, 103.95181E); and 3) Chek Jawa (CJ), Pulau Ubin (01.40914N, 103.99004E). In particular, samplings were conducted along the boardwalks to examine the canopy. For each study site, two mangrove transects and one non-mangrove transect, each 20 m long, were demarcated along boardwalks and sampled. Transects were selected based on qualitative assessment for the most densely vegetated areas on both sides of the boardwalk. Additionally for non-mangrove transects, transects were also selected based on qualitative assessment for the most representative vegetation adjacent to the mangrove forest patches. The habitats of these transects were different between the three sites: secondary, dryland forest dominated by shrubs for SBWR; grassy and herbaceous vegetation for PRP; and secondary coastal forest for CJ. The locations of these transects are shown in Fig. 1.

Sampling. — The study duration was about seven weeks from May–Jul.2013. Nocturnal surveys between 1930–2230 hours were conducted in each site approximately once a week. Each site was sampled six times. For each survey, opportunistic sampling of adult and nymph orthopterans was conducted up to 5 m into the vegetation on either side of the transect, and up to 2 m above ground for 15 minutes. This involved searching vegetation, sweeping vegetation, breaking off branches and examining the interior, and locating calls. After 15 minutes, the orthopterans were identified by MKT, counted, and released thereafter. Sampling was conducted with alternating starting transects during each survey trip to account for human error due to sampling fatigue and time differences. Specimens that could not be identified in the field were collected and euthanized for closer examination. They were subsequently deposited in the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore. A qualitative assessment of the vegetation types along the transects was also conducted. The dominant species was determined for each transect. Species of mangrove plants were identified based on a guide by Ng & Sivasothi (1999) and the identifications were verified by K. S. Koh and A. Y. H. Tan.

Data analysis. — The abundance (number of individuals of each species) and species richness (number of species) were determined. Species composition (specific assemblages of species) is illustrated in the Appendices. Species diversity, which accounts for both species richness and evenness, was quantified using Shannon-Weiner Index (H'). The population structure of *Svistella chekjawa* in the three study sites was separately analysed. This is to further justify that this endemic species is obligated to the mangrove forests of Singapore. For statistical analysis, the use of median and interquartile range (IQR), or mean and standard deviation (SD) depends on the normality test. Shapiro-Wilk test was used for normality test and Kruska-Wallis Rank Sum test was used for comparisons among the three sites. Two-tailed Wilcoxon test and Student’s t-test were used for pair-wise analyses. All analyses and the construction of box plots and linear regressions were performed using RExcel (RExcel, 2007).

RESULTS AND DISCUSSION

In total, 33 species of Orthoptera were recorded from the three sites. Suborder Ensifera is represented with 27 species, dominated by the family Gryllidae. Suborder Caelifera is represented with six species, with family Acrididae most specious (Fig. 2). 11 species were recorded from SBWR (eight species recorded from the mangrove transects and six from the control transect); 15 species from PRP (four species recorded from the mangrove transects and 12 from the control transect), and 22 species from CJ (13 species recorded from the mangrove transects and 14 from the control transect). All species recorded during the study are listed in Appendix 1. Specimen material collected for further examinations are listed in Appendix 2.

Fig. 1. The locations of the study's transects: A, Sungei Buloh Wetland Reserve; B, Pasir Ris Park; C, Chek Jawa (Google, 2013).

