A Study on Diversity and Habitat Characterisation of Odonata at Nalsarovar Bird Sanctuary, India

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Available online at: www.isroset.org

Received: 15/Mar/2019, Accepted: 07/Apr/2019, Online: 30/Apr/2019

Abstract- A study was carried out in Nalsarovar Bird Sanctuary to assess habitat characteristics preferred by Odonates (Dragonflies and Damselflies) in Nalsarovar Bird Sanctuary (Ramsar Site), Gujarat. The entire study area was stratified into 6 different habitat type. Transects Survey was carried out covering all habitats. Each transect was repeatedly surveyed covering all seasons. A total of 30 species of dragonflies and damselflies were encountered belonging to 5 families namely Libellulidae, Gomphidae, Aeshnidae, Coenagrionidae, and Lestidae during the entire study. The most habitat type utilized by Odonates, out of total individual encountered during survey are Habitat-Type-4 and Habitat-Type-2 and it contributes to around 64.3 % of Odonate within study area. However, most preferred habitat by Anisoptera (Dragonflies) is Habitat-Type-4. Similarly, most preferred habitat by Zygoptera (Damselflies) is Habitat-Type-6 and Habitat-Type-2. Relative frequency (%) and relative abundance (%) of each Odonate species (Dragonflies and Damselflies) were calculated based on data collection. Relative frequency (%) of *Trithemis pallidinervis* was recorded highest in most of the habitats and Relative abundance (%) of *Trithemis pallidinervis* highest in Habitat-Type-3 compared other species within habitat irrespective of seasonality. However, *Pantala flavescens* were recorded maximum in the majority of habitat due to its monsoon season migratory behaviour.

Keywords- Damselfly, Diversity, Dragonfly, Habitat, Habitat Characterisation, Nalsarovar Bird Sanctuary, Odonata

I. INTRODUCTION

Dragonfly (Suborder-Anisoptera) and Damselflies (Suborder-Zygoptera) both belong to Order Odonata. Odonates have three stages in life eggs, nymphs (larvae) and adult. The Odonates are amphibiotic insects. They spend a major part of their life cycle in a freshwater ecosystem. Odonate nymphs are carnivores and voracious feeder whereas adults are a predator of other insect species [1]. Distribution of Odonata varies among temporary to permanent waterbodies. Numbers of factors influencing Odonate diversity and assemblage composition including intra and interspecific competition have been identified. Odonata is very sensitive to its associated habitat and climate, which ultimately influence their distribution and abundance. Anisoptera (dragonflies) are abundant in all waterbodies compared to Zygoptera may be due to their high adaptability and dispersal of dragonflies whereas damselflies have limited dispersal ability and adaptation to the environmental changes. The factors that mainly influence dragonflies and damselflies diversity and assemblage composition are habitat structure and complexity predation, pollution and water chemistry [2,3,4,5]. The relationship of adult Odonate assemblage composition to habitat constraints are associated with hunting, mating, roosting/sheltering and oviposition behavior, however, such behavior and activities are less understood [6].

Odonata is one of the most ancient groups of insects that first appeared during the Carboniferous era, about 250 million years ago [7]. Globally 5,952 species of Odonates under 652 genera have been reported (Schorr and Paulson, 2013) [8]. India harbors 474 species and 50 subspecies belonging to 142 genera in 18 families [9].

Nalsarovar Sanctuary is one of the important wetlands of India and Gujarat. It is internationally recognized as a Ramsar Site of Gujarat. It is also designated as a Sanctuary i.e. protected area and an Important Bird and Biodiversity Area (IBA) [10]. Nalsarovar wetland is a seasonal wetland. The basin of Nalsarovar is of elongate undulating saucer type and its overall shape is very gentle, running from east to northwest and northwest to south. Generally, the depth of water does not exceed 3 meters [11,12]. There are more than 300 elevated plateaus in the basin locally called ‘Bet’ or ‘Thalais’ meaning islets as they remain above the water surface. The natural and seasonal spread of wetland of Nalsarovar is of irregular shape. It is moreover elliptical in shape. It is shallow and in most parts muddy. This depressed portion had come into existence by tectonic uplift of an
estuary as also by increased sedimentation and aeolian infill [13]. Studies on various aspect of Nal Sarovar is done in the past including birds and biodiversity study [10,14,15]. The entire study was carried out in Nalsarovar wetland.

