A Treatise on Dragonflies
(Order: Odonata, Class: Insecta)
of rice ecosystems in Eastern India

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2017
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ABSTRACT

This study highlights the 75 species of dragonfly fauna associated with rice ecosystems in eastern India out of which 15 species were regular and rest were sporadic. From the general taxonomic point of view all the species were grouped under 5 families of under order Odonata. Comparing different body parts the double branching keys were prepared for easy identification of 15 common dragonfly species recorded in rice ecosystems of West Bengal. Each key begins with a couplet (a pair of alternative) and each of which leads to another couplet. Finally the reader reaches the specific identity of species. Free hand drawing of wings of the 50 dragonflies were also used for separate identification of these insect species. In addition to this, different studies were made on courtship and mating, egg laying habitats, nymphaal development, longevity, flight capacity of dragonfly to make the study more interesting to the reader. The population build up of dragonfly, favors to certain altitude as well as availability of water which is reverse to the other group of insects. Three different localities were selected at 9.75 m (Chakdaha), 200 m (Cooch Behar) and 1250 m (Kalimpong) of which former two represent an unique physiographic ecological system in Eastern India characterized by extreme diversities of dragonfly inhabiting there. The studies on natural enemies of dragonfly along with their major threats indicated that about 2, 4 and 4 species were critically endangered, endangered and vulnerable in rice ecosystem of West Bengal. Dragonflies are very sensitive to changes in landscape...
and are reliable indicators of wetland health. Therefore the effective conservation of dragonfly depends entirely on conservation of their habitats. Different studies were made to estimate the role of dragonfly in integrated pest management of rice crop in West Bengal. An investigation was also carried out to find out the crop stage wise diversification of individual predator and found that dragonfly was more diverse during flowering to ripening stages of crop respectively. The values Simpson and Shanon diversity index showed that dragonflies are specific flowering to ripening stage of crop. Subsequently the value of Margalef index and Menhinick index also indicated that the aforesaid predators were more diverse in flowering stage of crop whereas it was least in vegetative stage of crop. The studies on colonization and succession of major dragonfly taxa in the rice field indicated that it followed a uniform pattern in relation to growth stages as well different phases in the rice field. The studies on relative abundance of dragonfly in different ecosystems reflected that their population in fields could be conserved and enhanced through maintenance of rice weed flora on bund or allowing ratoon rice after the rice crop during fallow period. The fallow land has limited effect on incidence of insect predator in rice crop. The relative ranking chart of 50 important predators in rice ecosystem of West Bengal indicates that the insect belonging to Coleopteran (17) were top of the list whereas dragonfly was third (10). The validity of chart may increase over time and they will need to be updated periodically.

\textbf{Keywords:} Dragonfly, rice, nymph, biodiversity, index, wings, threat, conservation, weed

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1. INTRODUCTION

Dragonflies (Order - Odonata, class Insecta) are prominent and colourful insects of wetlands. The Odonata is appropriately named as it derives its name from the Greek word “Odonto” meaning tooth and it refers to the strong teeth found on the mandibles of most adults. They are ancient groups of insects, evolved during Permian about 250 million years ago. About 7000 species of Odonata belonging to 630 genera and 28 families were reported from the world over (Emiliyamma et al. 2005). In India about 500 species and subspecies were reported out and of this, about 200 species were found in the peninsular India. Prasad and Varshney (1995) listed 499 species of dragonflies and damselflies from India.

The life history of odonata is closely associated with wetlands. They were also believed to be the descendants of the Protodonata that existed 300+ million years back. Among the Protodonates were members of the family Meganeuridae that included giant forms, which had a wingspan of 60 cm. to 1 meter, making them the largest hexapods ever to have existed. Fossil evidences indicate that dragonflies closely related to the modern ones that had appeared in the Mesozoic Era. The protodonate, *Meganeura monyi* Bron, was the recognized ancestor of the modern odonates. The fossil had been collected from the upper carboniferous rocks along with ancestors of mayflies and cockroaches.

Those odonates with their wingspan of about 70 cm probably have devoured the ancestors of mayflies. In the Mesozoic Era the evolution of modern Odonata has started and the dragonflies have to devour the Dipterans, Lepidopterans, Hymenopterans etc after the evolutions. Basically, the odonates are divided into two groups, the robust build ones that are also strong fliers- the Dragonflies- and the thin bodied, weak fliers- the Damselflies. Some species of odonata, especially *Pantala flavescens* (Fab.) are migratory in behavior and can fly several hundred kilometers over the land and sea. The adults medium to large (from < 2cm to >15 cm long) with a maximum wingspan of 17 cm in the South American giant damselfly (Pseudostigmatidae: Mecistogaster). They have a mobile head with large multifaced compound eyes, three ocelli, short bristle like antennae, and mandibulate mouthparts.

The thorax possesses three pairs of legs which are poorly adapted for walking but are excellent for catching prey. The thorax is also enlarged to accommodate the flight muscles of two pairs of elongate membranous wings that are richly veined.

The slender 10-segmented abdomen terminates in clasping organs in both sexes; males possess secondary genitalia on the ventral of the second to third abdominal segments; females often have an ovipositor at the ventral apex of the abdomen. In adult Zygopterans the eyes are widely separated and the fore and hind wings are equal in shape with narrow bases.

The wings are large, long and transparent which make the dragonflies the most accomplished fliers of the animal kingdom.
2. MATERIALS & METHODS

Location and Climate

The regional studies on biodiversity of dragonfly in rice crops were conducted in both southern and northern part of West Bengal during 2012 to 2017. In southern part the field trials were conducted at Regional Research Station, Chakdaha located between 20.50° - 24.50° North latitude and 86.0° - 89.0° East longitude with a mean sea level rise of 9.75 m. Normal rainfall ranges between 1271mm to 1800 mm, maximum and minimum temperature varies between 20.4 °C to 37.0 °C and 9.0 °C to 27.4 °C respectively (Fig. 1).

Fig. 1. Location of West Bengal In Eastern India (Source: Google)
The survey study was conducted at Cooch Behar in Terai zone of northern part of West Bengal respectively, which is located between 20°31’ and 27°31’ North latitudes and between 87°9’ and 88°53’ East longitude.

**Sampling of the terrestrial arthropod predator community**

The dragonfly fauna consisting of both nymphs and adults inhabiting the rice field proper as well as weed habitat, ratoon crop and rice fallows were sampled using a standard sweep net. The dragonfly nymphs within the enclosed space; on rice plants, weeds and water/ground surface were obtained by the sweep net, and flushed into a container with 70% alcohol for storage. A total of 20 random samples were obtained on each sampling day for each of the species of dragonfly. In order to ensure a uniform capture efficiency using the sweepnet, usage time per sample was increased with increasing growth and age of the rice plant. Insect predators collected in sweeps were immediately sprayed with chloroform and put either into labeled plastic containers with 70% ethanol or kept in insect box after drying in a dehydrator at 60 °C for 72 hours. The dragonfly collected from the rice fields using the different methods were identified and classified into the smallest possible taxa using available keys and guides for the different taxa. The Odonata were also identified using de Fonseka (1997). Some of the dragonflies were confirmed by the experts at Zoological Survey of India, Kolkata, India.

**Experimental details**

Field trials were conducted at the Regional Research Sub-station, Chakdaha, under Bidhan Chandra Krishi Viswavidyalaya during 2012-17. The high yielding locally adopted variety Swarna (MTU-7029) and IET-4786 were planted on *Kharif* (rainy) and *Rabi* (winter) seasons respectively in each year supplemented with different doses of fertilizers and pesticides in a randomized block design with three replications. Observations were recorded randomly from m² area /plot at 7 days interval starting from 15 days after transplanting.

Both the experiments were laid in randomized block design with different treatments. Plot size was 5 m x 4 m and distance between plot to plot and replication were 0.5 and 2 m respectively.

**Enumeration of dragonfly species in weed habitat, ratoon crop and rice fallow**

The dragonflies in the rice field bunds were sampled by taking 10 sweeps from the weeds while walking along a bund transect (one sweep/m) at each of five randomly selected locations (using numbered paper slots) on each sampling day. The intensity of population of dragonfly were in the range of 1/100 m² area was low (+) whereas 1 to 4/100 m², more than 5/100 m² area, more than 50/100 m² which were denoted by low (+), medium (+ +), high (+ + +) and extra high (+ + + +) respectively. A total of 104
sweep net samples were collected during the entire study period at weekly intervals from the rice field. In the laboratory each sample was sorted into different species and counted. The sampling was done in the forenoon from 8 to 11 a.m. and in the afternoon from 4 to 6 p.m.

Data analyses

Data obtained on the abundance of dragonfly from the rice and non-rice habitats were compared using Means and Standard Error values (SE at 95% confidence limits). The diversity and species richness of dragonflies in the rice field proper and the bunds were compared using ecological indices reviewed by Magurran (1988), calculated separately for different species on each sampling day. The mean values of the two indices obtained for kharif (rainy) and rabi (winter) seasons were statistically analyzed using the SAS nested GLM Procedure (Littell et al., 1991). Using the pooled data of from the two seasons, the diversity of dragonfly at the three major growth stages of the rice crop (vegetative, reproductive, ripening) and on harvest (fallow period) were analyzed using the SAS Nested GLM Procedure.

Biodiversity indices such as richness indices, diversity indices like Simpson index, Shannon’s index, evenness index etc were used to estimate the diversity of insects in given habitat (Ludwig and Reynolds, 1988).

Various formulae used for calculating different parameters are given below.

Richness indices

\[ S = \text{It is directly measured species richness index i.e. } S = \text{number of species collected in the ecosystem.} \]

Margalef index \((R_1) = S - 1/\ln(n)\)

where:
S = number of species, \(n\) = total number of individuals of all the species, \(\ln\) = natural logarithm.

Menhinick index \((R_2)\)

\[ R_2 = S/\sqrt{n} \]

where:
S = number of species, \(n\) = total number of individuals of all the species.
\(R_1\) and \(R_2\) explain the relationship between \(s\) and \(n\) and they will vary with sample containing different \(n\) value i.e. as \(n\) increases, \(R_1\) and \(R_2\) decrease.
Diversity indices

Simpson’s index D (1949) is expressed as: \( D = \frac{1}{C} \)

Simpson’s index (D) gives the probability of drawing two individuals at random from a population belonging to a particular species. If the probability is high, the diversity is low.

\[ C = \sum p_i^2 \]

where:
\( p_i = \frac{n_i}{N} \) where \( n_i = \) number of individuals of the \( i^{th} \) species, \( N = \) total number of individuals of all the species.