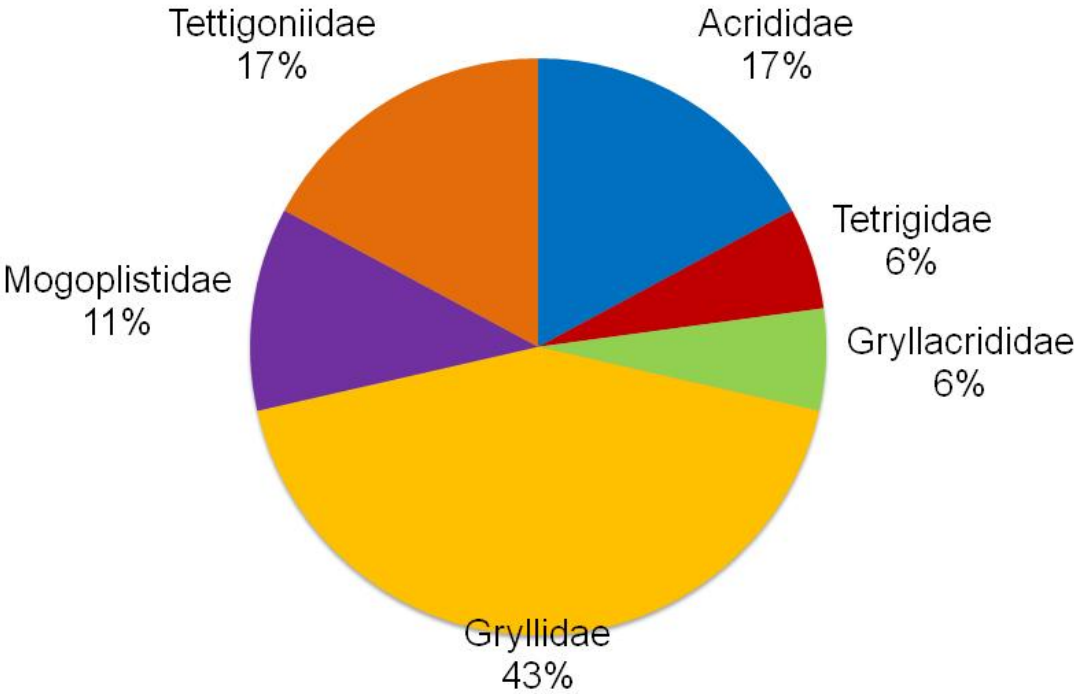

Fig. 2. Composition of orthopteran families found in Chek Jawa, Pasir Ris Park, and Sungei Buloh Wetland Reserve. Species recorded: four Acrididae, two Tetrigidae, two Gryllacrididae, 15 Gryllidae, four Mogoplistidae, and six Tettigoniidae; 33 in total.

The number of species by taxon are summarised below:

Order Orthoptera (33 species)
- Suborder Caelifera (six species)
  - Family Acrididae (four species)
  - Family Tetrigidae (two species)
- Suborder Ensifera (27 species)
  - Family Gryllacrididae (two species)
  - Family Gryllidae (15 species)
  - Family Mogoplistidae (four species)
  - Family Tettigoniidae (six species)

There were several noteworthy species of Orthoptera encountered in the course of this study. The most common and widely distributed species was the *Ornebius rufonigrus*, which was found in all sites (Fig. 3A). This species of scaly cricket was found in both the mangrove and non-mangrove transects. Another scaly cricket, *Ornebius tampines* was recorded in the mangrove transects of SBWR and CJ, outside of type locality (Sungei Tampines, PRP) for the first time (Fig. 3B, C). It was also recorded in the control transect of PRP. Curiously, *Ornebius tampines* was not recorded from the mangrove transects at PRP. This suggests that *Ornebius tampines* may be more of a mangrove-associated than a mangrove-obligated species. In contrast, *Svistella chekjawa* was recorded only from the mangrove transects, indicating that it is likely to be a mangrove obligate (Fig. 3D). Another interesting species recorded was the cricket *Lebinthus luae* (Fig. 3E). This cricket was recorded only from the control transect of CJ and in high abundance. Despite its dominance in the habitat, that is secondary coastal forest, this species was only recently described (Robillard & Tan, 2013). It has been found in coastal secondary forest (recorded from Labrador Nature Reserve, Semakau landfill, Sentosa Island, and Sensory Trail in Pulau Ubin) and in the secondary forest of Bukit Timah Nature Reserve as well (Tan, 2010, 2012; Tan et al., 2012).

