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Sakuntha D Gunarathna

Asian Journal of Conservation Biology

Asian Journal of Conservation Biology, July 2019. Vol. 8 No. 1, pp. 47-57 AJCB: FP0103
ISSN 2278-7666 ©*TCRP* 2019

Habitat quality and climate variability determine odonate species diversity and distribution patterns in selected habitats of southern Sri Lanka

Sandamini P.M.M.A, Gunarathna S.D. and Chandana E.P.S.*

Department of Zoology, Faculty of Science, University of Ruhuna, Matara 81000, Sri Lanka

(Accepted: June 15, 2019)

ABSTRACT

The present study was conducted to reveal the odonate diversity and distribution patterns in selected habitats with reference to habitat quality and climate variability in order to determine the conservation status of odonate species and to predict any future threats to odonate assemblages in selected habitats. Odonate assemblages were investigated for six month period at seven different sites in Matara and Hambantota district, Sri Lanka. Their exuviae, key vegetation types, water quality parameters and habitat disturbances were also studied. Climate data from 1998 to 2018 for studied habitats were analyzed. A total 40 odonate species were identified including 11 endemic species. Heat tolerant species and species which can scarcely be seen in dry zone were abundantly recorded at dry zone habitats in the present study. The present study reveals that there might be a significant direct effect of habitat quality on odonate species assemblages and distribution patterns in studied habitats and there might be an indirect effect of climate variability on odonate species assemblages and distribution patterns in studied habitats. Therefore, these data of relationship among odonate species diversity, habitat quality and climate variability in different ecological habitats will useful for conservation of odonates in particular habitats.

Keywords: Odonates, Habitat quality, Climate variability, Species assemblages, Dry zone

INTRODUCTION

Odonata is currently the only insect group represented a global assessment of conservation status (Dolny *et al*., 2012). Odonates are sensitive organisms for the structural changes in their habitats (Schindler *et al*., 2003). Being an indicator of overall habitat quality, odonates are used to monitor the conservation status of their habitats (Clausnitzer *et al*., 2009). They are good indicators for estimating complex changes in landscape and also freshwater habitats (Dolny *et al*., 2012). Odonates rely on water availability for their reproduction and life cycle completion. Therefore, small changes in rainfall pattern can largely affect the nature of their life cycle. Hence, climate variability, create changes in their availability (Collins and McIntyre., 2015). Their broad array of behaviours and their relative ease to identification is important for research studies on odonates (Dolny *et al*., 2012).

A strategic combination of indicator that measures the overall variability of the site and its capacity to support a prescribed environmental matter is a quality of that particular habitat (Beerens *et al*., 2015). Assessment of factors that leads to degrading the habitat quality and scoring methods are useful methods to identify the degree of changes of quality of the particular habitat (Shifley *et al*., 2009; Dolny *et al*., 2012). The major part of determining the habitat quality for wildlife in particular habitat is relating species which are inhabited in that habitat for its survival and reproduction with its habitat features (Grebner *et al*., 2012).

Climate variability refers to the climatic parameters of a region varying from its long term mean as every year in a specific time period the climate of the particular region is different (Selvaraju *et al*., 2006). Spatial and temporal changes in wildlife and health impacts on organisms are the major effects of climate variability (Patz *et al*., 2000; Selvaraju *et al*., 2006).

Sri Lanka has considerable odonate diversity associated with nationally and internationally important ecosystems. Bundala National Park (A Ramsar Wetland), Kalamatiya Sanctuary, Bandaththara marshland system, Ensalwatta estate which belongs to Sinharaja rainforest and Kosgahadola stream which belongs to Mulatiyana rainforest reserve are very important nature reserves in Southern Sri Lanka.

There are no published reports of odonate assemblages with reference to habitat quality and climate variability in Sri Lanka so far. These habitats used as indicator sites for the present study to assess the habitat quality and the effects of climate variability on the conservation status of odonates in particular habitats.

Hence the objective of the present study is to reveal the odonate diversity and distribution patterns in selected habitats with reference to climate variability and habitat quality in order to determine the conservation status of odonate species and to predict any future threats to odonate diversity and distribution patterns in selected habitats.

**Corresponding Author's E-mail: epschandana@zoo.ruh.ac.lk*

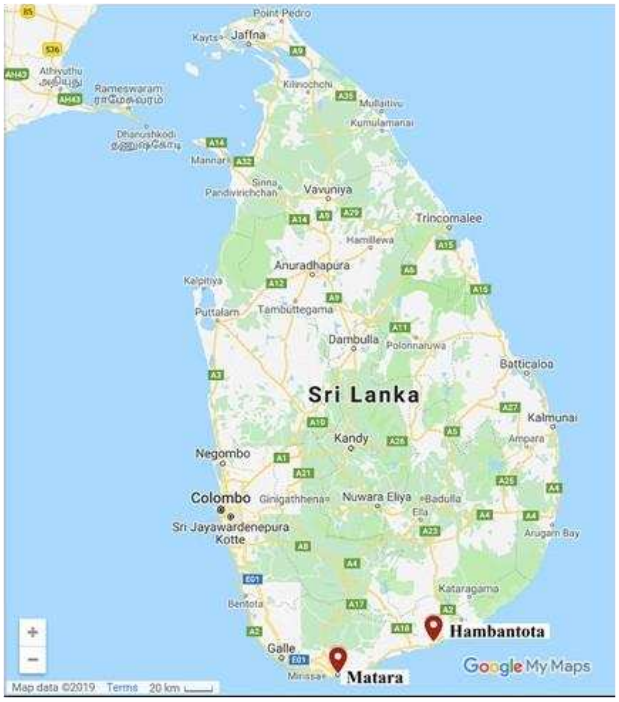

Figure 1. Location of Matara district and Hambantota district in the southern province, Sri Lanka

MATERIALS AND METHODS

Site selection

Seven different sites were selected for the present study from Matara district (5°56 ´N, 80°32´) and Hambantota district (6°07 ´N, 81°07´E) (Figure 1). Matara is the smallest district in Southern province with an area of 1282 Km^2 while Hambantota is the largest district in Southern province with area of 2609 Km^2 (Seo *et al*., 2005).