This equation is applicable only to finite population where all the individuals have to be counted accurately. Since it is impossible to count all the individuals, one worked with infinite population. Hence the aforesaid formula was modified and applied as:

\[ C = \sum_{i=1}^{S} n_i (n_i - 1)/N(N - 1) \]

where:
\( n_i = \) the number of individuals of \( i^{th} \) species, \( N = \) the total number of individuals of all the species.

Shannon-Weiner index (\( H' \)) is a measure of the average degree of uncertainty in predicting to what species an individual chosen at random from a collection of \( S \) species and \( N \) individual will belong. This average uncertainty increases as the number of species increases and as the distribution of individual among the species become even i.e. \( H' \) is zero if there is only one species in the sample and \( H' \) is maximum if all species are evenly distributed (perfect eveness). Thus we can arrive at the same \( H' \) for two samples, one having more number of species but low eveness and other having less number of species but perfect eveness is proportional abundance.

\[ \text{Shannon-Weiner index (H')} = -\sum (p_i \ln p_i) \]

where:
\( p_i = n_i / N \) where \( n_i = \) number of individual of the \( i^{th} \) species, \( N = \) total number of individual

Hill’s diversity numbers

Hill’s diversity numbers are \( N_0 = (0^{th} \text{ order}), N_1 (1^{st} \text{ order and } N^2 = 2^{nd} \text{ order}). These numbers measure the effective number of species representing a sample i.e. to measure the degree to which population abundances are distributed among the species.
where:
\( N_0 \) = indicate number of species in the sample
\( N_1 \) = measures the number of abundant species = \( eH' \) (\( H' \) = Mathematical function of Shannon-Weiner index, \( e \) = Simpson index)
\( N_2 \) = is the number of very abundant species = \( \frac{1}{D} \) (\( D \) = Simpsons index)

**Eveness indices**

The evenness index reaches its maximum when all the \( s \) species are equally abundant. On the other hand, when the species abundance is not equal but diverge from evenness the index decreases toward zero.

(i) \( E_1 \frac{H' \ln (S)}{\ln (N_0)}} = \frac{\ln (N_1)}{\ln (N_0)} \)

where:
\( H' \) = Shannon index, \( N_1 \) is the Hill’s diversity number - 1, \( N_0 \) is the Hill’s diversity number 0, \( \ln \) is the total logarithm.

(ii) \( E_2 = \frac{eH'}{S} = \frac{N_1}{N_0} \)

(iii) \( E_3 = \frac{eH'-1}{S-1} = \frac{N_1-1}{N_0-1} \)

(iv) \( E_4 = \frac{1/e}{D} = \frac{N_2}{N_1} \)

(v) \( E_5 = \frac{1}{D} - \frac{1}{eH' - 1} = \frac{N_2 - 1}{N_1 - 1} \)

**Berger-Parker dominance index**

This index give the dominant species in each stage of crop growth. It showed the proportion of total catch due to the dominant species as:

\( d = \frac{N_{\text{max}}}{N_T} \) (Southwood, 1978)

where:
\( N_T \) = total number of individuals in the sample and
\( N_{\text{max}} \) = number of individual in the abundant species.

Predator diversity was analyzed through Simpson index (Simpson, 1949) and Shannon-Weiner index (Shannon, 1948), while abundance of species in each sample was assessed through Berger-Parker Dominance index (Southwood, 1978).
Abbreviations

Abbreviations used: g = gram, h = hour, ha = hectare, kg = kilogram, l = litre, m = metre, mg = milligram, mm = millimeter, Post-em post emergence, AL = abdominal length, ALE = anterior lateral eye, AME = anterior median eye, AW = abdominal width, AL = abdominal length, ALE = anterior lateral eye, AME = anterior median eye, AW = abdominal width, SP = species, spp = species (Plural), Ssp = subspecies, Sspp = subspecies (plural), PLE = posterior lateral eyes, PME = posterior median eye, TL = total length.

3. RESULTS AND DISCUSSION

Distribution of dragonfly species in West Bengal

Sampling of the dragonfly community was conducted to determine species composition, abundance and distribution in the different habitat of the rice field. The study through three crop seasons revealed a total number of 75 species of dragonfly occurring both as regular and sporadic predator in rice crop (Table 1). Most of the odonata species were not found in hilly areas of West Bengal due to shortage of water body. Kakassery (2004) also reported that dragonfly are seen in the rice field not only for foraging food in the field but also as a part of their life cycle in that aquatic ecosystem.

**Table 1.** Dragonflies species recorded as regular (*) and sporadic (without mark) predator in rice ecosystems of Eastern India

<table>
<thead>
<tr>
<th>SL. No</th>
<th>Name of Species</th>
</tr>
</thead>
</table>
| 1.     | **Suborder: Anisoptera**  
|        | **Family: Gomphidae**  
|        | *Ictinogomphus rapax* (Rambur)*  
|        | *Macrogomphus annulatus* Selys  
|        | *Macrogomphus montanus* Selys  
|        | *Megalogomphus* sp  
|        | *Onychogomphus striatus* Fraser  
|        | *Paragomphus lineatus* (Selys)  
|        | *Phaenandrogomphus aureus* (Laidlaw) |
2. **Family: Aeshinidae**

   *Anaciaeschna jaspaedia* (Burmeister)  
   *Anax guttatus* (Burmeister)  
   *Anax imperator* (Leach.)  
   *Anax parthenope parthenope* Selys  
   *Gynacantha bainbriggei* Fraser  
   *Gynacantha basiguttata* Selys  
   *Gynacantha bayadera* Selys  
   *Gynacantha dravida* Lieftinck  
   *Hemianax ephippiger* (Burmeister)

3. **Family: Cordulegasteridae**

   *Anotogaster nipalensis* Selys*  
   *Chlorogomphus atkinsoni* (Selys)  
   *Chlorogomphus preciosus preciosus* Fraser

4. **Family: Cordulidae**

   *Epophthalmia vittata vittata* Burmeister*  
   *Macromia moorei moorei* Selys

5. **Family: Libellulidae**

   *Acisoma panorpoides panorpoides* Rambur*  
   *Aethriamanta brevipennis brevipennis* (Rambur)  
   *Brachydiplax chalybea chalybea* Brauer*  
   *Brachydiplax farinose* Kruger*  
   *Brachydiplax sobirna* (Rambur)*  
   *Brachythemis contaminata* (Fab.)*  
   *Bradinopyga geninata* (Rambur)  
   *Camacinia gigantean*Brauer)  
   *Cratilla lineate* (Brauer)  
   *Crocothemis servilia servilia* (Drury)*  
   *Cyclogomphus ypsilon* Selys  
   *Diplacodes lefebrrrii* Rambur*  
   *Diplacodes nebulosa* (Fab.)*  
   *Diplacodes trivialis* Rambur*
<table>
<thead>
<tr>
<th>Species</th>
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<tbody>
<tr>
<td>Epophthalmia vittata Burmiester</td>
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<tr>
<td>Gomphidia williamsoni Fraser</td>
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<tr>
<td>Gynacantha bayadera Selys</td>
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<td>Gynacantha dravida Lief.</td>
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<tr>
<td>Hemianax ephippiger Burmiester</td>
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<tr>
<td>Indothemis carnatica (Fab.)</td>
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<td>Lathrecista asiatica asiatica (Fab.)</td>
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<td>Macrodiplax cora (Brauer)</td>
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<tr>
<td>Nannophya pygmaea Rambur</td>
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<tr>
<td>Neurothemis fluctuans (Fab.)*</td>
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<td>Neurothemis fulvia (Drury)*</td>
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<tr>
<td>Neurothemis intermedia intermedia (Rambur)*</td>
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<tr>
<td>Neurothemis tullia Drury*</td>
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<tr>
<td>Onychothemis testacea Laidlaw</td>
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<tr>
<td>Orthetrum cancellatum cancellatum (Linnaceus)</td>
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<td>Orthetrum chrysis Selys</td>
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<tr>
<td>Orthetrum glaucum (Brauer)*</td>
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<td>Orthetrum japonicum internum Mac Lachlan</td>
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<td>Orthetrum luzonicum (Brauer)</td>
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<td>Orthetrum pruinosum neglectum (Rambur)</td>
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<tr>
<td>Orthetrum sabina sabina (Drury)*</td>
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<tr>
<td>Orthetrum taeniolatum (Schneider)</td>
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<tr>
<td>Orthetrum triangulare triangulare (Selys)*</td>
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<tr>
<td>Palpopleura sexmaculata sexmaculata (Fab.)</td>
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<tr>
<td>Pantala flavescens (Fab.)*</td>
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<td>Potamarcha congener (Rambur)*</td>
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<td>Rhodothemis rufa Rambur*</td>
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<tr>
<td>Rhyothemis variegata variegata (Linn.)*</td>
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<tr>
<td>Sympetrum hypomelas (Selys)</td>
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<tr>
<td>Tetrathemis platyptera Selys</td>
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<tr>
<td>Tholymis tillarga (Fab.)*</td>
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<tr>
<td>Tramea basilaris Palisot de Beau*</td>
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<tr>
<td>Tramea limbata Desj.</td>
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<tr>
<td>Tramea virginata Rambur</td>
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<tr>
<td>Trithemis aurora (Burmeister)*</td>
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<tr>
<td>Trithemis festiva (Rambur)*</td>
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<tr>
<td>Trithemis pallidinervis (Kirby)*</td>
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<tr>
<td>Urothemis signata Rambur*</td>
</tr>
<tr>
<td>Zygonix iris Selys</td>
</tr>
<tr>
<td>Zyxomma petiolatum Rambur*</td>
</tr>
</tbody>
</table>

-79-
Structural synopsis of the dragonfly biodiversity in rice ecosystems of West Bengal

