Institute of Biodiversity and Environmental Conservation

Comparative Aspects of the Ecology of Four Syntopic Species of Angle-headed Lizards, Genus *Gonocephalus* (Reptilia: Agamidae: Draconinae)

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Master of Science
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Wong Jye Wen

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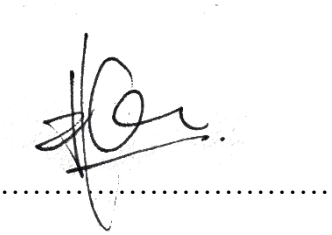
DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

Investigations on coexistence and resource partitioning among sympatric species of reptilians have been widely conducted in other parts of the world but remain poorly studied in Borneo and other parts of south-east Asia. While some generalisations of ecological aspects may be applicable to local reptilian species, species interactions may differ, depending on geographical location and environment conditions. In the present study, four *Gonocephalus* species (*G. bornensis*, *G. liogaster*, *G. doriae* and *G. grandis*) were selected for a study of their comparative biology, the rationale being their perceived ecological similarity and syntopic occurrence, to develop a better insight of the ecological phenomena of resource partitioning. Studies on ecology, specifically on home range, habitat preference, diet and thermal biology, with additional records of parasite, colouration and predation of populations at Kubah National Park, Sarawak, East Malaysia (north-western Borneo) were carried out from June 2018 to December 2019. A total of 16 lizards, representing four species, were equipped with temperature sensitive radio-transmitters, permitting the collection of data on movement and body temperature. Species of *Gonocephalus* generally occupy similar microhabitats, favouring areas with gentle to moderate slope, high canopy cover, are plastic in their usage of trees in terms of sizes or height, moderate distance to waterbodies, on tree trunk, tree branch, moderate to high humidity, moderate to high ambient temperature, low to median light intensity and low to median perch surface temperatures. All had moderate home range sizes that were similar across species and sexes. Nonetheless, species of *Gonocephalus* diverge slightly along the spatial dimension of their ecological niches by exhibiting different levels of preference towards aspects of microhabitats utilised, while the lack of interspecific home range overlaps propose that these species are occupying different parts of the forest, although a more extensive sampling that include more

individuals may be needed to confirm this. The four species were primarily shade-dwellers and have relatively low mean body temperatures. They exploit the thermal niche differently which are reflected from the spatial niche, and are likely influenced by the trophic niche. *G. bornensis* was overall a habitat generalist compared to its congeners, whereas *G. doriae* are relatively specialised. A total of 13 prey types were identified, consisting mainly of insects and other non-insect arthropod groups (earthworms and snails). However, there was insufficient evidence to conclude unequivocally that trophic resource partitioning contributed to coexistence among these species. Additionally, four nematode and three acarid species were successfully identified in these lizards. *G. doriae* serve as new host for *Orneoascaris* sp., and both *G. bornensis* and *G. liogaster* serve as new hosts for *Strongyluris* sp. Species of *Gonocephalus* displayed sexual dichromatism, where males are generally more colourful and vibrant compared to females. Individuals of the genus are able to quickly change skin colouration from dull to bright or vice versa for social interaction and thermoregulation. Furthermore, a *G. liogaster* was also found preyed upon by a *Ptyas carinata*, contributing to the list of predators of *Gonocephalus*. Overall, this study adds to the knowledge of these species and expands current understanding of resource partitioning and mechanisms of coexistence of lizard populations in Borneo's tropical rainforest, which may be beneficial for both conservation and management as well as future studies on other Bornean ectothermic species.

Keywords: Resource partitioning, coexistence, niche, lizard, Borneo

Perbandingan Aspek Ekologi Empat Spesies Sintopik Biawak Kepala Segi Besar, Genus Gonocephalus (Reptilia: Agamidae: Draconinae)

ABSTRAK

Kajian tentang spesis simpatrik dari segi pembahagian sumber dan perkongsian habitat masih kekurangan terutamanya di Borneo dan Asia Tenggara apabila dibandingkan dengan benua lain di dunia. Interaksi antara spesis mungkin berbeza dan bergantung kepada geografi dan kawasan sekitar. Bagi tujuan ini, empat spesis Gonocephalus (G. bornensis, G. liogaster, G. doriae dan G. grandis) telah dikenalpasti berdasarkan persamaan dari segi ekologi dan tindanan sintopic. Kajian telah dijalakan dari Jun 2018 sehingga Disember 2019 (18 bulan) khususnya atas julat pergerakan, keutamaan habitat, diet dan biologi haba. Tambahan pula, pembezaan dari segi warna spesis, jenis parasit dan kesan populasi dari pemangsaan di Taman Negara Kubah telah dikaji. Sebanyak 16 individu dipasangkan dengan pemancar radio sensitif suhu dimana bacaan pergerakan serta suhu badan telah dicatat. Spesis Gonocephalus yang dikaji secara umum memilih mikrohabitat yang serupa, dimana mereka mengutamakan kawasan yang mempunyai kecuraman cerun antara yang agak landai sehingga kecuraman yang sederhana serta kawasan penutupan kanopi yang tinggi, pokok yang berlainan saiz dan ketinggian, berdekatan dengan sumber air, di atas dahan atau batang pokok, kelembapan udara yang sederhana hingga tinggi, suhu kawasan sekitar yang sederhana hingga tinggi, kekuatan sumber cahaya yang sederhana hingga tinggi dan suhu permukaan tempat hinggap adalah rendah hingga sederhana. Semua spesis yang dikaji mempunyai jarak julat pengerakan yang serdehana tidak kira jantina. Namun, spesis Gonocephalus yang dikaji menyimpang sedikit dari sudut ruang dimensis relung ekologi masing-masing, dimana boleh dikatakan keempat-empat spesis ini mempunyai perbezaan dalam pengkhususan dan pemilihan habitat mereka. Kekurangan tindanan julat