Embilikala lagoon (EL) and Bundala Lagoon (BL) sites associated with Bundala National Park (BNP) two sites from Kalamatiya Lagoon (KL) and three different sites associated with Nilwala River were selected namely as upper area site (NRU), middle area site (NRM) and lower area site (NRL).

Bundala and Kalamatiya sites were located in Hambantota. BNP was designated in 1993 as the first Ramsar wetland in Sri Lanka. It falls within the southeastern semi -arid zone in Sri Lanka with hot and dry climatic conditions (6°11´N 81°11´E) (Figure 2). KL covers 606ha area and located on the south-eastern coast of Sri Lanka. The lagoon is in the dry zone of the country which receives an annual rainfall of 1000 - 1250 mm with 27^0C mean air temperature (Ekanayake *et al*., 2005), (6°1´N 80°95´E) (Figure 3).

Sites associated with Nilwala River were located in Matara district and those study sites are different from all other two sites as NRU is associated with Sinharaja rainforest (6°22'N 80°36' E) (Figure 4), NRM is associated with Mulatiyana rainforest reserves (6°10'N 80°34' E) (Figure 5) and NRL is associated with Kirala Kale ecotourism zone (5°59'N 80°33' E) (Figure 6). These sites are in the wet zone of Sri Lanka with 1063mm average rainfall and 26^0C average temperature.

Data collection

Odonate sampling

The study was conducted from June to December 2018. Each sites were visited monthly and sampling was carried out between 09.00h – 16.00h as discussed elsewhere (Loiola and Marco., 2011). Belt transect method was used for sampling (Mohagan and Villanueva., 2013). Plots were randomly established along the selected transect representing both riparian area and water body. Odo- nates were caught with a butterfly net or hand net and released after identification (Luke *et al*., 2017). Odonates were identified by using standard field guides (Bedjanic., 2004; Bedjanic *et al*., 2007; Sumnapala, 2017). Odonate exuvia was also studied. They were collected by using Surber quadrate sampler method and net and tray method (Hill *et al*., 2005). Exuviae were identified up to family level by using standard identification keys (Cham., 2007; Cham., 2009). Specific behaviour patterns of odonates (i.e. perching, hunting, mating and egg-laying) and associated plants were also studied. Associated plants were identified by using standard guides (Mühlberg and Lindsay., 1982; Weber., 2017).

Figure 2. Study sites of Bundala National Park

Figure 3. Study sites of Kalamatiya lagoon

Figure 4. Study sites of Nilwala River upper area

Figure 5. Study sites of Nilwala River middle area

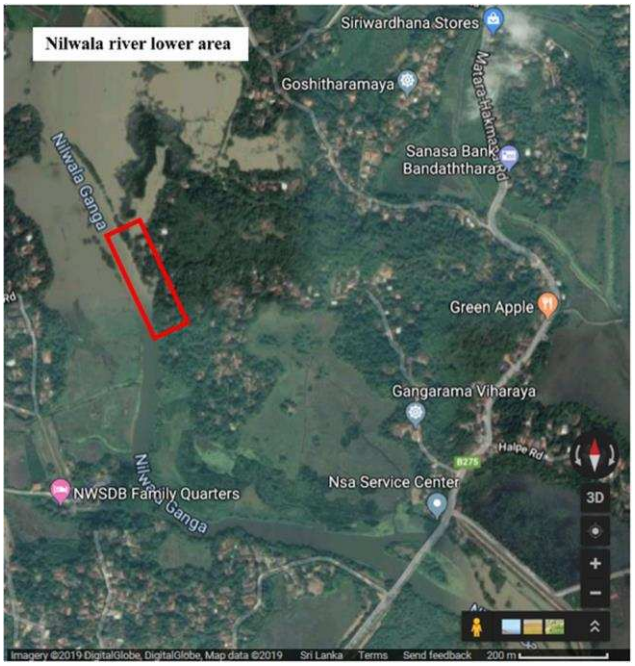

Figure 6. Study sites of Nilwala River lower area

Measuring habitat quality

Water quality parameters (pH, Conductivity, Salinity, Dissolved Oxygen, Biological Oxygen Demand, NO_3^- & PO_4^{3-}) of each study sites were measured according to standard methods described elsewhere (Luke *et al*., 2017). Habitat disturbances were studied according to methods described elsewhere (Dolny *et al*., 2012). Key vegetation types were identified by using standard field guides (Mühlberg and Lindsay., 1982; Weber., 2017).

Climate data

Climate data, (i.e. Minimum annual temperature, Maximum annual temperature & Annual rainfall of studied habitats) were obtained for 1998 - 2018 years from Department of Meteorology, Colombo, Sri Lanka.