The more important of the other special terms used in descriptions of the wings of dragonflies are the following: much used is made in taxonomic work of the two series of cross-vein that are nearest the costal margin of the wings; those of these cross-veins that are situated between the base of the wing and the nodus are termed the antenodal cross-veins; the first of these two series of antenodal cross-vein extend from the Costa to the subcosta, the second from the subcosta to radius. The two series of cross-vein nearest to the costal margin of the wings and between the nodus and the apex of the wing are termed the postnodal cross-veins. The first of the two series of postnodal cross-veins extend from the Costa to vein R₁, the second from vein R₁ to vein M₁, the postnodal cross-veins are termed the post cubital cross vein, near the base of the wing there is in dragonflies a well marked area of the wings, which is usually triangular in outline, frequently the triangle is divided by one or more cross-veins into two or more cells( Figs. 3, 10). The area lying immediately in front of the triangle is termed the super triangle; like the triangle this area may consist of a single cell or may be divided by one or more cross-veins. Other named areas are the basal anal area and the cubical area

Striking characteristic of wings of the dragonflies recorded in Eastern India

The dragon-flies are easily recognized by the relative size of the two pairs of wings and by the attitude of the wings when at rest. The hind wings are larger than the fore wings and are of a somewhat different shape( Figs. 2 to 49), but the most striking characteristic is the fact that the wings are extended horizontally when at rest. The wings are very strong. An important factor in strengthening of the wings of these insects is the development of a series of corrugations, which has resulted in certain veins becoming convex and others concave, this has progressed so far that there is a very perfect alternation of convex and concave vein. The most distinctive feature of the wings of the dragonfly is the fact that in the course of their development one or more branches, usually two, of the medial trachea invade the area of the radial sector. This results in vein R₅ occupying a position behind one or more usually two, of the branches of media.
Fig. 2. *Acisoma panorpoides panorpoides* Rambur

Fig. 3. *Aethriamanta brevipennis brevipennis* (Rambur)

Fig. 4. *Anaciaeschna jaspaedia* (Burmeister)
Fig. 5. *Anaciaeschna jaspaedia* (Burmeister)

Fig. 6. *Brachydiplax chalybea chalybea* Brauer

Fig. 7. *Brachydiplax farinose* Kruger
Fig. 8. *Brachydiplax sobirna* (Rambur)

Fig. 9. *Brachythemis contaminata* (Fab.)

Fig. 10. *Bradinopyga geninata* (Rambur)
Fig. 11. *C magician gigantean* (Brauer)

Fig. 12. *Crocothemis servilia servilia* (Drury)

Fig. 13. *Cratilla lineate* (Brauer)
Fig. 14. *Cyclogomphus ypsilon* Selys

Fig. 15. *Diplacodes lefebrii* Rambur

Fig. 16. *Diplacodes nebulosa* (Fab.)
Fig. 17. Diplacodes trivialis Rambur

Fig. 18. Epophthalmia vittata Burmiester

Fig. 19. Gomphidia williamsoni Fraser
Fig. 20. *Gynacantha bayadera* Selys

Fig. 21. *Gynacantha dravida* Lief.

Fig. 22. *Hemianax ehippeger* Burmiester
Fig. 23. *Indothemis carnatica* (Fab.)

Fig. 24. *Lathrecista asiatica asiatica* (Fab.)

Fig. 25. *Macrogomphus annulatus* Selys
Fig. 26. *Megalomphus* sp.

Fig. 27. *Onychothemis testacea* Laidlaw

Fig. 28. *Paragomphus lineatus* (Selys)
Fig. 29. *Orthetrum chrysis* Selys

Fig. 30. *Orthetrum glaucum* (Brauer)

Fig. 31. *Orthetrum luzonicum* (Brauer)
Fig. 32. *Orthetrum pruinosum neglectum* (Rambur)

Fig. 33. *Orthetrum sabina sabina* (Drury)

Fig. 34. *Orthetrum taeniolatum* (Schneider)
Fig. 35. *Orthetrum triangulare triangulare* (Selys)

Fig. 36. *Palpopleura sexmaculata sexmaculata* (Fab.)

Fig. 37. *Palpopleura sexmaculata sexmaculata* (Fab.)
Fig. 38. *Potamarcha congener* (Rambur)

Fig. 39. *Rhyothemis variegata variegata* (Linn.)

Fig. 40. *Rhodothemis rufa* Rambur
Fig. 41. *Tholymis tillarga* (Fab.)

Fig. 42. *Tetrathemis platyptera* Selys

Fig. 43. *Tramea basilaris* Palisot de Beau
Fig. 44. *Tramea limbata* Desj.

Fig. 45. *Tramea virginata* Rambur

Fig. 46. *Trithemis aurora* (Burmeister)
Fig. 47. *Trithemis festiva* (Rambur)

Fig. 48. *Trithemis pallidinervis* (Kirby)

Fig. 49. *Urothemis signata* Rambur
Fig. 50. Zyxomma petiolatum Rambur

Fig. 51. Zygonix iris Selys

4. GENERAL TAXONOMY OF THE SOME OF THE REGULAR SPECIES OF DRAGONFLIES OCCURRING IN RICE ECOSYSTEMS OF WEST BENGALE

Comparing different body parts the double branching keys were prepared for easy identification of dragonfly recorded in rice ecosystem of West Bengal. Each key begin with a couplet (a pair of alternative) and each of which leads to another couplet. Finally the reader reached the specific identify of specimen. In the present investigation separate orders as well as family wise key of insect predators are also prepared. The species keys are prepared by comparing the standard literature published in Books and Journals. Personal description was also added where the suitable references are not available for identification of this insect.
**Sub-Order I: Zygoptera (Dragonfly)**

**Sub-Order II: Anisoptera (Damselfly)**

**Key to the Sub-Order**

1. Wing unequal in size, hind wing broader at the base held horizontally, compound eye close together, ovipositor reduced………………………………………………Zygoptera

1'. Wing of equal in size, hind wing narrow at the base held vertically at rest., compound eye widely separated, female with well developed ovipositor.......Anisoptera

**Key to the nymphal stage of sub-order**

1. Nymph robust with rectal gill...............................................................Dragonfly

1'. Nymph slender with paddle like caudal gill..............................................Damselfly

**Sub-Order: Anisoptera**

**Super-family: Aeshnoidea**

**Family: Gomphidae**

**Family: Aeshnidae**

**Super-family: Libelluloidea**

**Family: Libellulidae**

**Key to the super family (Male)**

1. Head large, compound eye occupy the greater part of the surface of head, ocelli present, antennae 5 to 8 segmented of these 2 basal thick others form a bristle like organ, leg spiny, hind wing larger than forewing, in mature stage M1 and M2 veins placed in front of R8, medium space never traverse or reticulated, hyper trigone and subtrigone reticulated, abdomen with a slender or cylindrical tip ............Aeshnoidea

1'. Head large, compound eye well developed with 3 dorsal ocelli, antennae 3 to 7 segmented, wing with some pigmented cell or pterostigma or stigma near the apex, fore and hind wing with perfect corrugation.Lebelluloidea

**Key to the dragonfly species (Male) recorded in rice ecosystem of West Bengal**

1. Head, concolourous with thorax.................................................................2

1'. Head, not concolourous with thorax..........................................................17
2(1). Abdomen more than 20-25 m in length.................................................................3
2'. Abdomen less than 20-25m in length.....................................................................7
3(2). Anal appendage concolourous with abdomen.....................................................4
3'. Anal appendage not concolourous with abdomen..................................................5
4(3). Fron bright scarlet brown, thorax reddish brown without marking, abdomen along with anal appendages brilliant scarlet red, abdomen 25 to 29 mm, hind wing 32-37 mm .......................................................... *Rhodothemis rufa* (Rambur) (Plate - 1)
4'. Fron and vertex black, occiput olive green fringed with light yellow hair, thorax and abdomen 1 to 8 black with dorsal yellowish band, segment 9 with lateral basal stripe, anal appendage along with 10th segment black, abdomen 52 mm, hind wing 40 mm.......................................................... *Ictinogomphus rapax* (Rambur) (Plate - 2)
5(3'). Abdomen 8 to 10th segment concolourous with anal part...............................6
5'. Abdomen 10th segment concolourous with anal part.........................................8
6(5). Upper surface of the fron metallic blue, occiput brown with a yellow spot, thorax and abdomen 1 to 3 pruinased blue, 4 to 7 with broad yellowish lateral band, anal appendage along with abdomen 8 to 10 dark metallic blue, abdomen 20-24 mm, hind wing 25-28 mm................................. *Brachydiplax sobrina* (Rambur) (Plate - 3)
6'. Upper surface of the frons, vertex metallic blue, occiput black with yellow spot, thorax and abdomen 1 to5 pruinased white, 6 to 10 dark metallic blue, abdomen 21-25 mm, hind wing 26-30 mm....................... *Brachydiplax chalybea chalybea* (Brauer)
7(2'). Fron, thorax and abdomen 1 to 7 light azure blue, 8 to 10 black, anal appendage white, abdomen 15-18 mm, hind wing 16-21 mm ......................................................... *Acisoma panoripoides panoripoides* (Rambur) (Plate - 4)
7'. Fron, thorax and abdomen 1 to 3 azure blue or greenish yellow, 4 to 7 separated by black border, 9 to 10 segment black, anal appendage white, abdomen 18-20 mm, hind wing 22-23 mm............................... *Diplacodes trivialis* (Rambur) (Plate - 5)
8(5'). Hind wing varies 20-40 mm...............................................................................9
8'. Hind wing varies 45-50 mm...............................................................................16
9(8). Wing with reticulation......................................................................................10
9'. Wing without reticulation

10(9). Color reticulation at the base of the wing

10'. Color reticulation at any part of wing other than base

11(10). Frons bright red, thorax olivaceous with reddish tinge on dorsum, abdomen brick red marked with black, hind wing with rather variable dark reddish brown marking at the base, abdomen 30-35 mm, hind wing 40-45 mm

---

11'. Frons bright red, occiput bright orange, thorax red, abdomen red with mid dorsal carina, wing hyaline and base marked with pale brown, abdomen 24-35 mm, hind wing 27-38 mm

---

12(10'). Color reticulation distributed throughout the wing

12'. Color reticulation restricted only at the apex of wing

13(12). Frons, vesicle very dark metallic green, thorax metallic green with yellowish marking, abdomen black, wing pale with yellow tint throughout, abdomen 24-27 mm., hind wing 35-37 mm