The mangrove transects were compared between the three sites using two-tailed Wilcoxon test and/or Student's t-test (Table 1). There was no significant difference in abundance, species richness, and diversity (H') of orthopterans between SBWR and PRP (Table 1). However, abundance, species richness, and diversity (H') of orthopterans in CJ were significantly higher than those of SBWR and PRP (Table 1). Additionally, the abundance of *Svistella chekjawa* was higher in CJ than in PRP and SBWR. The results thus indicate that CJ supports a significantly greater orthopteran diversity compared to the two Singapore Island sites. While all species recorded in PRP were recorded in SBWR and CJ, one out of eight species (12.5%) was found exclusively in the mangrove forests of SBWR and four out of 13 species (30.8%) exclusively in that of CJ. Therefore, the results show that the orthopteran diversities in the three mangrove forest sites are not homogeneous, and that CJ has a much more distinct community compared to the two other sites.

Table 1. Summary of results and analysis for the comparison of orthopteran diversity in the mangrove transects between the three sites. * p-value < 0.05; ** p-value < 0.01; *** p-value > 0.05 (for normality test).

Parameters / **Sites**	**Median/ Mean**	**IQR/ SD**	**P-values** Normality Test	Group Analysis	Two-Sample Analysis Pasir Ris	Chek Jawa
Abundance	–	–	–	<0.001**	–	–
SBWR	0.50	2.00	0.002	–	0.087	<0.001**
Pasir Ris	1.67	1.15	0.068***	–	–	<0.001**
Chek Jawa	11.20	3.27	0.570***	–	–	–
Species richness	–	–	–	<0.001**	–	–
SBWR	0.50	2.00	0.002	–	0.191	<0.001**
Pasir Ris	1.00	1.00	0.029	–	–	<0.001**
Chek Jawa	4.50	2.25	0.088***	–	–	–
Diversity (H)	–	–	–	<0.001**	–	–
SBWR	0.00	0.69	<0.001	–	0.917	<0.001**
Pasir Ris	0.00	0.58	<0.001	–	–	<0.001**
Chek Jawa	1.29	0.40	0.395***	–	–	–

To examine the possible reasons for the difference in orthopteran diversities between the mangrove sites, the dominant plant species within the mangrove transects were determined. In most mangrove transects, a clear dominant species was found: *Bruguiera* species (family Rhizophoraceae) in the mangrove transects of CJ and PRP Transect 2; *Rhizophora* species (family Rhizophoraceae) in PRP Transect 1 and SBWR Transect 1; and SBWR Transect 2 consisted of a mixture of *Acanthus* species (family Acanthaceae), *Talipariti* (formerly *Hibiscus*; family Malvaceae), and *Bruguiera* species with no dominating species. Box plots were used to compare the abundance (Fig. 4A), richness (Fig. 4B) and diversity (*H′*; Fig. 4C) of Orthoptera in different dominant plant species. Abundance, species richness, and diversity (*H′*) of orthopterans were significantly higher in *Bruguiera*-dominated transects and lowest in *Rhizophora*-dominated transects. Additionally, the abundance of the mangrove-obligate species *Svistella chekjawa* was also significantly higher in *Bruguiera*-dominated transects and absent in other vegetation types (Fig. 4D). Since the mangrove forest transects in CJ are dominated by *Bruguiera*, the finding may also explain the significantly higher abundance of *Svistella chekjawa* in CJ compared to other sites. It may be suggested that *Bruguiera* may be a preferred food source for *Svistella chekjawa*. A study on the dietary preferences of *Svistella chekjawa* would provide more insight. Nevertheless, the findings showed that orthopterans and mangrove plants may be more directly related than previously thought.

In each site, the mangrove transects were compared with their respective control transect using Wilcoxon Rank-Sum test (Table 2). In SBWR and PRP, the abundance, species richness, and diversity (*H′*) were significantly higher in the control transects relative to the mangrove transects. But, in CJ, only the abundance was significantly higher in the control transect than in the mangrove transects whereas the diversity (*H′*) are significantly higher in the mangrove transects than control transect. The control transect in CJ is dominated by *Lebinthus luae*, skewing the

Table 2. Summary of results and analysis for the comparison of orthopteran diversity between the mangrove transects and control within each site. * p-value < 0.05; ** p-value < 0.01.