Data analysis

Shannon-Weiner Diversity Index, Jaccard Similarity Index and Species richness were calculated by using Past3 Software to measure species diversity and similarity among selected sites (Ball *et al*., 2014). Species were grouped based on the similarity of odonate assemblages and associated plant species in selected habitats by using hierarchical cluster analysis (Past3 software) (Hammer *et al*., 2001). Odonate diversity data of present study were compared with already published data in survey carried by Chandana *et al* in 2012 and odonate distribution patterns of the present study were compared with already published data in the photographic guide to the dragonflies of Sri Lanka by

Table 1. Summary of order anisoptera recorded in study sites

Family	Location / Odonate species	K	N.1	N.2	N.3	B	E
Libellulidae	Pied parasol *Neurothemis tullia*	+	-	-	+	-	-
	Black tipped percher *Diplacodes nebulosa*	+	-	-	-	+	+
	Oriental scarlet *Crocothemis sevilia*	+	-	-	+	-	+
	Wandering glider *Pantala flavescens*	+	+	-	+	-	-
	Asian skimmer *Ortherum glaucum*	+	-	-	+	-	-
	Blue percher *Diplacodes trivialis*	+	-	-	-	-	+
	Marsh skimmer *Ortherum luzonicum*	+	-	-	-	-	-
	Variegated flutterer *Rhyothemis variegate*	+	-	-	+	-	-
	Asian pintail *Acisoma panorpoides*	+	-	-	+	-	+
	Green skimmer *Orthetrum Sabina*	+	-	-	-	+	+
	Asian groundling *Brachythemis containata*	+	-	-	+	+	+
	Dancing dropwing *Trithemis pallidinervis*	+	-	-	-	-	+
	Costal pennat *Macrodiplax cora*	+	-	-	-	-	-
	Indigo dropwing *Trithemis festiva*	-	+	-	-	-	-
	Spine tufted skimmer *Ortherum chrysis*	-	+	-	-	+	-
	Spine legged redbolt *Rhodothemis ruta*	-	-	-	-	+	+
	Crimson dropwing *Trithemis aurora*	-	-	-	+	-	-
	Pink skimmer *Ortherum pruinosum*	-	+	-	-	-	-
	Sociable glider *Tramea limbata*	+	-	-	-	-	-
	Restless demon *Indothemis limbata*	-	-	+	-	-	-
Gomphidae	Rapacious flangetail *Ictinogomphus rapax*	-	-	+	-	-	-
	Sri lanka wall's grapple tail *Heliogomphus walli*	-	-	+	-	-	-

K – Kalamatiya sites, N.1 – Nilwala River upper area sites, N.2 – Nilwala River middle area sites,
N.3 – Nilwala River lower area sites , B – Bundala lagoon site, E – Embilikala lagoon site

Bedjanic *et al* in 2007. Data were statistically analyzed by using IBM statistics (SPSS version 25). Association of climate variability and habitat quality with odonate assemblages were tested by using binary logistic regression (Trull *et al*., 2018). Climate data were statistically analyzed by using descriptive statistics in IBM statistics (SPSS version 25).

RESULTS

Present study yielded a total 40 species of odonates including 18 zygopterans from 06 different families and 22 anisopterans from 2 different families. Family - Coenagrionidae and family - Platycnemididae were recorded dominantly among zygopterans and species of the family - Libellulidae was dominant among anisopterans (Table 1&2).

12 endemic species were recorded while only one migratory species (*Pantala flavescens*) was recorded during the study. 02 rare zygopterans, one rare anisopteran and 05 uncommon species were recorded including 03 zygopterans and 02 anisopterans. 06 "Endangered", 08 "Vulnerable" and 08 "Near Threaten" species were recorded while only one "Critical Endangered" species (*Libellago corbeti*) was recorded (Table 3).

Highest species (47.50%) composition among all selected dry zone habitats were recorded at KL (Figure 7). Highest species composition was recorded at NRU

Table 2. Summary of order Zygoptera recorded in study sites

Family	Location / Odonata species	K	N.1	N.2	N.3	B	E
Coenagrionidae	Common bluetail *Ischnura senegalensis*	+	-	-	-	+	+
	Yellow wax tail *Ceriagrion coromandelianum*	+	-	-	+	+	-
	Wandering wisp *Agriocnemis pygmaea*	+	-	-	-	+	-
	Dawn blue tail *Ischnura aurora*	+	-	-	-	+	-
	Blue sprite *Pseudagrion microcephalum*	-	-	-	-	+	-
	Malabar sprite *Pseudagrion malabaricum*	-	-	-	-	+	-
	Sri Lanka Black-tipped flashwing *Vestalis apicalis*	-	-	+	-	-	-
Caloptrugidae	Sri Lanka Green's gem *Libellago greeni*	-	+	+	-	-	-
Chlorocyphidae	Sri Lanka Ebony gem *Libellago corbeti*	-	-	+	-	-	-
	Sri Lanka Adam's gem *Libellago adami*	-	+	-	-	-	-
	Sri Lanka Shinning gossarmerwing *Euphaea splendens*	-	+	+	-	-	-
Euphaeidae	Sri Lanka Red striped threadtail *Elattoneura tenax*	-	+	-	-	-	-
Platycnemididae	Yellow featherleg *Copera marginipes*	-	-	+	-	+	-
	Sri lanka glittering threadtail *Elattoneura centralis*	-	+	+	-	-	-
	Marsh dancer *Onychargia atrocyana*	+	-	-	-	-	-
	Sri Lanka Two spotted threadtail *Elattoneura oculata*	-	-	+	-	-	-
	Sri Lanka Jungle threadtail *Elattoneura caesia*	-	+	-	-	-	-
Platystictidae	Sri Lanka Dark forest damsel *Platysticta aplicalis*	-	+	+	-	-	-