---

13'. Frons, thorax and abdomen dusky red, wing hyaline, male with a broad, smoky golden brown fascia extended from base to node, this fascia bordered by an opalescent white spot, abdomen 28-33 mm, hind wing 33-37 mm

---

14(12'). Faces, frons, thorax, abdomen reddish brown, black or dark brown, wing almost concolourous with body, apex of the wing clear or concolored abdomen 21-26 mm, hind wing 27-32 mm

---

14'. Faces, frons, occiput, thorax and abdomen black, wing steelly blue-black but apical half hyaline, abdomen 16-20 mm, hind wing 20-23 mm

---

15(9'). Front of fron golden yellow or dark brown, thorax olivaceous coated with yellowish hair, abdomen with black mid dorsal spot, and part black, abdomen 29-35 mm., hind wing 38-40 mm

---

15'. Frons yellowish marked with brown or black, thorax greenish yellow, abdomen 1 to 6th greenish yellow but intercepted by black mark, 7 to 10th segment black, abdomen
4 to 6 segment narrow, anal appendage white, both abdomen and hind wing 30-36 mm..................................................Orthetrum sabina sabina (Drury) (Plate - 12)

16(8'). Vertex dark green, fron greenish yellow, thorax, abdomen 1 pale green, 4 to 7 segment with bright orange spot, anal part and 10th segment yellow, abdomen 56-62 mm, hind wing 50-54 mm..............................................Anax guttatus (Burn) (Plate - 13)

16'. Vertex, fron dark brown, occiput black, densely fringed with black hair, thorax and first to ninth segment marked with bright citron yellow ring, segment 10 and anal appendage black, abdomen 54 mm, hind wing 45 mm.................................................................Anotogaster nipalensis (Selys)

17(1'). Frons and thorax olivaceous or faint greenish yellow, occiput brown, abdomen greenish yellow with reddish brown humeral stripe or reddish marked with faint dorsal brown stripe, abdomen 18-21 mm., hind wing 20 mm..........................Brachythemis contaminata (Fabricius) (Plate - 14)

17'. Frons and thorax olivaceous, abdomen black mark with ochreous, segment 10 black, abdomen 29-32 mm., hind wing 33-35 mm ..................................................Potamarcha congener (Rambur) (Plate - 15)

Adults

The adults are medium to large from <2 cm to >15 cm long, with a maximum wingspan of 17 cm. They have a mobile head with large multifaced compound eyes, three ocelli, short bristle like antennae, and mandibulate mouthparts. The thorax possesses three pairs of legs which are poorly adapted for walking but are excellent for catching prey. The thorax is also enlarged to accommodate the flight muscles of two pairs of elongate membranous wings that are richly veined. The slender 10 segmented abdomen terminates in clasping organs in both sexes; males possess secondary genitalia on the venter of the second to third abdominal segments; females often have an ovipositor at the ventral apex of the abdomen. In adult dragonflies the eyes are widely separated and the fore and hind wings are equal in shape with narrow bases. The wings are large, long and transparent and which make the dragonflies the most accomplished fliers of the animal kingdom.

Some of the adults stay close to the emergence site, while others may fly extreme distances in flocks. The rice fields are ideal wetland for some of the dragonfly which do not require extensive areas of open water. Identically dragonfly larvae are able to squirt water under high pressure from the gill chamber in the rectum out of the end of the abdomen. The action shoot them away forward from possible danger. The larvae are completely aquatic and effective predators. Newly emerged odonates leave their
emergence site and inhabit nearby landscape. During the maturation period, sequential changes occur in the colour of the body and wings.

![Dragonfly Image](image.jpg)

**Fig. 52.** A typical Dragonfly

**Courtship and Mating**

Sexually matured dragonflies return to breeding habitat from their foraging or roosting sites. Usually males mature earlier than females and reach the breeding habitat first. Most odonates are sexually dimorphic when they mature. Newly emerged males and females are similarly coloured. Males acquire bright colouration as they become sexually mature. Colours and patterns on the wings and body may play an important role in territoriality and courtship. Usually mating takes place during flight. During the breeding season, adult males generally establish territories along wetlands, which they actively patrol and guard against other co-specific males. Sexually mature and receptive females visit territories held by males. Resident males show aggressive behavior towards conspecific males, which enter their territory.

Aggressive behavior may be simple wing warning by perched males and a display of the abdomen. More elaborate aggressive encounters occur in flight, progressing from mutual threat display to physical fighting. Courtship is more evident in damselflies than in dragonflies. It ranges from simple submissive posture by males towards approaching females to elaborate displays where the male flies towards an egg laying site and allows itself to be carried by the water current for a short distance. Competition over sexually receptive females is very intense among male Odonates. A receptive female adopts a characteristic posture towards a potential male and pairing follows immediately. The last abdominal segments of the male have claspers, which are used to hold the female by her thorax. Prior to mating, the male fills his secondary genitalia present on the ventral side of the abdominal segment 2nd and 3rd with sperm.
from the primary genital opening on the ninth abdominal segment. During this process, the male zygopteran clasps the front of the female prothorax, while the male anisopteran clasps the female head. The pair then flies together in a ‘tandem position’ (Fig. 53). In the next stage, the female bends its abdomen round and forwards to bring its genitalia in contact with male genitalia, thus forming ‘the wheel position’ (Fig. 54).

The copulation may last from few seconds to many hours. This lock and key mechanism prevents mating across closely related species. Oviposition occurs soon after copulation. In most cases, the male remains associated with the female in tandem position while ovipositing. This behaviour ensures that the eggs laid are fertilised by guarding male (Emiliyamma 2005). Multiple mating in both males and females is common among odonates. Satpathi (2010) reported that adults of some of the dragonflies matured within a week and tried to find suitable breeding ground in the rice field. The virgin male always drove out other males having identical body size. The author also found that during the mating the male dragonfly clasps the female head. The pair dragonflies then flies together in a “tandem position” followed by “wheel position” from few second to many hours.

![Fig. 53. Tandem position](image1)
![Fig. 54. Wheel position](image2)

**Egg laying habitats**

Eggs are oval and are directly inserted into water or submerged plants/debris or mud by means of robust ovipositor but quite a number of species oviposit in the aerial part of plant (Fig. 55). They lay their eggs in all type of aquatic habitats, from still stagnant water to fast flowing rivers to water collected in tree holes. Egg laying commences immediately after copulation. Satpathi (2010) reported that as soon as mating is completed the female dragonfly released their egg masses rapidly by skimming the water surface dipping the abdomen at intervals.
Fig. 55. Some species oviposit in the aerial part of plant

Usually, males guide the females to the egg laying site and also guard her from other aggressive male while she lays. In many cases, the male continues to hold the female and flies with her to an egg-laying site or just accompanies her. It is usually observed that territory holding males accompany females and non-territory holding males maintain physical contact with the female while laying egg. Usually during this period the female is very vulnerable to the attack by other males. Non-mated males attack the mated pair and try to hijack the female. In such cases the hovering male anchors the egg-laying female. Egg laying habitats are highly specific for each species. The number of eggs laid by an ovipositing female varies from a few hundred to several thousands, laid usually in batches in rows, or in a zigzag pattern or scattered at random. Eggs of endophytic species are elongated, and it is the characteristic of a few anisopteran families. First eggs are laid in or near fresh water, depending on whether the female possesses a complete ovipositor or not. Eggs hatch in 5 to 45 days in West Bengal. In Pantala flavescens (Fabricius), Crocothemis servilia (Drury) the eggs have a gelatinous substance which expands and becomes adhesive on contact with water.

This gelatinous material sometime adhered with mosses in rice field which helps the eggs from being carried away from one field to other by water currents but with the maturity of the crop fields dried and the dragonflies could not build up their population in rice field (Fig. 56).

Dragonflies use a number of distinct method for egg laying in weed and ratoon crop in rice fields. During off season when the rice crops are harvested the female inserted their eggs either in to the stem of weed or submerged ratoon rice plant. Orthetrium sabina sabina (Drury), Pantala flavescens (Fabricius), Crocothemis servilia (Drury), Diplacodes trivialis (Rambur), Neurothemis tullia (Drury), Trithemis pallidinervis (Kirby), Brachythemis contaminata (Fab.), Brachydiplex sobrina (Rambur), Orthetrum triangulare (Selys), Neurothemis fulvia (Drury), Rhyothemis variegata variegata (L.), Tholymus tillaraga (Fab.) and Rhodothermis rufa (Rambur) deposited egg in shallow depth of water in rice field whereas Tramea virginia (Linn.), Potamarcha congener (Rambur), Acisoma panorpoides (Rambur), Anatogaster
nipalensis (Selys), *Tramea basilaris burmeistry* (Kirby) and *Anax guttatus* (Burn) prefer the deepwater ponds or lakes.

![Image](image_url)

**Fig. 56.** Professor Chitta Ranjan Satpathi studying the biology of dragonfly simultaneously in two different habitats of rice field in Eastern India

Dragonflies use a number of distinct method for egg laying in weed and ratoon crop in rice field. During off season when the rice crops are harvested the female inserted their eggs either in to the stem of weed or submerged ratoon rice plant. *Orthetrium sabina sabina* (Drury) dips towards and flips at droplet of water on to the leaves of water weeds so that eggs stick into plant. Among the 21 species of odonata *Orthetrium sabina sabina* (Drury), *Pantala flavescens* (Fabricius), *Crocothemis*
servilia (Drury), Diplacodes trivialis (Rambur), Neurothemis tullia (Drury), Trithemis pallidinervis (Kirby), Brachythemis contaminata (Fab.), Brachydiplex sobrina (Rambur), Orthetrum triangulare (Selys), Neurothemis fulvia (Drury), Rhyothemis variegata variegata (L.), Tholymus tillaraga (Fab.) and Rhodothemis rufa (Rambur) breed near water and lay eggs in water, whatever may be amount of water available.

**Nymphal development**

The eggs hatch out into prolarva which after a variable period, from a few days to several months depending on the species and the atmospheric temperature. For the first few days, the newly hatched prolarva, live on the yolk retained in their bodies. There are several (9 to 16) larval instars before the final instars that leads to the emergence of the emago.