Odonates larval (nymphs) and adult stage play a significant role as a predator in the wetland ecosystem as a biocontrol agent. However, Odonates also act as biocontrol agent of may disease-causing species including mosquitoes i.e. a vector of malaria and dengue and helminths i.e. parasites of birds especially of poultry and wild ducks which thereby aid transmission of these diseases [16,17,18,19,20,21,22,23,7]

Studies on aquatic insects are limited within the Gujarat state. However, few Studies focused on aquatic and semi-aquatic insects were carried out in past [24,25,26,27,28,29]. However, Odonata being such an important semi-aquatic insect worldwide including state like Gujarat (with many seasonal wetland), there is a gap of studies on habitat characterisation and preference of dragonflies and damselflies. However, no studies focusing on habitat characterisation of dragonflies and damselflies are focused within Gujarat state. Considering the important role played by Odonata in terms of monitoring wetland health. An effort was made to study habitats of Odonate species within Nalsarovar Bird Sanctuary. This study can be used as a benchmark for future conservation of odonate within Gujarat state.

II. STUDY AREA

The study was carried out at Nal Sarovar Sanctuary, Gujarat state, India. Nal Sarovar is located between 22°78’ N and 22°96’ N latitude and 71°92’ E and 72°64’ E longitudes. The lake area is spread over two districts viz., Ahmedabad and Surendranagar. It has an area of 147 sq. km. [31] Biogeographically, the area falls in Gujarat-Rajwara Biotic Province (4B) of the Semi-Arid biogeographical zone [32]. There are about 12 villages located on the periphery of this wetland. They include Kayla, Vekaria, Meni, Darji, Digvijaygarh, Shiyal, Paraí, Mulbavla, Ranagadh, Bhagvnpur, Nani Kathechi, and Shahpur.

The natural and seasonal spread of wetland of Nal Sarovar, has an irregular configuration, though the basin is elliptical in shape. It is shallow with a maximum depth of 3m and in most parts muddy. Among the wetlands of Gujarat, Nal Sarovar is unique both in structural and physical characteristics. Geologically it is the remnant - relict of an oceanic creek - locally called as Nal. This depressed portion had come into existence by tectonic uplift of an estuary and also by increased sedimentation and aeolian infill [33].

Being a natural lake, the area under the submergence varies seasonally and annually depending upon the rainfall and the climate of the area is arid to semi-arid in nature. The temperature attains a maximum of 45°C during the month of May and falls below 7°C in January. The rise in the temperature after peak winter accelerates the rate of evaporation of water in the lake and thereby results in rapid drying [10,34]. The rainfall is erratic. During the good rainfall years, the total area under submergence swells to around 350 sq. km whereas submergence area is often 60 sq km during winter of normal rain year. The entire land of Nal Sarovar and its environs is salt-affected with saline/alkaline salts concentrated in the upper layer of clayey, medium black soil [12].

Apart from rainfall and the temperature, wind also plays an important role in the area. During summer the wind velocity can be as high as 60km/hr which also accelerates the rate of evaporation of water from the lake [10].

The change in water quality between fresh and brackish keeps the bio-cycles of organisms. Nal Sarovar provides adequate depression over a large area for the existence of submerged aquatic vegetation. Moreover, in and around its shallow water near the shores and islets, it supports emergent hydrophytic vegetation. Both the submerged and emergent vegetation, as well as algae, constitute primary producers of this aquatic ecosystem. They support large epiphytic macro-invertebrates and also provide cover to a variety of organisms [35,10,34] The major habitats of Nal Sarovar wetland include Open Water Habitat, Emergent Hydrophytic Cover, Muddy Habitat, Islets ('bel'), Shore-land, Agriculture fields surrounding the Lake, wasteland surrounding the Lake and Inlets and Outlets of Lake [34] (Map 1).

III. MATERIALS AND METHODS

Sampling Strategies: A study of odonates was carried out from February 2015 to February 2017 at Nalsarovar Bird Sanctuary. Study area was stratified into 6 different habitat type including 1) Habitat-Type-1 - Marshy and muddy habitat with Emergent hydrophytic and emergent rooted floating leaf habitat cover in pockets of water holes with variable depth of water, 2) Habitat-Type-2 - Openwater with both submerged hydrophyte and emergent vegetation with depth more than 2 feet, 3) Habitat-Type-3 - Openwater with emergent vegetation...
with depth more or equal to 2 feet, 4) Habitat-Type-4 - Openwater with shallow water and emergent vegetation with depth less than 2 feet, 5) Habitat-Type-5 - Other habitats including Scrubland /Grassland /Agriculture (seasonally variable water depth and area get dried up in summer) and 6) Habitat-Type-6 - Shoreland with submerged hydrophyte in a puddle with the Variable depth of water. Transects were laid in different habitats using GPS for the odonate survey within the study area. All fourteen transects were regularly and repeatedly surveyed. Fixed belt transects of 500 m length and width of 5 m on both side of transect were followed for the study of odonates. The survey was carried out covering all major habitats and different seasons. Individuals of Odonates were recorded during the survey, photographed and then released back to the field. Species were mainly photographed using digital photos by Camera with Powershot SX60 HS camera with 16.1 megapixels, ultrasonic, full HD 65X optical zoom. Species were identifications using standard taxonomic literature [7,36,37,38]. The raw data of all the sites collected from the field were transferred in an electronic format in spreadsheet layout (Microsoft excels). The data was analyzed to calculate relative frequency (%) and relative abundance (%) of each species in each selected habitat.