K – Kalamatiya sites, N.1 – Nilwala River upper area sites, N.2 – Nilwala River middle area sites, N.3 – Nilwala River lower area sites, B – Bundala lagoon site, E – Embilikala lagoon site

site and NRM site (35.48%) among selected wet zone sites (Figure 8). Highest species richness (19 species) was recorded at study sites of KL among all studied habitats (Figure 9). According to the Shannon Weiner Index, highest species diversity was recorded at KL sites (H = 2.944) and lowest species diversity was recorded at NRL site (H = 1.792) among all studied habitats.

Cluster Analysis of Odonate species based on Jaccard Similarity Index reveals two major species assemblages based on their occurrences in habitats. Con- spicuous similar diversity of odonates were recorded between NRU site and NRM site (Similarity = 0.28) (Figure 10).

11 exuviae were observed under three different families as family – Libellulidae, family – Coenagrionidae and family – Gomphidae (Figure 11). Among them, exuviae from family – Libellulidae were abundantly recorded (Table 4).

According to the comparison of odonate diversity data between present study and study conducted in 2012 at same habitats, large number of odonate species were recorded in the present study than previous studies. Accord- ing to the comparison of odonate distribution patterns with previous data, heat-tolerant species or species live in dry conditions (Coastal pennat (*Mcarodiplax cora*), Sociable glider (*Tramea limbata*)) and species which scarcely be seen in dry zone (Marsh Skimmer (*Orthetrum luzonicum*)) were abundantly recorded at KL site (dry zone) in present study (Figure 12).As major human disturbances, garbage disposal, soil manipulations and land clearance were observed at NRL site as regular disturbances. Garbage disposal, land clearance

Table 3. Abundance, ecological status and conservation status of recorded odonates at study sites.

Odonate species			**Odonate species**		
Zygoptera	**IC**	**AE**	**Anisoptera**	**IC**	**AE**
Common bluetail	LC	CR	Pied parasol	LC	VR
Yellow wax tail	LC	VR	Black-tipped percher	NT	UR
Wandering wisp	LC	VR	Oriental scarlet	LC	CR
Shinning gossamer wing	NT	VE	Wandering glider	LC	VM
Red striped thread tail	EN	UE	Asian skimmer	NT	CR
Dark forest damsel	EN	CE	Blue percher	LC	VR
Black-tipped flashwing	VU	CE	Blue persure	LC	CR
Green's gem	EN	CE	Variegated flutterer	LC	CR
Ebony gem	CR	RE	Asian pintail	LC	CR
Two-spotted thread tail	EN	UE	Green skimmer	LC	VR
Dawn blue tail	NT	CR	Asian groundling	LC	VR
Malabar sprite	LC	CR	Dancing dropwing	NT	CR
Yellow featherleg	LC	CR	Costal pennat	VU	UR
Sri Lanka Dark glittering thread tail	VU	CE	Indigo dropwing	VU	CR
Marsh dancer	VU	UR	Spine tufted skimmer	VU	CR
Adam's gem	VU	CE	Spine legged red bolt	NT	CR
Jungle thread tail	VU	UE	Crimson dropwing	LC	CR
Blue sprite	LC	CR	Sri lanka wall's grapple tail	EN	CE
			Sociable glider	LC	CR
			Restless demon	NT	RR
			Rapacious flangetail	LC	CR
			Pink skimmer	NT	CR

IC – IUCN conservation status, AE – Abundance and Ecological status
For IC; CR – Critically endangered, EN – Endangered, VU – Vulnerable, NT– Near threaten, LC – Least concern
For AE; C – Common, U – Uncommon, V – Very common, R – Rare, R– Resident, M – Migrant, E – Endemic