*Fig. 57. Dragonfly nymphs or naiads*

_Dragonfly_ larvae are also called nymphs or naiads (Fig. 57 & 58). Nymphs are carnivorous and play crucial roles as highly effective predators in aquatic ecosystems. The body is divided into three parts as in adult. They are bottom living, concealed under mud and have their bodies covered with hairs.

They can change their color according to surrounding in which they live. They are stouter and have respiratory gills inside their rectal chambers, thus virtually breathing through their anus. This mechanism also enables to propel themselves forward by expelling water out with pressure.
At metamorphosis the pharate adult moves to the water/land surface where atmospheric gaseous exchange commences. The dragonfly larva is much stout and flattened (Fig. 59).

When the time for emergence of the imago arrives, the nymph stops eating, and appear swollen. The nymph leaves the water, climb up some suitable object or stem of rice plant or even crawl up the banks and climb on stems of plants there and attach
itself supported by legs. After a short while, the insect bends up and grasps the supporting object with the help of its legs and draws out remaining part of the body from the larval skin (Fig. 61). The wings expand quickly, and once they are dry, the imago flies away. The imago is long lived, active and aerial (Fig. 60).

Satpathi 2010 reported that the development period of dragonfly varies according to the different species recorded in rice ecosystem. The dragonflies which breed in the rice fields usually completed their nymphal development within 35 days but the survival of adults depends upon climate and availability of food. As soon as the nymph matured and the wing pads are fully formed they crawled up out of water, climbed on tiller of rice plant and emerged as an adult with functional wing. Mostly, emergence happens during early morning. There, its larval skin splits along the back and the adult emerged out, wrinkled and soft, in a process lasted about an hour or so, after which the body becomes hard and wings stiff. The larval case left behind, called exuviate, can often be seen attached to rice stems or fallen logs near water, and can be used for identifying the species. Author also recorded that there are several larval instars varying from 9 to 20 according to the temperature, food and species available in a particular ecosystem. Author also found that the mature nymphs spent a substantial period in the “pharate state” (cloaked within the cuticle of previous) awaiting condition favorable for the next stage. In rice ecosystem it was 32 days whereas in adverse condition it was up to 2 months to few years because in this state the double cuticle layer restrict water loss during the developmental period.
Longevity

Most of the records of longevity in nature refer only to the reproductive period. During this, dragonflies live up to 6 weeks. If maturation period is included, it may extend up to 7-9 and 8-10 weeks, respectively. It is known that aestivating spread wings (Lestidae) can live much longer as adults.

Flight

Dragonfly surpass all other groups of insects in their flying skills. They have uncoupled wings, that is unlike moths, butterflies, wasps and bees, fore and hind wings are unattached to each other and they beat independently. The powerful thoracic muscles help them in long sustained flight and good maneuver ability.

![Fig. 61. 180° turn of wings during backward movement of dragonfly](image1)

![Fig. 62. Cross section of fore wing and hind wing of dragon fly](image2)

Dragonfly hover and turn 180° while in flight and can fly backwards (Fig. 61 & 62). Dragonflies are stronger fliers than damselflies and they can reach a speed up to 25-30 km per hour. The differences in flying abilities influence their dispersal and geographic distribution. It is generally observed that big and powerful fliers have wider geographic range than small and weak fliers do. Some weak fliers are dispersed by wind. For example, *Potamarcha congener* (Rambur) is a weak flier and is dispersed by wind throughout plains of West Bengal. Generally it was observed that dragonflies which breed in temporary pools migrate. One of our most common species, *Pantala flavescens* (Rambur) migrates immediately after the monsoons whereas *Brachydiaplex sobrina* (Rambur), congregate over small ponds before the shower. Large swarms of these dragonflies move through prominent clearings in the landscapes such as highways and railway tracks.
It is not yet clear how and where they migrate. Dragonflies have no defensive mechanism excepting the flight power. Some of them mimic Hymenopterous insects, although it has got survival value but it can not be said what is the evolutionary priority of cause and effect. Satpathi (2010) found that the adults of dragonfly after emergence take rest on sticks or perchers put in the rice field or bushes nearby the rice fields.

**Preying**

The nymphs or noids are predatory on other aquatic organisms, whereas the adults catch terrestrial aerial prey. Even though the species are usually highly specific to a habitat, some have adapted to urbanization and use man-made water bodies. Being primarily aquatic, their life history is closely linked to specific aquatic habitats. Most of the dragonflies are day fliers but *Brachydiplex sobrina* (Rambur), actively hunt during twilight hours. Large numbers of adults sometime congregate especially during dawn and dusk in rice fields to feed on *Cofana specta* (Dist.). They hold their prey in their legs and eat either while on flying or resting on weeds or ratoon rice plants or rice fallows. They feed in flight, using the legs to capture the prey and transfer it to the jaws. The legs are highly specialized for this purpose, particularly with regard to its position, relative length, articulation and complement of spines. Adults normally fly below the rice canopy searching for flying insect as well as hoppers on plants. Darter dragonflies capture their prey by perching at a vantage-point and making short sallying flights and hawker dragonflies hunt by flying continuously. In this, they resemble insectivorous birds like flycatchers and swifts respectively. Sometimes dragonflies are supposed to string, but in really they are harmless. Satpathi (2010) conducted a study where the wings of dragonflies were marked by yellowish dye to find out their behavioral changes in nature where the adults preyed on some specific insects in rice fields which were easily visible to their multifaceted eyes.

The nymph is also a sophisticated predator. Their cryptic colouration and keen eyesight make them an effective predator. They feed on diverse aquatic organisms such as small crustaceans, aquatic insects, tadpoles and small fishes. The nymphs of these odonata feed on almost any kind of insect that are small enough for them to handle. They burry them beneath the weed, loose gravel, mud, ratoon effectively concealing themselves from passing prey. When suitable prey come they use their killer mask or modified lower lip of their mouthparts. During rest this mask covered the other mouthpart like mask. The labium of the nymph is long and hinged with 2 inward pointing claws on the end. As and when the prey comes close it shoots the labium forward very rapidly. The claws of the front pair of leg are used to pull the prey inside the face. The dragonfly nymphs are voracious carnivores feeding on any moving and sizeable prey including their own kind. They are biocontrol agents and many species of odonates inhabiting agro ecosystems play a crucial role in controlling pest populations. But some systematically stalk their prey much like birds of prey or as tigers do. Economically they are of great importance in destroying noxious flies and
mosquitoes, as well as smaller moths which are regarded as pests. Life in the tropics would soon become unbearable were it not for the beneficient work of vast number of dragon flies acting as scavengers of the atmosphere. Some species which take to the wing only after dark or at dusk live entirely on mosquitoes (Fraser 1933, 1934 & 1936).

**Role of Dragonfly in integrated pest management of rice**

Out of 131 species of insect predators in the plains of West Bengal 21 species of Dragonfly spend their life cycle in aquatic and terrestial ecosystem. First eggs are laid in or near fresh water, depending on whether the female possesses a complete ovipositor or not. Among the 21 species of odonata Orthetrium sabina sabina (Drury), Pantala flavescens (Fabricius), Crocothemis servilia (Drury), Diplacodes trivialis (Rambur), Neurothemis tullia (Drury), Trithemis pallidinervis (Kirby), Brachythemis contaminata (Fab.), Brachydiplex sobrina (Rambur), Orthetrum triangulare (Selys), Neurothemis fulvia (Drury), Rhyothemis variegata variegata (L.), Tholymus tillaraga (Fab.), Rhodothemis rufa (Rambur), Tramea virginia (Linn.), Potamarcha congener (Rambur), Acisoma panorpoides (Rambur), Anatogaster nipalensis (Selys), Tramea basilaris burmeistry (Kirby) and Anax guttatus (Burn) frequently visit the rice field in search of prey.

The dragonflies which breeds in the rice field usually completed its nymphal development within 35 days but the survival adults depends upon climate and availability of food. Satpathi (2010) also reported that among the different components of the biological control in rice ecosystems dragonfly is a predator both in adult and nymphal stages.

Adults are terrestrial whereas their nymphs are aquatic. Among the large numbers of Odonatan species Brachythemis contaminata (Fab.), Orthetrum sabina Sabina (Drury.), Crocothemis servilia servilia Drury, Diplacodes trivialis (Rambur), Pantala flaviscens Fab. were very common in rice field (Satpathi & Sarkar 2009 & 2009). Large numbers of dragonflies were found to fly above the sky and the eggs were laid on waterbodies immediately after the land preparation in rice field. After eclosion the “pronymph” immediately moults to the first true nymph, which is the first feeding stage. The nymphs are predatory on insect pests of rice crop whereas adults catch terrestrial aerial prey. The adult of the dragonfly captures the prey at the ground level whereas the nymphs prefer rice hoppers that fall on the water. As the nymphs of dragonflies grow the food also changes, they also climb up the rice stems to search for insect pests of rice. Sometime the mature nymphs of dragonfly were found to capture the adults of leaf folder, stem borer and other insects.

The mature nymphs usually climb up at night to capture moths as well as hopper in the rice field. In the next stage the skin splits at the head and the adults come out, wait for the sun and fly off to feed either the moths of stem borer, leaf roller, caseworm, gall midge or the adults of brown plant hopper, white backed plant hopper, green leafhopper, zigzag hopper (Satpathi 2010).

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The mechanism of quick take off assist the dragonfly to catch the rice pests (Satpathi & Sarkar 2010). To accelerate this mechanism number of dragon perchers of the equal height of the particular rice variety were installed at certain interval in rice field which led to a substantial decline of population of pest at Regional Research Station, Chakdaha under Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India.

**Distribution of dragonflies in West Bengal**

Three different localities were selected 9.75 (Chakdaha), 200 m (Cooch Behar) and 1250 m (Kalimpong) above mean sea level, which represent an unique physiographic ecological system characterized by extreme diversities of dragonfly inhabiting in Eastern India. The study through three crop seasons revealed a total number of 14 species of dragonfly occurring regularly in rice crop. From the general taxonomical point of view all the dragonflies were grouped under 2 families and 14 species.

**Table 2.** Common Dragonfly species recorded in rice ecosystem of three different altitudes of West Bengal (Population / 100 m² area).