Parameters / **Sites**	**Mangrove Forests** Median	IQR	Min	Max	**Control** Median	IQR	Min	Max	**Two-Sample Analysis *p* Values**
Abundance									
Sungei Buloh Wetland Reserve	0.50	2.00	0.00	2.00	7.50	3.75	6.00	10.00	<0.001**
Pasir Ris Park	1.00	1.25	0.00	4.00	12.00	0.75	10.00	13.00	<0.001**
Chek Jawa	10.50	3.50	7.00	18.00	17.50	7.00	12.00	33.00	0.008**
Species richness									
Sungei Buloh Wetland Reserve	0.50	2.00	0.00	2.00	4.00	0.75	3.00	5.00	<0.001**
Pasir Ris Park	1.00	1.00	0.00	3.00	5.50	1.75	4.00	8.00	<0.001**
Chek Jawa	4.50	2.25	3.00	8.00	4.00	0.75	2.00	8.00	0.361
Diversity (H′)									
Sungei Buloh Wetland Reserve	0.00	0.69	0.00	0.69	1.17	0.25	0.94	1.42	<0.001**
Pasir Ris	0.00	0.58	0.00	1.10	1.59	0.40	1.20	1.98	<0.001**
Chek Jawa	1.29	0.40	0.94	1.96	0.67	0.26	0.22	1.81	0.018*

abundance and diversity (*H′*). These suggest that both secondary dryland forest in SBWR and herbaceous grassy area in PRP clearly supported a greater orthopteran diversity than mangrove forests and that orthopteran diversity between mangrove forests and secondary coastal forests are less straightforward. Thus, the results appeared to support the general consensus that the diversity of herbivorous insect is relative lower in mangrove forests compared adjacent habitats, possibly due to the limited flora diversity in mangrove forests (Abe, 1988; Burrows, 2003).

The species assemblages between the mangrove and control transects were also compared. In SBWR, five of the eight species (62.5%) recorded in the mangrove transects were not found in the control and three out of the six species (50.0%) from control transects were not found in the mangrove forests. In PRP, three out of four species (75.0%) were found exclusively in the mangrove transects and 11 out of 12 species (91.7%) were found exclusively in the control

Fig. 3. Noteworthy species recorded from the three mangrove sites: A, *Ornebius rufonigrus* male adult (body length, BL = ca. 28 mm) from CJ; B, *Ornebius tampines* male from SBWR (BL = ca. 10 mm); C *Ornebius tampines* female from PRP (BL = ca. 9 mm); D, *Svistella chekjawa* male adult from CJ (BL = ca. 6 mm); E, *Lebinthus luae* male (BL = ca. 33 mm) and female (BL = ca. 37 mm) adults from CJ. (Photographs by: H. Yeo [A, D] and M. K. Tan [B, C, E]).