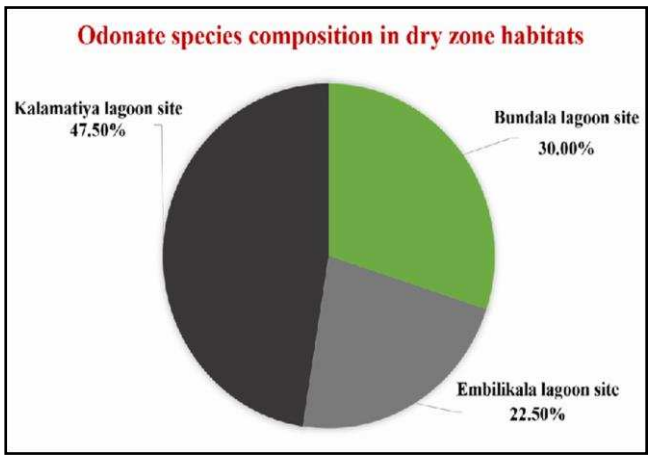

Figure 7. Odonate species composition among study sites of the dry zone

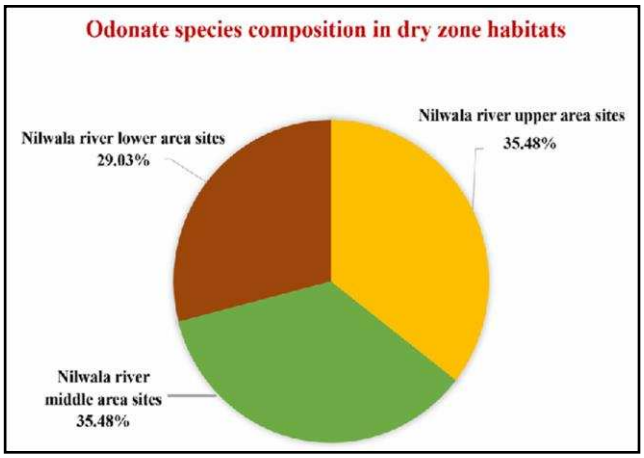

Figure 8. Odonate species composition among study sites of the wet zone

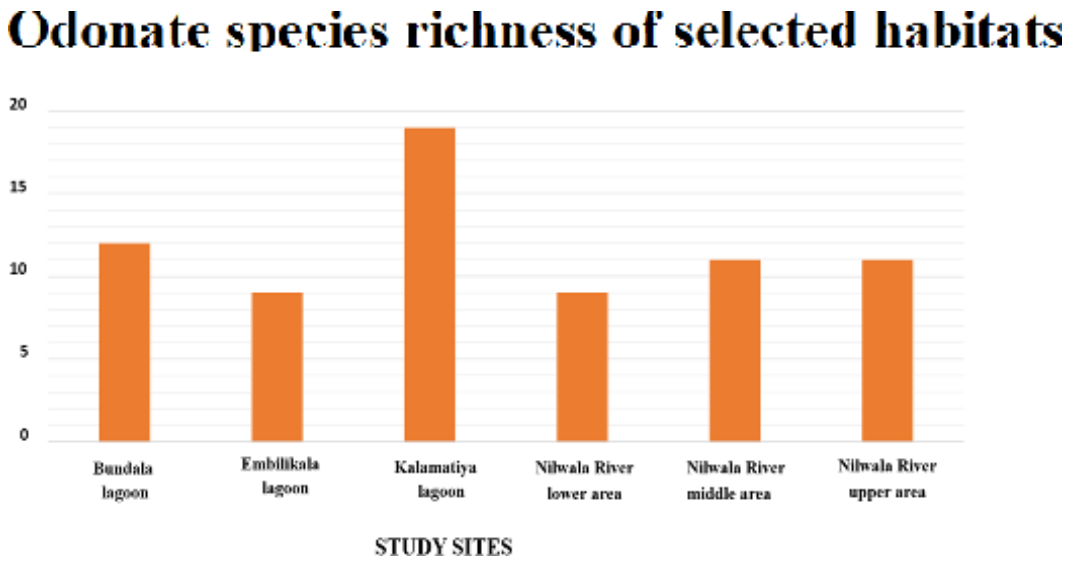

Figure 9. Odonate species richness at study sites

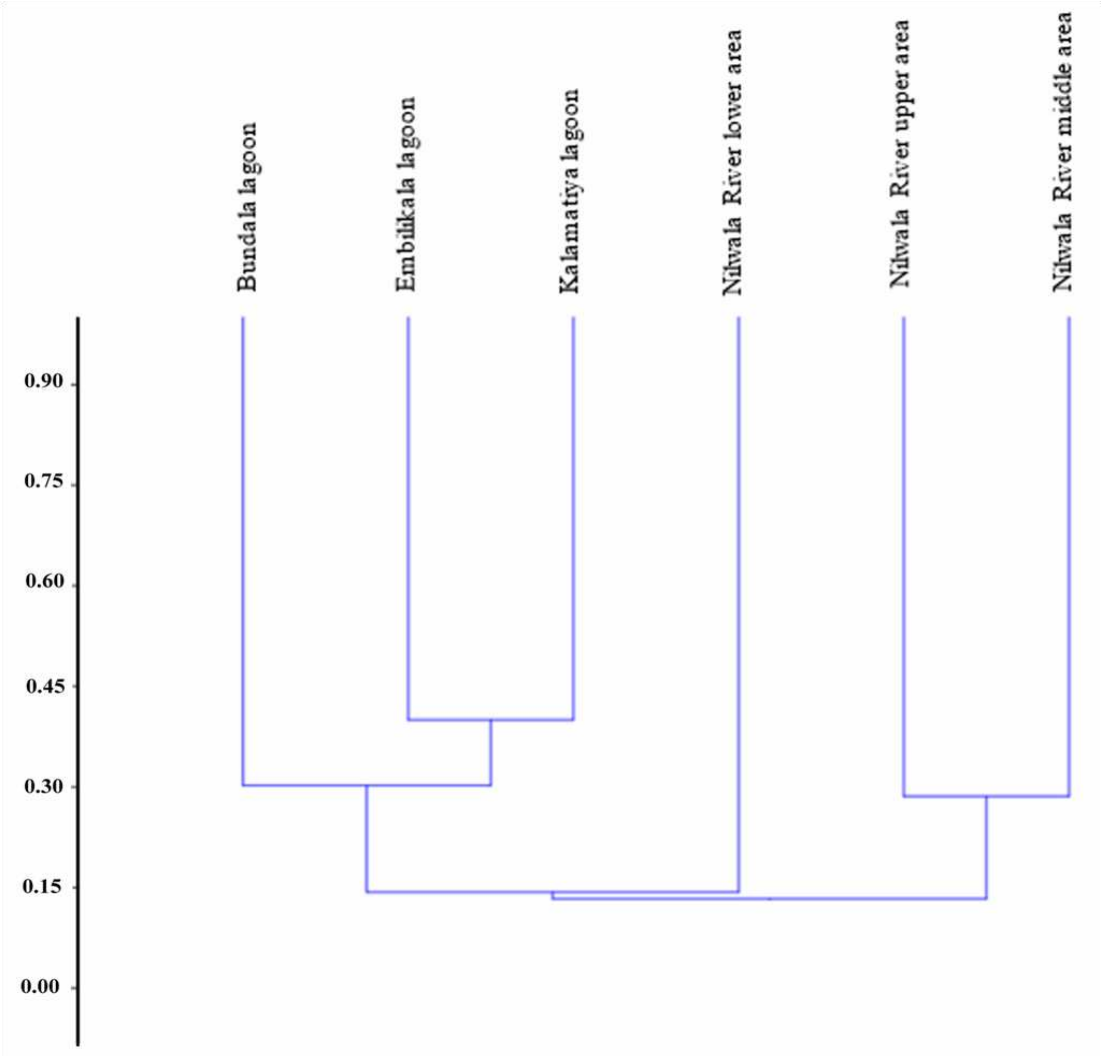

Figure 10. Hierarchical cluster analysis of odonate species

Table 4. Summary of exuviae identification at different study sites

Location	**Family**	**No. of exuviae**
Mawarala	Libellulidae	01
	Coenagrionidae	01
Bundala lagoon	Gomphidae	01
	Libellulidae	03
	Coenagrionidae	02
Kalamatiya lagoon	Gomphidae	01
	Libellulidae	02

Table 5. Summary of habitat disturbances observed at different study sites

Sites	**K**	**B**	**E**	**N.1**	**N.2**	**N.3**
Disturbances						
Garbage disposal	√	√	√	√	√	√
Soil manipulation	√	√				√
Land clearance	√	√				√
Habitat fragmentation	√	√				
Grazing	√					
Other		√	√			√

Table 6. Summary of dominant vegetation types recorded at different study sites

Plant species	**K**	**N.1**	**N.2**	**N.3**	**B**	**E**
Panicum repens (Etora)	+	-	-	-	-	-
Prosopis juliflora (Kalapu andara)	+	-	-	-	+	+
Hydropila sp. (Ikiriya)	+	-	-	-	-	+
Typha angustifolia (Pan)	+	-	-	-	+	+