<table>
<thead>
<tr>
<th>SL No</th>
<th>Family</th>
<th>Scientific Name</th>
<th>Localities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gomhidae</td>
<td><em>Ictinogomphus rapax</em> (Rambur)</td>
<td>9.75 m. from mean sea level (Chakdaha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200 m from mean sea level (Cooch Behar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1250 m from mean sea level (Kalimpong)</td>
</tr>
<tr>
<td>2</td>
<td>Libellulidae</td>
<td><em>Acisoma p. panorpoides</em> Rambur</td>
<td>9.75 m. from mean sea level (Chakdaha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200 m from mean sea level (Cooch Behar)</td>
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<td></td>
<td></td>
<td></td>
<td>1250 m from mean sea level (Kalimpong)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td><em>Brachythemis contaminata</em> (Fabricius)</td>
<td>9.75 m. from mean sea level (Chakdaha)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>200 m from mean sea level (Cooch Behar)</td>
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<td></td>
<td></td>
<td>1250 m from mean sea level (Kalimpong)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td><em>Brachydiplax chalybea</em> Brauer</td>
<td>9.75 m. from mean sea level (Chakdaha)</td>
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<td></td>
<td></td>
<td></td>
<td>200 m from mean sea level (Cooch Behar)</td>
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<td></td>
<td>1250 m from mean sea level (Kalimpong)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td><em>Diplacodes trivialis</em> (Rambur)</td>
<td>9.75 m. from mean sea level (Chakdaha)</td>
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<td></td>
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<td></td>
<td>200 m from mean sea level (Cooch Behar)</td>
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<td></td>
<td></td>
<td></td>
<td>1250 m from mean sea level (Kalimpong)</td>
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</table>
Taking the distribution of insect predator species of three crop seasons in three different localities together, the numbers recorded were 14, 14 and 2 in Chakdaha, Coochbehar and Kalimpong respectively. The rice fields are ideal wetland for some of the dragonflies which do not require extensive areas of open water. Both adult and nymphs are predators, mainly catching other insects in air and water respectively. The nymphs of these odonata feed almost on any kind of insect that is small enough for them to handle. Adults of 14 dragonflies recorded in rice ecosystem usually captured different types of insect including gall midge adult small moths of rice stem borer, leaf folder, adults of plant hopper and leaf hopper.

They hold their prey in their legs and eat either while on flying or resting on weeds or ratoon rice plant or rice fallow. Some cannibalism also found among themselves when the sufficient foods were not available in the rice field. Initially the active stout adult chase the comparatively weaker individual of the same or different species.

They immediately cut the thin neck after capturing their prey. Therefore the dragonfly could be considered as general predator as it had no specification for selection of prey. The dragonfly nymphs are voracious carnivores. The nymphs hunt by stealth, creeping around very slowly on the bottom of the mass of water in which

<table>
<thead>
<tr>
<th>6. Diplacodes nebulosa (Fabricius)</th>
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<th>+</th>
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<tbody>
<tr>
<td>7. Orthetum chrysis Selys.</td>
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<td>+</td>
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<tr>
<td>8. Orthetum luzonicum (Brauer)</td>
<td>+</td>
<td>+</td>
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<tr>
<td>9. Orthetum sabina sabina (Drury)</td>
<td>+</td>
<td>+</td>
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<tr>
<td>10. Neurothemis tullia tullia (Drury)</td>
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<td>+</td>
</tr>
<tr>
<td>11. Pantala flavescens (Fab.)</td>
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</tr>
<tr>
<td>12. Rhyothemis v. variegata (Linnacus)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>13. Trithemis aurora (Burmeister)</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

+ = Low.( less than $1/m^3$ ), – = Nil
they live on water vegetation (weed). During rest this mask covered the other mouthpart like mask. The labium of the nymph is long and hinged with 2 inward pointing claws on the end.

**Food**

The dragonflies are predacious, both in the immature instars, and as adult. The adults feed on a great variety of insects, which they capture by flight, and the larger dragonflies habitually eat the smaller ones, but a large part of their food consists of mosquitoes and other midges, butterflies, moths, bees and odonates on flight.

**Natural enemies of Odonata**

Dragonflies encounter a large number of predators throughout their life. Large dragonflies, robberflies (Asilidae) and spiders are important invertebrate predators (Fig 63). Parasite females climb or swim beneath the water to search for the eggs in the submerged plants. Usually during this breeding period the female is very vulnerable to the attack by other males. Non-mated males attack the mated pair and try to hijack the female. Some dragon flies lay eggs in submerged plants. In such cases the hovering male anchors the egg-laying female. This predation forms an important link in the transfer metacercariae and cysts of the parasite. Larval stages of water mite (Hydrachnidia) parasitise odonates. The mite larvae infest the final instar host larvae. The larvae briefly feed on the host larvae and when the adult dragonfly emerges.

![Fig. 63. Natural enemies: Spider (Salticidae) and Robberflies (Asilidae)](image_url)
The mite larvae get attached to the adult host. Mite larvae pierces the host body and starts feeding. The larvae detach only when the host comes back to water for egg laying. The detached mite larvae complete two more larval stages as predator before moult ing into an adult. Salticids (Jumping spiders) sometime attack odonates.

**Bio indicators**

**Fig. 64.** Surrounding of Bombay road in West Bengal before 2006 (Source: Google)

**Fig. 65.** The watershed areas are changed into high road in West Bengal after 2006 (Source: Google)
Dragonfly, because of their specific habitat and landscape requirement, are very sensitive to changes in landscape and are reliable indicators of wetland health. In addition to the direct role of predators in ecosystems, their value as indicators of quality of the biotype is now being increasingly recognized. For example, in Southern part of West Bengal it has been shown how species assemblages of dragonflies change with human disturbance.

Although some new township grews after 1960 but major construction of road, building started after 2006 which causes major landscape changes specially the changes of watershed area in the district of Nadia, Burdwan, North and South 24 Parganas, Howrah, Hooghli and East Midnapur (Figs. 64 & 65)

The study also confirm the observations of Andrews et al. (2008) who found that families like Bamboo tails, Glories, Torrent darts, Torrent Hawks and Club tails are good indicators of health of riverine ecosystems in Western Ghats. Odonates are also good indicators of environmental changes as they are sensitive to changes in the habitats, atmospheric temperature and the weather conditions. Since these insects prefer humid tropics, they are more in number in the tropical environment. These insects also do not occur in the salforsts due to lack of undergrowth. The number of species in the Ganga basin is more than that of other ecosystem in India, due to occurrence of huge number of breeding areas. Odonates are active mainly in the daytime, with the change of seasons the activity during 24-hour cycle changes. In summer due to early sunrise and late sunset dragonflies remain active for longer period of the day while in winter this is reverse due to short duration of daylight (Mitra 2006). Dragonflies mostly occur in the vicinity of different freshwater habitats like rivers, streams, marshes, lakes and even small pools and rice fields. (Tiple et al. 2008).

Odonata and plants: Relation of odonata with plants have been studied properly, although fossil records are available since Miocene. In west Bengal Orthetrum sabina sabina (Drury), Pantala flavescens (Fabricius), Crocothemis servilia (Drury), Diplacodes trivialis (Rambur) visit to capture gall midge adult, along with other hopper pests available in the rice field. It was recorded that in England Anax imperator Leach prefers environment with Pinus, Bitula and Colluna vegetations, Tholymis tillarga Hagen, Pantala flavescens (Fab.) take shelter under broad leaves, smaller odonates rest and roost in the bushes. Larvae of Rhinocypha in the Western Himalayas remain hidden under covers of mosses and other vegetation, species Copera, Platycnemis, Mortonagrion prefer dark undergrowth of jungles (Mitra 2006).

Major threats to dragonflies in rice ecosystem

Habitat loss, degradation, or modification, both in the aquatic and the terrestrial environments, represent the major threats to Odonata in rice ecosystem of West Bengal. As indicated in Figs. 66 & 67, the three most wide-ranging threats are water scarcity, urbanization and indiscriminate use of insecticide. All of which are particularly significant for threatened species. As noted above, a high proportion of
species in West Bengal are water body associated, with only 30.5% of species in the cosmopolitan families Coenagrionidae and Libellulidae, most members of which favor open unshaded habitats.

Fig. 66. Major threat to dragonfly in rice ecosystem

Fig. 67. The water body of the outlet of a river Ganga transformed to new town in Kolkata, is one of the major threat to build up dragonfly population in West Bengal, India (Source Google)

Forest clearances may originally be for timber harvesting, but are often followed up by the establishment of villages by tribal people of Bankura, Purulia and Birbhum. However, degradation of nature reserves by encroachment, development of tourism facilities and illegal logging are probably a significant problem, particularly in Birbhum, Jalpaiguri, Hooghly and East Midnapore. An emerging threat is from the
industrial park in Kalyani, Durgapur, Dankuni, Surrounding of G.T. Road, Bombay High road, NH -34, Asansol, Siliguri and Brrackpore. The woods of Bankura, Midnapore, Burdwan, Siliguri were been dramatically deforested by recent construction activities which will apparently culminate in a new leisure town. Dam construction in Bankura (Kangasabati), Birbhum (Panchet, Mython), Burdwan (Durgapur), Murshidabad (Faracca) represent a significant threat to running water odonates in West Bengal. Thermal power developments in upstream of the Rupnarayan in West Midnapore, Bakreswar river in Birbhum, Faracca in Murshidabad which have resulted in spectacular deforestation along the River. Strict enforcement of regulations in nature reserves and national parks by the relevant authorities, together with expansion of existing protected areas and designation of new ones, particularly in forest areas, would undoubtedly enhance the efficacy of the protected areas systems as a means of conserving odonates across the region. The downstream impact of Kangsabati, Durgapore Tilpara on rivers of Kansai, Damodore, and Maurakhsi can be mitigated to some extent if a natural water regime with normal seasonal fluctuations, albeit much reduced discharge, is permitted by the dam design. This can reduce disturbance to the breeding and larval habitats of many riverine dragonflies.