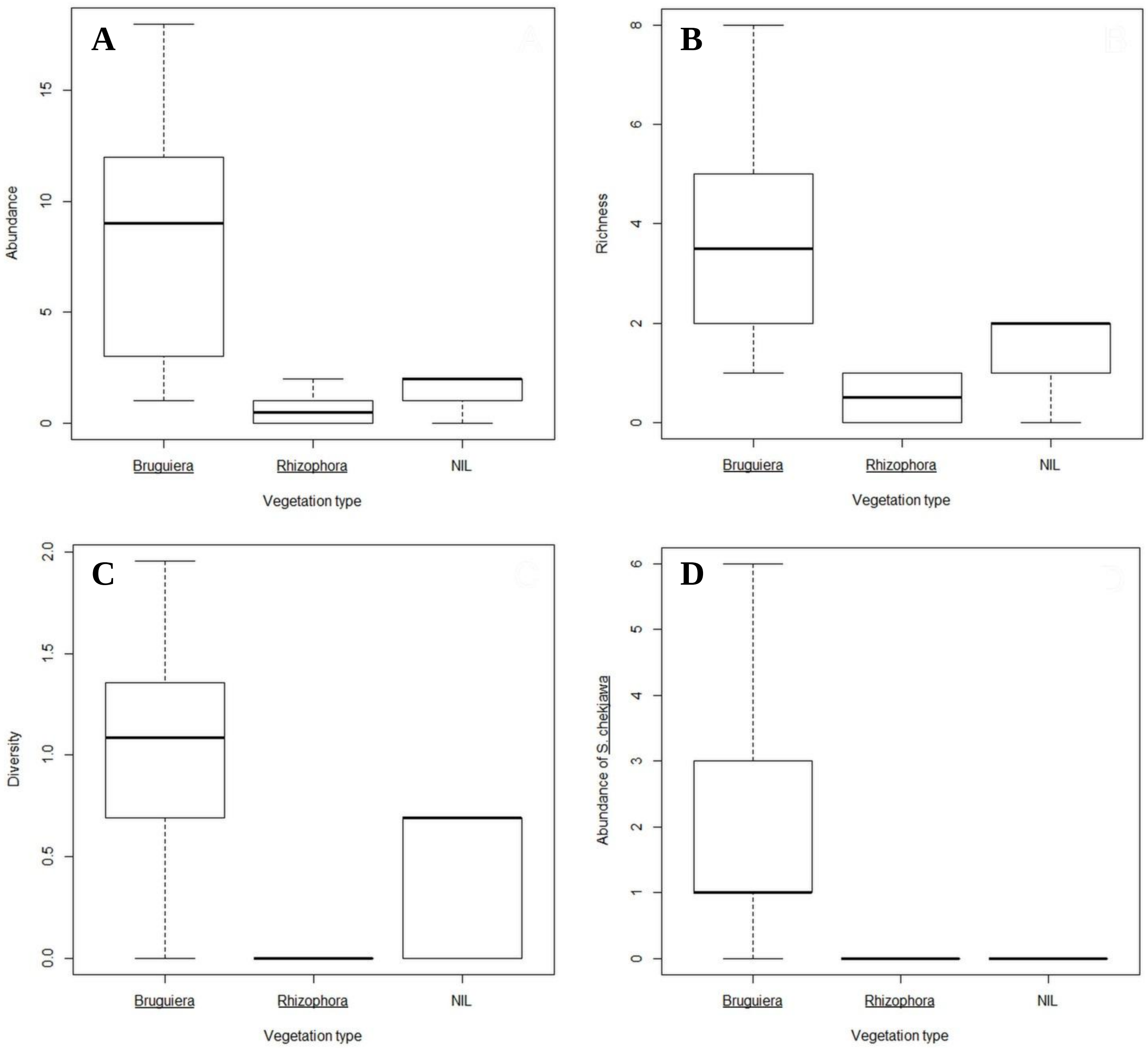

Fig. 4. Boxplots with whiskers from minimum to maximum: A, abundance; B, species richness; and C, diversity (*H′*) of Orthoptera; and D, abundance of *Svistella chekjawa* between mangrove transects of different dominant plant species. The bold line within the box represents the median. NIL represents no dominating plant species.

transects. In CJ, eight out of 13 species (61.5%) were found exclusively in the mangrove transects whereas nine out of 14 species (64.3%) were found exclusively in the control transects. These showed that the species assemblages were different between mangrove and non-mangrove habitats. While the host-specificity and specialisation of the orthopterans recorded were not studied here, the results do provide some preliminary evidence that the orthopterans, as with many herbivorous insects in mangrove forests, are adapted and perhaps even specialised to life in mangrove forest habitats (Lever, 1952; Murphy, 1990; Burrows, 2003). Hence, it is clear that although mangrove forests support a lower orthopteran diversity than inland vegetated habitats, the conservation of the mangrove forest habitat and its entomofauna remains important because of its distinct species assemblages.