IV. RESULTS AND DISCUSSION

Species Richness: A total of 30 species of dragonflies and damselflies were encountered belonging to 5 families namely Libellulidae, Gomphidae, Aeshnidae, Coenagrionidae, and Libellulidae during the entire study (Table 1). Out of total Odonate (30 species) encountered during the entire study, a total of 21 species of dragonflies (Suborder – Anisoptera) encountered belonged to 3 families. However, among Anisoptera, 18 species namely Diplacodes lefebrevrii (Rambur, 1842), Tramea limbata (Desjardins, 1832), Trithemis festiva (Rambur, 1842), Orthetrum glaucum (Drury, 1770), Indothemis carnatica (Fabricius, 1798), Macrodiplax cora (Brauer, 1867), Rhyothemis variegata (Linnaeus, 1763), Brachythemis contaminata (Fabricius, 1793), Bradinopyga gominata (Rambur, 1842), Orthetrum sabina (Drury, 1770), Diplacodes trivialis (Rambur, 1842), Brachydiplax sobrina (Rambur, 1842), Trithemis pallidinervis (Kirby, 1889), Trithemis kirbyi (Kirby, 1889), Tramea basilaris (Rambur, 1842), Crocothemis servilia (Drury, 1770), Acisoma panorpoides (Rambur, 1842), Pantala flavescens (Fabricius, 1798) which belongs to 13 Genera and family Libellulidae, 1 species namely Ictinogomphus rapax (Rambur, 1842) which belonged to 1 Genus and family Gomphidae, 2 species namely Hemianax ephippiger (Burmeister, 1839), Anax guttatus (Burmeister, 1839) which belonged to 2 Genera and family Aeshnidae were encountered during survey. Similarly, a total of 9 species of Zygoptera (damselflies) encountered belonged to 6 Genera and 2 families during the entire study. Among zygopterans, 8 species namely Pseudagrion microcephalum (Rambur, 1842), Enallagma cyathigerum (Charpentier, 1840), Ceriagrion coromandelianum (Fabricius, 1798), Ischnura aurora (Brauer, 1865), Rhodischnura nursei (Morton, 1907), Agriocnemis pygmaea (Rambur, 1842), Ischnura senegalensis (Rambur, 1842), Pseudagrion decorum (Rambur, 1842) belonged to 6 Genera and 1 family Coenagrionidae. A single species namely Lestes species belonged to 1 Genus and 1 family Lestidae were encountered during survey.

Habitat-wise species richness: Total 22 Odonate species including 16 species belonging to Anisoptera (dragonfly) and 6 species belonging to Zygoptera (damselfly) were encountered utilizing Habitat-Type-1. Total 27 Odonate species including 18 species belonging to Anisoptera (dragonfly) and 9 species belonging to Zygoptera (damselfly) species were encountered in Habitat-Type-2. Total 17 Odonate species including 12 species belonging to Anisoptera (dragonfly) and 5 species belonging to Zygoptera (damselfly) were encountered in Habitat-Type-3. Total 28 Odonate species including 21 species belonging to Anisoptera (dragonfly) and 7 species belonging to Zygoptera (damselfly) were encountered in Habitat-Type-4. Total 25 Odonate species including 17 species belonging to Anisoptera (dragonfly) and 8 species belonging to Zygoptera (damselfly) were encountered in Habitat-Type-5. Total 27 Odonate species including 18 species belonging to Anisoptera (dragonfly) and 9 species belonging to Zygoptera (damselfly) were encountered in Habitat-Type-6.

The most preferred habitat types by different species of Odonates out of total species encountered during study were Habitat-Type-4 (93.3 %), Habitat-Type-2 (90 %) and Habitat-Type-6 (90 %). The most habitat type utilized by Odonates out of total individual encountered is Habitat-Type-4 (40.1 %) and Habitat-Type-2 (24.2 %). It contributes to around 64.3 % of Odonate within study area.