![Image](image.jpg)

**Fig. 68.** Endangered species

The result also support the observation of Mitra (2006) who reported that water body play important roles in odonata life and distribution. They prefer permanent water bodies where sources of perenial water are available. For example, deserts support lesser number of species than water regions. In case of rainforest areas like Arunachal Pradesh has got large number of permanent perennial water sources and
supports 91 species and subspecies, while in the oceanic islands like the Andamans and Nicobars perennial where water resources are scanty only 47 species occur there; on the otherhand Calcutta city is provided with large number of aquatic bodies and supports nearly 60 species and subspecies. Emiliyama et al. (2005) recorded one species of Acisoma Rambur 1882, three species of Brachydiplex Bauer 1868, one species of Brachythemis Brauer 1868, three species of Crocothemis Brauer 1868, three species of Diplacodes Kirby, fifteen species of Orthetrum Newman 1853, six species of Neurothemis Brauer 1868, one species of Pantala Hagen 1861, four species of Rhyothemis Hagen 1867, one species of Sympetrum Newman 1833, three species of Trithemis Brauer 1868, one species of Zyxomma Rambur 1842, one species of Ictinogomphus two species of Tramea Hayen 1861, two species of Anax Leach 1815, one species of each Tholymis Nagen 1867, Rhodothemis sp., Potamercha Karsch 1868, Anotogaster Selys 1854. in India respectively. Identically Rai et al. (2000) also reported 140 genera and 500 species of dragonflies from India.

Table 3. Threatened dragonfly species in rice ecosystems of West Bengal

<table>
<thead>
<tr>
<th>Threat Category</th>
<th>Species</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critically Endangered</td>
<td>Chlorogomphus preciosus Fraser</td>
<td>From Terai to lower Gangetic Alluvial zone, from terai to sea coast</td>
</tr>
<tr>
<td></td>
<td>Chlorogomphus atkinsoni (Selys.)</td>
<td>From upper Gangetic Alluvial zone to lower Gangetic Alluvial zone.</td>
</tr>
<tr>
<td>Endangered</td>
<td>Phaenandrogomphus aureus (Laidlaw)</td>
<td>From Terai to sea coast</td>
</tr>
<tr>
<td></td>
<td>Onychogomphus striatus Faser</td>
<td>From upper Gangetic alluvial zone to sea coast</td>
</tr>
<tr>
<td></td>
<td>Anatogaster nipalensis Selys</td>
<td>From upper Gangetic alluvial zone to lowe Gangetic Alluvial zone</td>
</tr>
<tr>
<td></td>
<td>Epoptalmia vittata vittata Burmeister</td>
<td>From Terai to sea coast</td>
</tr>
<tr>
<td>Vulnerable</td>
<td>Macrogomphus montanus Selys.</td>
<td>South Bengal</td>
</tr>
<tr>
<td></td>
<td>Paragomphus lineatus (Selys.)</td>
<td>South Bengal</td>
</tr>
<tr>
<td></td>
<td>Stylogomphus inglisi Fraser</td>
<td>From Terai to sea coast</td>
</tr>
<tr>
<td></td>
<td>Macromia moorei moorei Selys</td>
<td>South Bengal</td>
</tr>
</tbody>
</table>
Conservation measures

The effective conservation of Odonata depends entirely on conservation of their habitats. No other erasures are of any real value. However, dragonflies do not need huge protected areas; in fact many small areas will probably serve them better than a few scattered big areas, as long as the protected areas are looked after properly. The degradation of dragonfly habitats arising from changing land-use can be ameliorated by appropriate development planning controls, such as maintenance of forest riparian corridors along streams running through logging concessions or agribusiness plantations, limits on water abstraction, and nondevelopment buffer zones along or around natural water bodies. Effective stream buffers are rarely maintained in practice, even when touted as such, but they are an essential part of dragonfly conservation. It is important that at least some stream buffers are extended into conservation areas around the sources of streams (e.g. so that tiny seepages and trickles are included) to protect the substantial part of forest dragonfly diversity found in these places. These streams are generally considered too small to deserve a buffer of their own. Protected areas already exist in many of the best remaining dragonfly habitats in India, but the effectiveness of conservation policies and measures is often poor due to inadequate enforcement. Strict enforcement of regulations in nature reserves and national parks by the relevant authorities, together with expansion of existing protected areas and designation of new ones, particularly in forest areas, would undoubtedly enhance the efficacy of the protected areas systems as a means of conserving odonates across the region. The downstream impact of dams on small and large rivers can be mitigated to some extent if a natural water regime with normal seasonal fluctuations, albeit much reduced discharge, is permitted by the dam design. This can reduce disturbance to the breeding and larval habitats of many riverine dragonflies.

Species diversity

Developmental time dependent on the temperature of the water in which the nymph live as long as adequate food is available. An investigation was made to find out the crop stage wise diversification of individual predator and found that dragonfly was more diverse during flowering to ripening stages of crop respectively.

Simpson index of diversity (D) for dragonfly had the highest value at ripening stage (D = 11.904) and lowest value at vegetative stage (D = 8.771). The highest and lowest value indicate maximum and minimum species diversity during that period (Table 4).

Shannon-Weiner index (H') indicated the combined effect of species richness and evenness on species diversity. The highest species diversity for dragonfly (H' = 2.636) was also found in flowering to ripening stage of the crop respectively (Table 4).

Berger-Parker index had the maximum value for dragonfly (0.428) at flowering to ripening stage of crop indicating most abundant species which constituted 42.8% of total population count (Table 4).
This result is in consonance with the view of Kandibane et al. (2005) who stated that the species of dragonfly preferred tillering stage of crop because the canopy of rice crop covered the entire surface area to create a favorable microclimate for the abundance of dragonfly species.

**Table 4.** Diversity indices of dragonflies in three different stages of rice crop in West Bengal, India.

<table>
<thead>
<tr>
<th>Rice crop stages</th>
<th>Total abundance of dragonfly/100m$^2$</th>
<th>Population ranges of dragonflies</th>
<th>Simpson Index ($D$)</th>
<th>Berger-Parker Index</th>
<th>Shannon – Weiner index ($H$)</th>
<th>Dominant species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative stage</td>
<td>15</td>
<td>1-2</td>
<td>8.771</td>
<td>0.125</td>
<td>2.476</td>
<td>Orthetrum sabina sabina (Drury)</td>
</tr>
<tr>
<td>Vegetative to flowering stage</td>
<td>12</td>
<td>2-2</td>
<td>9.009</td>
<td>0.166</td>
<td>2.497</td>
<td>Orthetrum sabina sabina (Drury)</td>
</tr>
<tr>
<td>Flowering to ripening stage</td>
<td>7</td>
<td>1-3</td>
<td>11.904</td>
<td>0.428</td>
<td>2.639</td>
<td>Brachythemis contaminate (Fab.)</td>
</tr>
</tbody>
</table>

The result is in agreement with the view of Bambaradeniya and Edirisinghe (2008) who stated that the species richness diversity of terrestrial arthropods increased gradually with the crop age. The mean species diversity of terrestrial arthropods of vegetative, reproductive and ripening were significantly different and the highest diversity was recorded during the reproductive stage. The early colonization and build up of arthropod communities observed in the field proper were similar to those recorded by Heong et al. (1991) and Schoenly et al. (1996) where pest phytophages increased in number faster than predator. The dominance of predators during ripening stage of crop can be attributed to an increase in their abundance of prey. Ripening of the rice crop reduce the vegetation resulting on reduction of dragonfly. The result is confirmation with Gangurade (2007) who reported highest pest species richness during the tillering stage, while predator species richness was highest during milk stage of rice in Philippines.
Diversity of major dragonfly species under specific order in different stages of rice crop

Among the dragonflies *Orthetrum sabina sabina* (Drury) and *Brachythemis contaminata* (Fabricius) were noticed to dominate the other species in the rice field right from starting of flowering to ripening stage of crop. The study was conducted to find out the crop stage wise diversification of individual predator and it has recorded that all the predators were more diverse during flowering and reproductive stage of crop (Table 5).

**Table 5.** Parameter and indices to express the extend of diversity of Dragonflies in rice ecosystem of West Bengal

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>No of species</th>
<th>Richness index</th>
<th>Hill’s diversity index</th>
<th>Evenness Index</th>
</tr>
</thead>
<tbody>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Margalef Index</td>
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<tr>
<td></td>
<td></td>
<td>(R&lt;sub&gt;1&lt;/sub&gt;)</td>
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<td>Menhinik Index</td>
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<td></td>
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<td>(R&lt;sub&gt;2&lt;/sub&gt;)</td>
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<td>No (s)</td>
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<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
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<td>N&lt;sub&gt;2&lt;/sub&gt;</td>
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<td>No (S)</td>
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<td>E&lt;sub&gt;1&lt;/sub&gt;</td>
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<td>E&lt;sub&gt;2&lt;/sub&gt;</td>
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<td>E&lt;sub&gt;3&lt;/sub&gt;</td>
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<td>E&lt;sub&gt;4&lt;/sub&gt;</td>
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<td></td>
<td>E&lt;sub&gt;5&lt;/sub&gt;</td>
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</tr>
<tr>
<td>Vegetative</td>
<td>20</td>
<td>3.749</td>
<td>1.586</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>11.89</td>
<td>8.74</td>
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<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.82</td>
<td>0.59</td>
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<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.57</td>
<td>0.73</td>
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<tr>
<td></td>
<td></td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetative to flowering</td>
<td>20</td>
<td>3.962</td>
<td>1.818</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>12.14</td>
<td>8.99</td>
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<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.83</td>
<td>0.59</td>
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<td></td>
<td></td>
<td>10</td>
<td>0.57</td>
<td>0.73</td>
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<tr>
<td></td>
<td></td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowering to ripening</td>
<td>20</td>
<td>4.428</td>
<td>2.340</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>13.95</td>
<td>11.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.87</td>
<td>0.69</td>
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<td>10</td>
<td>0.68</td>
<td>0.85</td>
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<tr>
<td></td>
<td></td>
<td>0.84</td>
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</tr>
</tbody>
</table>

The highest values of Margalp index (R<sub>1</sub> = 4.428) and Menhinik index (R<sub>2</sub> = 2.340) during flowering to ripening stage whereas it was lowest (R<sub>1</sub> = 3.749, R<sub>2</sub> = 1.586) in vegetative stage. Here the species richness was relatively high S = 20 of which highest value of abundant and most abundant species without considering crop stages
were 13.95 and 11.90 respectively. The evenness indices reached to its highest level 0.87 in $E_1$ and minimum 0.57 in $E_3$ regardless of the crop stage. Here only $E_1$ was strongly influenced by species richness whereas $E_2$ and $E_3$ were simply influenced by species richness in rice ecosystems of West Bengal. The maximum values of $E_4$ and $E_5$ ranged from 0.73 to 0.84 and 0.71 to 0.85 respectively.