CONCLUSIONS

From the study in the three mangrove forest patches in Singapore, as many as 33 species of Orthoptera were recorded. However, analyses of the orthopteran abundance, richness, and diversity suggest that the three sites are different. Comparison with adjacent non-mangrove habitats also shows very contrasting species assemblages with the mangrove forest habitats. Mangrove habitats are precious to our natural heritage, including their orthopteran diversity. This is especially since there are unique orthopteran species new to science and which so far are known to associate only with the mangrove forests of Singapore. This study has also showed that the distribution of opthopterans in the three patches of mangrove forests is not homogeneous. While nature reserves tend to be gazetted for the relative richness in biodiversity, the study showed that non-gazetted sites (PRP and CJ) seem to also support a greater orthopteran diversity compared to SBWR. It was also shown that *Svistella chekjawa* is a mangrove-obligate, endemic species, and thus potentially of high conservation concern. The findings suggest that the different patches of mangrove forests around Singapore all have their own conservation value and raise concerns with regard to potential reclamation plans of and around these mangrove forests. Therefore, the study of the orthopterans in mangrove forests may provide a different understanding of our mangrove forests as well as an alternative perspective of their conservation status.

ACKNOWLEDGEMENTS

The author thanks Yeo Huiqing; Justin Tan, Alan Tan, Anshari Rahman, Ang Hui Ping, Robin Ngiam, and Lim Weihao; and Mirza Rifqi bin Ismail, Eunice Soh and Fiona Loh for assistance in the samplings. The author is also grateful of Koh Kwan Siong and Alan Tan for verifying the identities of mangrove plants. The permission to conduct this study was granted by the National Parks Board, Singapore (Research permit NP/RP10-073-2a).

LITERATURE CITED

Abe, K., 1988. Arboreal arthropod community of mangrove forest in Halmahera, Indonesia. In: Ogino, K. & M. Chihara (eds.), *Biological System of Mangroves: A Report of the East Indonesians Mangrove Expedition 1986*. Ehime University, Japan. Pp. 141–151.

Aksornkoae, S., 1993. *Ecology and Management of Mangroves*. IUCN, Bangkok. 176 pp.

Alongi, D. M., 2002. Present state and future of the world's mangrove forests. *Environmental Conservation*, **29**: 331–349.

Burrows, D. W., 2003. *The Role of Insect Leaf Herbivory on the Mangroves* Avicennia marina *and* Rhizophora stylosa. Unpublished PhD Thesis, School of Tropical Biology, James Cook University. 287 pp.

Chong, V. C. & A. Sasekumar, 1994. Status of mangrove fisheries in the ASEAN region. In: Wilkinson, C. R. (ed.), *Living Coastal Resources of Southeast Asia: Status and Management*. Australian Institute of Marine Science, Townsville. Pp. 56–61.

Clough, B. F., 1993. *Conservation and Sustainable Utilization of Mangrove Forests and their Present State of Conservation in the South-east Asia/Pacific Region*, *Mangrove Ecosystems Technical Reports, Volume 1*. International Society for Mangrove Ecosystems, Okinawa. 202 pp.

Duarte, C. M. & J. Cebrian, 1996. The fate of marine autotrophic production. *Limnology and Oceanography*, **41**: 1758–1766.

Duke, N. C., M. C. Ball & J. C. Ellison, 1998. Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology and Biogeography*, **7**: 27–48.

Google, 2013. *Google Earth 7.0.2.8415*. Google, California. http://earth.google.com/. (Accessed 10 Jun.2013).

Hong, P. N. & H. T. San, 1993. *Mangroves of Vietnam*. IUCN, Bangkok. 173 pp.

Lever, R. J. A. W., 1952. A Malayan leaf typing caterpillar from mangroves periodically submerged in seawater. *Entomologist's Monthly Magazine*, **88**: 95.

Murphy, D. H., 1990. The natural history of insect herbivory on mangrove trees in and near Singapore. *Raffles Bulletin of Zoology*, **38**: 119–203.

Ng, P. K. L. & N. Sivasothi, 1999. *A Guide to the Mangroves of Singapore I: The Ecosystem and Plant Diversity*. Singapore Science Centre, Singapore. 160 pp.