Habitat-wise Relative frequency (%) and Relative abundance of Odonate species

Relative frequency (%) and Relative abundance of Odonate species were calculated utilizing the data collected during the survey in each habitat. Analysis was based on the percentage of Relative frequency and Relative abundance derived from the calculation. Details of each are given further.

Relative frequency (%): During the entire survey, relative frequency (%) of Trithemis pallidinervis were recorded maximum followed by Rhodischnura nursei, Orthetrum sabina, Ischnura senegalensis, and Crocothemis servilia in Habitat-Type-1 (Figure 1). Relative frequency (%) of Trithemis pallidinervis were recorded maximum followed by Crocothemis servilia, Pseudagrion decorum, Ischnura senegalensis Orthetrum sabina and Brachythemis contaminata in Habitat-Type-2 (Figure 2). Relative frequency (%) of Crocothemis servilia were recorded maximum followed by Trithemis pallidinervis, Pantala flavescens, Hemianax ephippiger and Orthetrum sabina in Habitat-Type-3 (Figure
Relative frequency (%) of *Trithemis pallidinervis* were recorded maximum followed by *Orthetrum sabina*, *Ischnura senegalensis*, *Crocothemis servilia*, and *Brachythemis contaminata* in Habitat-type-4 (Figure 4). Relative frequency (%) of *Trithemis pallidinervis* were recorded maximum followed by *Orthetrum sabina*, *Crocothemis servilia*, followed by *Brachythemis contaminata* and *Rhodischnura nursei* in Habitat-Type-5 (Figure 5). Relative frequency (%) of *Trithemis pallidinervis* were recorded maximum followed by *Brachythemis contaminata*, *Crocothemis servilia*, and *Orthetrum sabina* in Habitat-Type-6 (Figure 6).

Relative abundance (%): Relative abundance (%) of *Pantala flavescens* were recorded maximum followed by *Brachythemis contaminata* and *Ischnura senegalensis* in Habitat-Type-1 (Figure 1). Relative abundance (%) of *Pantala flavescens* were recorded maximum followed by *Ischnura aurora*, *Trithemis pallidinervis*, and *Brachythemis contaminata* in Habitat-Type-2 (Figure 2). Relative abundance (%) of *Trithemis pallidinervis* were recorded maximum followed by *Pantala flavescens*, *Rhodischnura nursei* and *Orthetrum sabina* in Habitat-Type-3 (Figure 3). Relative abundance (%) of *Pantala flavescens* were recorded maximum followed by *Brachythemis contaminata*, *Trithemis pallidinervis*, *Macrodiplax cora*, and *Rhyothemis variegate* in Habitat-type-4 (Figure 4). Relative abundance (%) of *Rhyothemis variegate* were recorded maximum followed by *Pantala flavescens* and *Brachythemis contaminata* in Habitat-Type-5 (Figure 5). Relative abundance (%) of *Pantala flavescens* were recorded maximum followed by *Trithemis pallidinervis*, *Brachythemis contaminata*, *Rhyothemis variegate* and *Ischnura aurora* in Habitat-Type-6 (Figure 6).