pergerakan spesis yang dikaji mencadangkan bahawa mereka menduduki sudut dan bahagian yang berlainan dalam hutan yang sama. Semua spesis yang dikaji kerap memilih kawasan yang berteduh dan mempunyai purata suhu badan yang agak rendah. Spesis Gonocephalus ini berkemungkinan menggunakan pengkhususan terma secara berlainan yang barangkali dipengaruhi oleh pengkhusuan ruang dan trofik. Sebanyak 13 jenis spesis mangsa telah dikenalpasti yang kebesarannya adalah serangga dan arthropod seperti cacing tanah dan siput. Namun, data yang dikumpul tidak mencukupi bagi menjelaskan hubungan pembahagian sumber trofik dan perkongsian habitat. Selain itu, empat spesis nematod dan tiga spesis akarid telah dijumpai dalam spesis yang dikaji. G. doriae yang dijadikan inang bagi Orneoascaris sp. dan G. bornensis serta G. liogaster berfungsi sebagai inang bagi Strongyluris sp. Spesis Gonocephalus menunjukkan perbezaan luaran dari segi jantina, secara umumnya jantan mempunyai lebih banyak warna dari betina. Individu dalam genus mampu menukar warna kulit dengan cepat daripada kusam kepada cerah atau sebaliknya untuk interaksi sosial dan pentermokawalaturan. Satu rekod dimana, G. liogaster telah ditemui dibaham oleh Pytas carinata, menyumbang kepada senarai pemangsa Gonocephalus. Kajian ini telah menambah pengetahuan tentang spesies ini dan meluaskan pemahaman semasa tentang pembahagian sumber dan mekanisme kewujudan Bersama populasi biawak di hutan hujan tropika Borneo.

Kata kunci: *Pembahagian sumber, kewujudan bersama, niche, biawak, Borneo*

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LIST OF ABBREVIATIONS

%FO	Percentage of Frequency of Occurrence
%N	percentage of abundance
%V	percentage of volume
°C	Degree Celsius
asl	Above sea level
AT	Ambient Temperature
ca.	Circa
CC	Canopy Cover
CT	Circumference of Tree
df	Degrees of freedom
DSLR	digital single-lens reflex camera
DW	Distance to Waterbody
e.g.	exempli gratia
et al.	et alia
F	Test statistic for a One-Way ANOVA
FG	Female *Gonocephalus*
g	Gram(s)
GB	*Gonocephalus bornensis*
GD	*Gonocephalus doriae*
GG	*Gonocephalus grandis*
GL	*Gonocephalus liogaster*
h	Hour
ha	Hectare

IRI	Index of Relative Importance
IUCN	International Union for Conservation of Nature
KDE	Kernel Density Estimation
km	Kilometer(s)
LI	Light Intensity
m	Meter(s)
MCP	Minimum Convex Polygon
MD	Mean Distance travelled between location
MDD	Mean Daily Displacement
MG	Male *Gonocephalus*
mm	Millimeter(s)
MSH	Melanophore Stimulating Hormone
n.d.	No Date
nMDS	Non-metric Multidimensional Scaling
No.	Number
NP	National Park
OTUs	Operational Taxonomic Units
P	P-value
PS	Perch Surface
PST	Perch Surface Temperature
PT	Gut Passage Time
r	Pearson Correlation Coefficient
R^2	Coefficient of Determination
RH	Relative Humidity
S	Slope

SD	Standard Deviation
SE	Standard Error
SVL	Snout-vent length
t	Computed t-test statistic
T_a	Ambient Temperature
T_b	Body Temperature
T_s	Perch Surface Temperature
UPGMA	Unweighted Pair Group Method with Arithmetic mean
VES	Visual Encounter Survey
VP	Vertical Position
WT	Weight

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Many ecologists have examined spatial, feeding, and thermal patterns to understand how animals interact among each other and/or with their environment (e.g., MacArthur, 1958; Pianka, 1969; Ballinger et al., 1970; Pianka , 1971a; Cooke et al., 2016; Klenovšek et al., 2013). Species commonly coexist in populations with two or more closely related species (Sillero & Gomes, 2016), and in many of these studies, closely related species in the same community have shown to utilise some of their environmental resources differently, indicating the presence of niche segregation. Hutchinson (1957) regarded niche as a multidimensional space formed by axes corresponding to the environmental factors, where a species can successfully survive and reproduce. Similar species coexist through partitioning resources along certain axes of the multidimensional niche space, while competing over other axes. In other words, they differentiate themselves in one or more aspects of their ecology, which are presumably caused, maintained and/or reinforced by interspecific competition (Hutchinson, 1959; Pianka, 1973; Schoener, 1974). Hutchinson (1978) later defined these axes as “scenopoetic” axes, that included physical and chemical variables, and "bionomic" axes, which are resources that can be competed for (spatial and trophic niches). For species to coexist, some environmental variables or resources from these axes can sometimes interact and influence each another (Tracy & Christian, 1986). Additionally, closely related species were also said to exhibit character displacement to coexist in a community, whereby they acquire distinct observable functional features overtime that is believed to be developed from specialisation on different resources (Brown