Paarmann, W. & N. E. Stork, 1987. Canopy fogging, a method of collecting living insects for investigations of life history strategies. *Journal of Natural History*, **21**: 563–566.

RExcel, 2007. *R Console (32 bit). R-2.15.2.*The R Foundation for Statistical Computing, Vienna, Austria.

Roberts, H. R., 1973. Arboreal Orthoptera in the rain forests of Costa Rica collected with insecticide: A report on the grasshoppers (Acrididae), including new species. *Proceedings of the Academy of Natural Sciences of Philadelphia*, **125**: 49–66.

Robertson, A. I. & N. C. Duke, 1987. Insect herbivory on mangrove leaves in North Queensland. *Australian Journal of Ecology*, **12**: 1–7.

Robertson, A. I., R. Giddins & T. J. Smith, 1990. Seed predation by insects in tropical mangrove forests: Extent and effects on seed viability and the growth of seedlings. *Oecologia*, **83**: 213–219.

Robertson, A. I., D. M. Alongi & N. C. Duke, 1992. Food chains and carbon fluxes. In: Robertson, A. I. & D. M. Alongi (eds.), *Tropical Mangrove Ecosystems. Coastal and Estuarine Studies 41*. American Geophysical Union, Washington, D. C. Pp. 293–329.

Robillard, T. & M. K. Tan, 2013. A taxonomic review of common but little known crickets from Singapore and the Philippines (Insecta: Orthoptera: Eneopterinae). *Raffles Bulletin of Zoology*, **61**: 701–725

Spalding, M., F. Blasco & C. Field, 1997. *World Mangrove Atlas.* The International Society for Mangrove Ecosystems, Okinawa. 178 pp.

Stork, N. E., 1991. The composition of the Arthropod fauna of Bornean lowland rain forest trees. *Journal of Tropical Ecology*, **7**: 161–180.

Tan, M. K., 2010. Orthoptera in Pulau Ubin. *Nature in Singapore*, **3**: 245–268.

Tan, M. K., 2012. *Orthoptera in the Bukit Timah and Central Catchment Nature Reserves (Part 2): Suborder Ensifera*. Raffles Museum of Biodiversity Research, National University Singapore, Singapore. 70 pp. Uploaded 14 Nov.2012. http://rmbr.nus.edu.sg/raffles_museum_pub/caelifera_btnr_ccnr.pdf. (Accessed at 4 Jun.2013).

Tan, M. K., R. W. J. Ngiam & M. R. B. Ismail, 2012. A checklist of Orthoptera in Singapore parks. *Nature in Singapore*, **5**: 61–67.

Tan, M. K. & T. Robillard, 2012. Two new cricket species (Orthoptera: Gryllidae and Mogoplistidae) from the mangrove areas of Singapore. *The Raffles Bulletin of Zoology*, **60**: 411–420.

Tomlinson, P. B., 1986. *The Botany of Mangroves*. Cambridge University Press, Cambridge. 419 pp.

Urban Redevelopment Authority, 2008. *Master Plan 2008*. Urban Redevelopment Authority, Singapore. http://www.ura.gov.sg/MP2008/index.html. (Accessed 4 Jun.2013).

Veenakumari K. & M. Prashanth, 2009. A note on the entomofauna of mangrove associates in the Andaman Islands (Indian Ocean: India). *Journal of Natural History*, **43**: 807–823.

Yee, A. T. K., W. F. Ang, S. Teo, S. C. Liew & H. T. W. Tan, 2010. The present extent of mangrove forests in Singapore. *Nature in Singapore*, **3**: 139–145.

APPENDIX 1

A checklist of the Orthoptera recorded during the surveys. The classification was based on the Orthoptera Species File Online Version 5.0/5.0 (Eades et al., 2013). The families, subfamilies, and genera are arranged alphabetically for ease of reference.