Mimosa pudica (Nidikumba)	+	-	-	+	+	+
Opuntia dileni (Katu pathok)	+	-	-	-	+	+
Ceratophyllum demersum (Coon tail)	+	-	-	-	-	-
Cuscuta sp. (Anga-mula nathiwel)	+	-	-	-	-	+
Echinochloa crusgalli (Water grass)	+	-	-	-	+	+
Soneratia caseolaris (Kirala)	+	-	-	+	+	+
Dichrostachys cinerea (Katu andara)	+	-	-	-	+	+
Luziola sp. (Water grass)	+	-	-	-	-	-
Chrysopogona ciculatus (Tuththiri)	+	-	-	-	-	-
Acrostichum aureum (Keremkoku)	+	-	-	-	-	-
Cynodon dactylon (E-thana)	+	-	-	-	-	-
Halosarcia indica (Palu)	+	-	-	-	-	-
Cyperus procerus (Nut grass)	+	-	-	-	-	-
Panicum sp.	-	+	-	+	+	+
Sphagneticola trilobata (Kaha karabu)	-	+	+	-	-	-
Clidemia sp. (Kata-kalu bovitiya)	-	+	+	-	-	-
Syngonium angustatum (Wel-kohila)	-	-	+	-	-	-
Capparis sp. (Welangiriya)	-	-	+	-	-	-
Nelumbia sp. (Nelum)	-	-	-	+	-	-
Nymphoides indica (Kumudu)	-	-	-	+	-	+
Lagenandra ovatu (Ketala)	-	-	-	+	-	-
Trichopu szeylanicus (Bim-pol)	-	-	-	+	-	-
Nymphea sp. (Manel)	-	-	-	+	-	+
Ipomea sp. (Bimthamburu)	-	-	-	+	-	-
Nelumbo nucifera (Olu)	-	-	-	+	-	-
Cassia auriculata (Ranawara)	-	-	-	-	+	+
Acanthus ilicifolius (Katu-ikiriya)	-	-	-	+	-	-

K – Kalamatiya sites, N.1 – Nilwala River upper area sites, N.2 – Nilwala River middle area sites, N.3 – Nilwala River lower area sites, B – Bundala lagoon site, E – Embilikala lagoon site