**Collonisation and Succession of dragonfly with respect to pest and environment.**

The colonization and succession of dragonfly taxa in the rice field habitat was observed to follow a uniform pattern in relation to the growth stage of rice crop as well as the different phases in the rice field (Table 6). During land preparation the field was submerged with water and the dragonfly adults were found to lay their eggs. The dominance of dragonfly during the flowering to ripening stage of crop can be attributed to an increase in relation to an abundance of their prey. Harvesting of rice crop remove insect pests resulting in the reduction of dragonfly population in rice fields. Swift and Anderson, (1994), found that he maintenance of diversity within agricultural environment is widely recognized as being essential for their agronomic sustainability.

Matson *et al.* (1997) reported that an important principle of integrated pest management is to maximize natural control and therefore the temporal change in arthropod abundance, diversity, species richness and community structures are important considerations in designing pest management strategies. After rice establishment both pest and dragonfly species colonize and over time progressively increase in diversity. The rice field predator is one of the important component of that biodiversity (Altieri and Nicholl, 1999).

Their communities may vary with the environment crop stage and cultivation practices. Rice field often support high level of predator biodiversity, which play an important role in the agricultural productivity of these systems.

It is evident from the Table 6 that the incidence of dragonfly species changes with their host and their habitat. During field preparation 8 species of dragonfly were colonized along with rice pests. The number of dragonfly species increased to 13 and 8 during flowering and ripening stages of crop respectively. Although number of insect pests recorded but rice stem borer and rice plant hoppers dominated the other species in rice field.

The arthropod pest and dragonfly population in rice field were intimately associated with each other.

The observation was in agreement with Thorbek and Bilde (2004) who reported that adjacent, less disturbed, refuge areas are colonized by predators following husbandry event, demonstrating significant special dynamics among farmland arthropod. Abundance of predators could show a shift seasonally and geographically, but a few species of dragonflies were been shown to highly impact on pest population.
Table 6. Major dragonfly species colonized along with key pests in different stage / phage of rice field in the plains of West Bengal

<table>
<thead>
<tr>
<th>Stage/Phase</th>
<th>Major taxa of dragonfly which colonized in rice field</th>
<th>Key pests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land preparation to nursery</td>
<td>Brachythemis contaminata (Fabricius)</td>
<td>Small grasshopper, adult leafhopper</td>
</tr>
<tr>
<td></td>
<td>Brachydiplax chalybea Brauer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crocothemis servillia (Drury)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diplacodes trivialis (Rambur)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diplacodes nebulosa (Fabricius)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orthetrum chrysis Selys</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orthetrum luzonicum (Brauer)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orthetrum sabina sabina (Drury)</td>
<td></td>
</tr>
<tr>
<td>Transplanting to Flowering stage</td>
<td>Acisoma p. panorpoides Rambur</td>
<td>Adults of Yellow stem borer, Larva and adults of Leaf roller, Adult and nymphs of Green leaf hopper, brown planthopper, white backed planthopper, adults of Caseworm and Gall midge.</td>
</tr>
<tr>
<td></td>
<td>Brachythemis contaminata (Fabricius)</td>
<td></td>
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<tr>
<td></td>
<td>Brachydiplax chalybea Brauer</td>
<td></td>
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<tr>
<td></td>
<td>Crocothemis servillia (Drury)</td>
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<td></td>
<td>Diplacodes trivialis (Rambur)</td>
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<td></td>
<td>Diplacodes nebulosa (Fabricius)</td>
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<tr>
<td></td>
<td>Neurothemis tullia tullia (Drury)</td>
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<td></td>
<td>Orthetrum chrysis Selys</td>
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<td>Orthetrum luzonicum (Brauer)</td>
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<td></td>
<td>Orthetrum sabina sabina (Drury)</td>
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<td></td>
<td>Pantala flavescens (Fab.)</td>
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<td></td>
<td>Rhyothemis v. variegata (Linnacus)</td>
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<td></td>
<td>Trithemis aurora (Burmeister)</td>
<td></td>
</tr>
<tr>
<td>Flowering to harvesting</td>
<td>Brachythemis contaminata (Fabricius)</td>
<td>Larva and adults of Leaf roller, adult and nymphs of Plant and Leaf hopper, Adults of rice yellow stem borer.</td>
</tr>
<tr>
<td></td>
<td>Crocothemis servillia (Drury)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diplacodes trivialis (Rambur)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ictinogomphus rapax (Rambur)</td>
<td></td>
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<tr>
<td></td>
<td>Neurothemis tullia tullia (Drury)</td>
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<td></td>
<td>Orthetrum chrysis Selys</td>
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<tr>
<td></td>
<td>Orthetrum sabina sabina (Drury)</td>
<td></td>
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<tr>
<td></td>
<td>Pantala flavescens (Fab.)</td>
<td></td>
</tr>
</tbody>
</table>
Simultaneously with the terrestrial predator aquatic nymphs were recorded in vegetative stage, which peaked in flowering followed by sudden disappearance at the ripening stage of crop. The studies on off seasonal survival of dragonfly showed that the maximum numbers of this insect were recorded in weed habitat (0.881/m²) followed by rice fallow land (0.299/m²) and ratoon (0.126/m²) in rice ecosystems of West Bengal (Table 7). This is confirmation with the previous study of Haq and Karim (1990) who reported that transplanted Amon (rainy) rice (July to Sept.) harbored more insect predators than ratoon rice crop at other time of year in Bangladesh.

Table 7. Relative composition (number/100 m² per sample) of dragonflies species in weed habitat, ratoon crop and rice fallow land

<table>
<thead>
<tr>
<th>Order/Family</th>
<th>Weed habitat</th>
<th>Ratoon</th>
<th>Rice Fallow land</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual No. / m²</td>
<td>TR No. / m² ±SEM</td>
<td>Actual No. / m²</td>
</tr>
<tr>
<td>Gomphidae &amp; Libellulidae</td>
<td>0.881</td>
<td>5.498 ±0.054</td>
<td>0.126</td>
</tr>
</tbody>
</table>

TR No = Transformed values

Some aquatic predators live on the surface of the water in rice field. When the stem borer, leaf folder and case worm larvae attempt to disperse, many use the water and are attacked by aquatic predators. The natural balance between insect pests and their natural enemies is often disturbed by indiscriminate use of chemical insecticides

Relative Ranking of dragonfly among the predators recorded in rice fields of West Bengal

The study could be used to provide initial guidance before embarking on a much more comprehensive study of dragonfly importance in a particular area. The ranking chart in the present investigation gives a current status of predator importance. Their validity will increase over time and they will need to be updated periodically.

Three consecutive years survey across the 3 regions at 3 different attitudes could give a comprehensive idea about the status of the dragonfly. These estimates were cross checked with the ranking given by progressive farmers and friends who could rank.
About fifty insect predators were ranked and it could be found that the highest number of predators belonged to the order Coleoptera (17) followed by Hemiptera (13), Odonata (10), Hymenoptera (3), Neuroptera (2), Orthoptera (1) and Dermaptera (1) respectively. If the entire cropping seasons are divided in 3 different parts as July-August as early (E), August-September as medium (M) and October to November as late (L) be as on the maximum intensity of population could be found in mid season (23) followed by late (18) and early (9) respectively. The basic methodology was to tract each predator separately. It would also be useful, however to get an overview of the predator situation in rice ecosystems of West Bengal. It is possible to do this converting pest ranks into score. The system is considered to be valid as a means of Crude' ranking in which large differences in aggregate score will reflect real difference in importance.

5. CONCLUSIONS

This study highlights the richness of the dragonfly fauna associated with rice ecosystems in Eastern India. Rice crop being a relatively short duration annual crop harbored 75 dragonfly species which are most important group of biological control organisms in rice ecosystem upto 200mt altitude from mean sea level of West Bengal.

Dragonfly, because of their specific habitat and landscape requirement, are very sensitive to changes in landscape. Therefore the effective conservation of dragonfly depends entirely on conservation of their habitat. Although eastern India represent an unique physiographic ecological system which is characterized by extreme diversities of dragonfly inhabiting there but the present study indicates 2, 4 and 4 species are critically endangered, endangered and vulnerable respectively in rice ecosystems of West Bengal.

The studies of different index indicated that dragonflies are specific to particular growth stage of crop but it follows an uniform pattern in relation to growth stage as well different phases in the rice field. The population of dragonfly in rice fields could be conserved and enhanced through maintenance of rice weed flora on bund or allowing ratoon rice after the rice crop during fallow period.

Acknowledgement

The author is grateful to Director of Research, BCKV, WB, to allow me to conduct this experiment at our Regional Research Station, Chakdaha, WB, India. The author is also thankful to his Research Scholars especially Anupom Mondal who has taken some observation and also provided some photographs to prepare this manuscript.
References


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( Received 02 August 2017; accepted 03 September 2017 )
PLATES 1-15

**P-1. Rhodothemis rufa**  
(Rambur)

**P-2. Ictinogomphus rapax**  
(Rambur)

**P-3. Brachydiplax sobrina**  
(Rambur)

**P-4. Acisoma panoripoides panoripoides**  
(Rambur)
P-5. Diplacodes trivialis
(Rambur)

P-6. Crocothemis servilia servilia
(Drury)

P-7. Rhyothemis variegata variegata
(Linn.)

P-8. Tholymis tillarga
(Fabricius)
P-9. *Neurothemis fulvia* (Drury)

P-10. *Neurothemis tullia tullia* (Drury)

P-11. *Pantala flavescens* (Fabricius)

P-12. *Orthetrum sabina sabina* (Drury)
P-13. *Anax guttatus*  
(Burn)

P-14. *Brachythemis contaminata*  
(Fabricius)

P-15. *Potamarcha congener*  
(Rambur)