Species	Sungei Buloh Wetland Reserve		Pasir Ris Park		Chek Jawa	
	Transect	Control	Transect	Control	Transect	Control
SUBORDER **CAELIFERA**						
FAMILY **ACRIDIDAE**						
Subfamily **Catantopinae**						
Traulia azureipennis (Serville)						+
Xenocatantops humilis (Serville)	+			+	+	
Subfamily **Cyrtacanthacridinae**						
Valanga nigricornis (Burmeister)				+		
Subfamily **Oxyinae**						
Pseudoxya diminuta (Walker)				+		
FAMILY **TETRIGIDAE**						
Subfamily **Tetriginae**						
Coptotettix sp.						+
Tetriginae sp.						+
SUBORDER **ENSIFERA**						
FAMILY **GRYLLACRIDIDAE**						
Subfamily **Gryllacridinae**						
Gryllacris sp.					+	+
Gryllacridinae sp.	+	+			+	+
FAMILY **GRYLLIDAE**						
Subfamily **Eneopterinae**						
Lebinthus luae Robillard & Tan						+
Nisitrus vittatus (de Haan)		+				
Subfamily **Euscyrtinae**						
Euscyrtus concinnus (de Haan)				+		
Subfamily **Gryllinae**						
Gymnogryllus sp. (black)						+
Loxoblemmus sp.						+
Velarifictorus sp.						+
Subfamily **Podoscirtinae**						
Aphonoides sp.					+	
Aphonoides sp. 2						+

Species	**Sungei Buloh Wetland Reserve**		**Pasir Ris Park**		**Chek Jawa**	
	Transect	**Control**	**Transect**	**Control**	**Transect**	**Control**
Subfamily **Trigonidiinae**						
Amusurgus sp. 1	+	+		+	+	
Amusurgus sp. 2 (new)	+					
Homoeoxipha lycoides (Walker)				+		
Svistella chekjawa Tan & Robillard			+		+	
Svistella sp. (black-headed)				+		
Green Trigonidiinae sp.	+				+	
Unknown Trigonidiinae sp.		+		+		
FAMILY **MOGOPLISTIDAE**						
Subfamily **Mogoplistinae**						
Apterornebius sp.						+
Ornebius cf. *pullus* Ingrisch		+				
Ornebius rufonigrus Ingrisch	+	+	+	+	+	+
Ornebius tampines Tan & Robillard	+			+	+	
FAMILY **TETTIGONIIDAE**						
Subfamily **Conocephalinae**						
Conocephalus melaenus (de Haan)				+		
Subfamily **Phaneropterinae**						
Elbenia or *Phaulula* sp.	+		+		+	+
Holochlora obtusa Brunner von Wattenwyl			+		+	
Phaneroptera brevis (Serville)				+		
Unknown Phaneropterinae sp.					+	+
Unknown Phaneropterinae sp. 2 (black)					+	

APPENDIX 2

Information on the material collected and examined. All specimens collected are adults. Remark: M = male, F = female.

S/No.	Species	Sex	Locality	Transect	Date	ZRC Ref No.
1.	*Ornebius tampines*	M	SBWR	2	10 Jun.2013	ZRC.ORT.468
2.	*Amusurgus* sp. 2 (new)	F	SBWR	2	10 Jun.2013	ZRC.ORT.469
3.	*Ornebius tampines*	F	Pasir Ris Park	Control	12 Jun.2013	ZRC.ORT.470
4.	*Elbenia* or *Phaulula* sp.	F	Pasir Ris Park	1	12 Jun.2013	ZRC.ORT.471
5.	*Gryllacris* sp.	F	Chek Jawa	2	14 Jun.2013	ZRC.ORT.472
6.	*Gryllacris* sp.	M	Chek Jawa	Near 2	14 Jun.2013	ZRC.ORT.473
7.	*Ornebius tampines*	F	Chek Jawa	1	26 Jun.2013	ZRC.ORT.474
8.	*Aphonoides* sp. 2	F	Chek Jawa	Control	5 Jul.2013	ZRC.ORT.475
9.	*Holochlora obtusa*	M	Chek Jawa	1	12 Jul.2013	ZRC.ORT.476