Table 7. Summary of water quality parameters measured at different study sites

Location / Parameter	K	N.1	N.2	N.3	B	E
pH	8.4±0.3	6.4±0.4	7.0±0.2	7.2±0.1	7.6±0.1	7.7±0.2
Conductivity (µs/ cm)	37.2±3.4	25.4±0.8	64.8±0.6	60.2±0.1	41.5±3.9	37.1±0.9
Temperature (°C)	30.5±0.5	27.3±0.3	30.5±0.5	31.0±0.1	32.0±0.6	33.5±0.5
Salinity (ppm)	0.3±0.1	0.1±0.1	0.2±0.1	0.3±0.1	0.6±0.1	0.8±0.1
DO (m mol dm^{-3})	6.3±0.4	9.7±0.4	12.2±2.0	7.5±0.1	4.7±0.1	6.9±0.1
BOD (m mol dm^{-3})	2.8±0.7	8.0±0.5	8.0±0.2	5.0±0.1	4.1±0.5	3.7±0.1
Nitrate (mg l^{-1})	0.3±0.3	0.7±0.3	0.9±0.3	0.1±0.1	0.5±0.1	0.2±0.1
Phosphate (µg l^{-1})	360.0±10.0	380.0±30.0	425.0±15.0	495.0±15.0	417.5±7.5	405.0±5.0

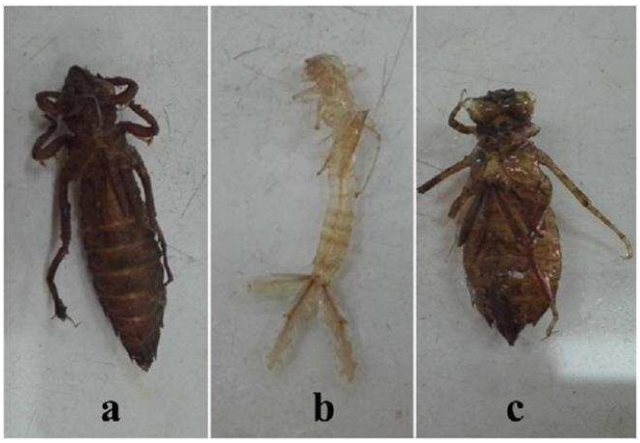

Figure 11. Exuviae of odonates recorded in present study under three different families

and grazing were recorded at KL and Bundala lagoon sites as repeated disturbances in every several years. Only one major disturbance (Garbage disposal) was identified at NRU and NRM sites (Table 5). Key vegetation types recorded during the study period in both wet zone and dry zone sites are given in Table 6.

According to the water quality parameters measured at study sites, considerable difference of salinity measurements of Embilikala lagoon was identified than that of Bundala lagoon (Table 7). According to the statistical analysis, water quality parameters among study sites of NRU, NRM and NRL were significantly different and water quality parameters between study sites of BNP were also significantly different.

There is a considerable increasing pattern can be identified for both minimum and maximum average annual temperature of Hambantota district from 1998 – 2018. According to the annual rainfall fluctuations for past 20 years from 1998 – 2018, the conspicuous increasing pattern can be identified in both Matara and Hambantota districts.

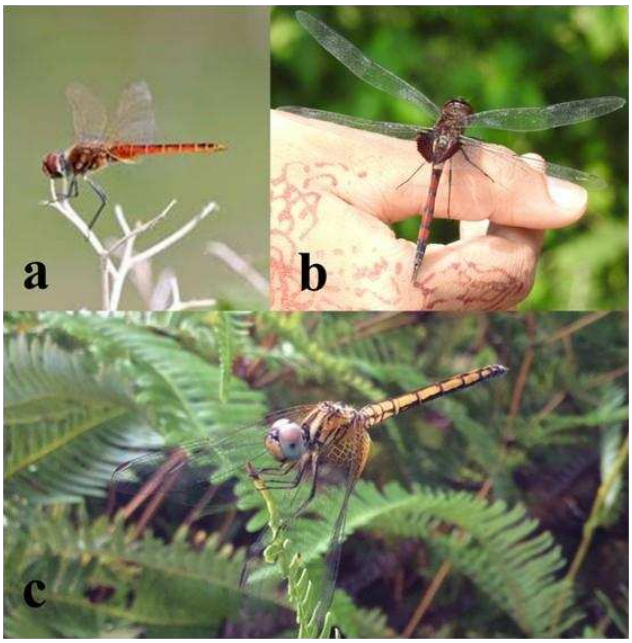

Figure 12. Odonate species recorded in Kalamatiya lagoon site

According to the binary regression analysis of climate data and habitat disturbances with odonate assemblages in selected habitat; habitat quality has a significant relationship with odonate assemblages (P = 0.002) at 0.05 significant level while climatic variability has no significant relationship with odonate assemblages. The influence of habitat quality on the conservation status of odonate species in selected habitats may increase (Exp (B) = 0.033) for the coming years.

DISCUSSION

In the present study, two lagoon sites were selected in BNP namely Bundala lagoon and Embilikala lagoon. Less number of habitat disturbances were identified at

Embilikala lagoon than Bundala lagoon site. However, the intensity of these human disturbances was larger than that of Bundala lagoon. In Embilikala lagoon these habitat disturbances were identified as repeated, regularly and constantly occurring disturbances caused by human activities. Due to their wide range of distribution, odonates are easy to record and susceptible to specific types of habitat changes induced by human activities (Schindler *et al*., 2003). Therefore, it might be the reason for recorded low number of odonate species (09 species) and lower diversity of odonates (H= 2.197) in that site among all studied habitats in dry zone. The intensity of disturbances of Bundala lagoon was lower than that of Embilikala lagoon. It might be the reason for better habitat quality in Bundala lagoon site than Embilikala lagoon site. As well as vegetation diversity of Bundala lagoon site is higher than Embilikala lagoon site. Adult odonates diversity and abundance often correlated with local abundance of vegetation (D'amico *et al*., 2004). Hence, the well-developed vegetation structure of Bundala lagoon might be the reason for recorded large species richness (12 species) and higher diversity (H= 2.485) in Bundala lagoon site than Embilikala lagoon site.