However, relative frequency and relative abundance of *Acisoma panorpoides*, *Brachiodylax sobrina*, *Bradinopyga geminate*, *Ceriagrion coromandelianum*, *Indothemis carntica*, *Pseudagrion microcephalum* utilizing Habitat-Type-1 were recorded relatively less (Figure 1). Relative frequency and relative abundance of *Anax guttatus* and *Orthetrum glaucaum* utilizing Habitat-Type-2 were recorded relatively less (Figure 2). Relative frequency and relative abundance of species *Agriocnemis pygmaea*, *Ischnura aurora*, *Ischnura senegalensis*, *Macrodiplax cora*, *Rhyothemis variegate*, *Tramea basilaris* and *Tramea limbata* utilizing Habitat-Type-3 were recorded relatively less (Figure 3). Relative frequency and relative abundance of *Brachydiplax sobrina*, *Bradinopyga geminate*, *Enallagma cyathigerum* and *Ictinogomphus rapax* utilizing Habitat-Type-4 were recorded relatively less (Figure 4). Relative frequency and relative abundance of *Acisoma panorpoides*, *Ceriagrion coromandelianum*, *Diplacodes lefebivrii*, *Enallagma cyathigerum*, *Ictinogomphus rapax* utilizing Habitat-Type-5 were recorded relatively less (Figure 5). Relative frequency and relative abundance of species *Acisoma panorpoides*, *Ictinogomphus rapax*, *Orthetrum glaucaum*, *Tramea basilaris* utilizing Habitat-Type-6 were recorded relatively less (Figure 6).
Habitat selection is very important for the survival and distribution of Odonates. Adults typically fly away from water for several or many days after emergence. Adults generally would not prefer to return until reproductively mature. However, very few species are known to return back to the place of emergence precisely to the pond [39]. Dispersal during the maturation period is often sufficiently extensive and is a very important task for the distribution of individuals and species. Major indications employed during habitat selection can be inferred from the microgeographic distribution of adults and from the microhabitat requirements of larvae [40]. During the entire study, it was recorded that the most preferred habitat by Anisopteran (Dragonflies) is Openwater with shallow water and emergent vegetation with depth less than 2 feet. Similarly, most preferred habitat by Zygoptera (Damselflies) is Shoreland with submerged hydrophyte in a puddle with the variable depth of water and Openwater with both submerged hydrophyte and emergent vegetation with depth more than 2 feet. Odonate species such as Crocothemis servilia were relatively frequent in Openwater with emergent vegetation with depth more or equal to 2 feet and Rhyothemis variegata were relatively more abundant in habitats including Scrubland/Grassland/Agriculture with seasonally variable water depth and area get dried up in summer. Trithemis pallidinervis were relatively frequent in most of the habitats and relatively abundant in Openwater with emergent vegetation with depth more or equal to 2 feet. Pantala flavescens were recorded maximum in the majority of habitat may be due to its migratory behaviour during monsoon season.

Odonates are absent usually in temporary ponds and Ponds/wetlands lacking trees or with little aquatic vegetation (Fischer 1961 and Fischer 1964). [41,42]. Both type and distribution of aquatic plant affect Odonates (especially larval stages) in their number and special distribution (Kime 1974, Macan 1964 and Sonehara 1967). [43,44,45]. Gujarat being semi-arid region the wetlands are generally seasonal in occurrence. Similarly, wetland associated resources like water and wetland-related aquatic flora and fauna also change along with its seasonal changes. During the survey, majorly Odonates species (Dragonflies and Damselflies) were recorded around vegetation/microhabitat at Nalsarovar Bird Sanctuary includes Emergent hydrophytes (Typha angustata, Phragmites sp, Fimbrystylis sp. and other sedge), rooted with floating leaves hydrophytes (Ipomoea aquatica and Nympha sp.), Submerged hydrophytes (Chara sp. - macroalage, Potomogeton sp. and Hydrilla sp.), Free-floating hydrophytes (Lemma sp.). Some wetland associates vegetation’s (Aleuropus logopoides), Shrubs (Salvadora persica, Prosopis juliflora, Zizyphus sp. and other shrubs), Grasses patches (Cyanodon sp. and Paspalum sp.), Herbs (Suaeda sp.), climbers and around dry shrubs and emergent vegetation patch. Some dragonfly species including Bradinopyga geminata (Rambur, 1842) and Acisoma panorpoides (Rambur, 1842) majorly recorded around paved cement and degraded algal bloom respectively (Table 15). Trithemis festiva (Rambur, 1842), Macrodiplax cora

![Figure 6: Relative frequency (%) and Relative abundance (%) of Odonate species in Habitat-Type-6](image-url)
(Brauer, 1867), *Rhyothemis variagata* (Linnaeus, 1763), *Brachydiplax sobrina* (Rambur, 1842), *Trithemis pallidinervis* (Kirby, 1889), *Trithemis kirbyi* (Kirby, 1889), *Crocothemis servilia* (Drury, 1770), *Ietinogomphus rapax* (Rambur, 1842) were recorded around emergent hydrophytes like sedges. Some damselflies species were encountered on vegetation/microhabitat including Emergent hydrophytes like sedges, macroalage and around algal bloom, around some wetland associates vegetation’s, Grasses patches, Shrubs, Herbs and climbers. This observation may indicate Odonate preference towards wetland associated vegetation and special distribution of Odonates in similar wetland and can also be used for conservation of Odonates in similar wetlands.

**ACKNOWLEDGMENTS**

Authors are thankful to Gujarat Forest Department for support during entire research and also thankful to Forest managers for providing necessary facilities in field. The author is also thankful to Dr. Preeti Srivastava, Ex-faculty at Mahatma Jyoti Rao Phoole University (MJRPU) and faculties of the university for support and research related guidance.

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