Although Bundala lagoon and Embilikala lagoon located in BNP, their water quality parameters were significantly different. Blue sprite (*Pseudagrion microcephalum*) and Malabar sprite (*Pseudagrion malabaricum*) were recorded only at Bundala lagoon sites. The recorded higher salinity of water was identified in Embilikala lagoon than Bundala lagoon. Malabar sprite and Blue sprite prefer brackish water for their reproductive behaviour (Bedjanic *et al*., 2007). Therefore, differences in their water quality parameters might be the reason for Blue sprite and Mala- bar sprite recorded only at the Bundala lagoon site.

Among all study sites large number of habitat disturbances were identified at KL sites. However, it was recorded as repeated disturbances occurred at particular time of every several years. Nevertheless, well-developed vegetation structure were identified at KL sites. Habitat selection of adult odonate is strongly dependent on vegetation structure (Clausnitzer *et al*., 2009). Therefore, although large number of habitat disturbances were recorded, higher species richness was identified in KL sites might due to well-developed vegetation structures. Adult odonates are suitable indicators to indicate health of the habitats (Dolny *et al*., 2012). Therefore higher diversity of KL sites might be an indication of good habitat quality of KL sites than the sites associated with BNP. Due to Jaccard similarity index, reveal similar diversity pattern between Embilikala lagoon site and KL sites. Though they were situated in two different locations, as Shafie *et al*., recorded in 2011; it might be happened due to similar vegetation structure of these two sites.

Heat tolerance species or species that can live in dry, hot conditions as Coastal pennat (*Macrodiplax cora*) and Sociable glider (*Tramea limbata*) and species that scarcely be seen in dry zone as Marsh skimmer (*Orthetrum luzonicum*) were abundantly recorded at KL. It might be due to the increasing pattern of temperature fluctuation of Hambantota district. Temperature is known to affect odonate physiology and it might influence changes in geographical distribution of donates (Hassall and Thompson *et al*., 2008). Therefore presence of heat tolerance species and species that scarcely be seen in the dry zone were recorded in present study than previous studies might indicate that increasing trend of the temperature of Hambantota district may affect the distribution pattern of particular odonates.

Among the study sites of wet zone habitats, lowest habitat disturbances were recorded at sites of NRU and sites of NRM. The garbage disposal was identified as the major habitat disturbance caused by human at those sites. It might be the reason for present habitat features at those sites. Therefore recorded higher diversity (NRM - H=2.398, NRU – H=2.303), higher species richness (11 species) and higher species composition (35.48%) can be identified at NRU and NRM among all study sites of wet zone. Endemism is also high in these sites. All most all endemic species recorded in the present study were identified at these two sites. Optimum habitat conditions of these sites might be the reason for recorded higher endemism in these two sites. Lower species composition (29.03%) was recorded at study sites of NRL as higher habitat disturbances were identified at NRL site among all study sites of wet zone habitat. It might be the reason for lowest species richness (09 species) and lowest species diversity (H=1.792) at the NRL. According to hierarchical cluster analysis, similar diversity pattern of odonate assemblages can be identified between study sites of NRU and study sites of NRM. It might be due to similar vegetation structure of these two study sites.

Study of odonate exuviae is essential to avoid biased surveys in odonates studies because sometimes larvae might be found at water bodies, but no emerging of individuals cannot be identified due to changes of habitat quality (Raebel *et al*., 2012). Odonates larvae strongly depend on the substratum type such as aquatic vegetation present of the water body (Clausnitzer *et al*., 2009). Therefore by studying odonates larvae also gives an indication of habitat quality. Exuviae study gives clues about the odonate which use particular habitat for their life cycle completion (Raebel *et al*., 2010). According to the identification of exuviae in the present study, odonates of family-Libellulidae, family-Coenagrionidae and family- Gomphidae might be used NRM sites, Bundala lagoon site and KL sites for their life cycle completion.

High variability of odonate species diversity was recorded in present study than study conducted in 2012 at present study sites. It might be due to the climate variability especially, variability of rainfall pattern trough past few years. Because of odonate reproductive behaviour highly rely on availability of freshwater, increasing rainfall and changing rainfall pattern might be the reason for differences in diversity and distribution patterns of odonates in study sites.

Binary logistic regression indicates that there might be a significant direct effect of habitat quality on odonates assemblages in studied habitats and there might be an indirect effect of climate variability on odonates assemblages in studied habitats. Presence of "Endangered", "Vulnerable", "Critically endangered" and "Near threatened" odonate species in studied habitat might be an indication of the importance of conservation

of the study sites. Conservation of existing natural habitats in the dry zone and wet zone of Southern province, Sri Lanka might be critical for the long term survival of these valuable ecological indicators.

ACKNOWLEDGEMENTS

Permission to study odonate species diversity and distribution patterns were granted by the Department of Wildlife Conservation under the permit no WL/3/2/53/18. The authors wish to thank Department of Wildlife Conservation, Sri Lanka and Department of Zoology, University of Ruhuna, Sri Lanka. The financial assistance from Harischandra Mills. Plc.Ltd. Matara,Sri Lanka is acknowledged.

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