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Evolution and Multi Scale Effect of Environment on Odonata: A Case Study

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Abstract

Biodiversity conservation and management are worldwide concern where determining the diversity levels of indicator groups of ecosystem should permit the prediction of other taxa to be present i.e., the importance and appropriateness of using invertebrate groups as indicator. This review included evolutionary aspects and environmental effect on Odonata and the role anthropogenic activity in the development of Odonata. As dragonflies are so easily observed they have considerable potential as bio-indicators. Dragonflies therefore have a potential health and economic value which is not yet fully exploited. A count of dragonflies would provide a quick, and therefore low-cost, indication of the health or sickness of the lake or river.

Keywords: Climate, Odonata, Bio-indicator, Environment, Lifecycle, Conservation.

Introduction

All life began from a common ancestor. According to most scientists, animal life is thought to have evolved from a flagellated Protista. This Protista evolved by a cellular membrane folding inward, which became the first digestive system in the kingdom Animalia (Campbell, et al., 1999). As time went on, the kingdom Animalia became more diversified and the class Arthropoda arose and within the order of Arthropods there exits the largest class in the animal kingdom; Insecta. Insects share such common features as three pairs of legs, usually two pairs of wings, a pair of compound eyes, usually one pair of antennae, and a segmented body. According to fossil records, insects appeared quickly after plants in order to possibly fill in a new niche. Wingless insects first appeared in the Devonian period approximately 380 million years ago following the development of the vascular seedless plants.

The evolution of insects occurred in four stages (Columbia University Press, 2003). The first stage is known as the Apterygote stage having simplest forms of insect. They did not have wings, nor developed legs or body parts. The second stage, known as the Paleoptera stage, involves the formation of wings on the insects.
Fossils of the first winged archaic insects date back to the late Carboniferous period about 300 million years ago. These insects were in the order Paleodictyoptera, which is the oldest group of winged insects.

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Paleodictyoptera were the precursors to the modern day Odonata. Dragonflies, which belong to the order Odonata, are one of the oldest insects still around today and they have not changed much from their ancestors. All Odonata share some similar characteristics in vision, life cycle, habitat, morphology flight, hunting prey and mating. Compound eyes allow for keen eyesight in the dragonfly (Trueman et al., 2001) gives the dragonfly a sensitive motion detector to hunt and capture prey.

The Odonata have a long history in the fossil record relative to other orders, with fossils present from the Lower Permian (Wootton, 1981). This fact, coupled with a range of adaptations which have enabled them to colonise temperature and subarctic habitats from their tropical origins (Pritchard and Leggott, 1987), make them ideally suited to surviving current climate change.

External Morphology

The body of the dragonfly is divided into three major sections, head, thorax and abdomen. The compound eyes are very large to assist the insect with its active hunting lifestyle and chewing–biting type of mouth parts. The abdomen is long and segmented. The thorax possesses three pairs of legs which are poorly adapted for walking but are excellent for catching prey. The wings are large, long and transparent and make the dragonflies the most accomplished fliers of the animal kingdom.

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Life cycle

Life cycle for all dragonflies begin as eggs. Some species of dragonflies lay their eggs on plants located above or below the water. In other species, the female dragonfly may not have a functional ovipositor, which is used to attach the egg to a surface and as a result may bury their eggs in the sand or mud or directly in the water. The egg can hatch anywhere from 7 to 9 days or up to several months, depending upon the species. Larvae (nymph) live totally in the water and are voracious hunters. All odonata share the characteristic of having a grasping labium, which is used for capturing prey. Larvae spend all of their time beneath the surface of the water using gills to breathe, and feeding on other vertebrates. Larvae may go through up to 30 moults over a time period of 3 months to 10 years depending upon species. Dragonflies can live a long life as adults from 4 months to 10 years.

Habitat ecology for Odonata

Identifying habitat types based on species presence has potential applications both in terms of choosing and assessing the species as indicators (Sato and Riddiford, 2007). The variables determining the appearance of dragonflies' species are quantity and quality of shoreline structures, reeds and shade (Schindler et al., 2003). Reeds provide important biotopes for nymphs and adults and their spatial heterogeneity can increase dragonflies diversity through creation of microhabitats (Samways and Steytler, 1996). Zygoptera species also can use reeds as oviposition sites (Corbet, 1999). Zygoptera are weak flies compared to Anisoptera and reeds provide shelters, for example, wind (Thompson et al., 2003). C. mercuriale showed strong association with reeds in southern England (Rouquette and Thompson, 2007). The importance of shade for appearance of dragonflies also is recognized.

Effect of Temperature

Hassall and Thompson (2015) reviewed on the effects of environmental warming on Odonata and suggested directions for research, particularly laboratory studies that investigate underlying causes of climate-driven macro-ecological patterns. They studied that the temperature is known to affect Odonata physiology including life-history traits such as developmental rate, phenology and seasonal regulation as well as immune function and the production of pigment for thermoregulation. A range of behaviours are likely to be affected which will, in turn, influence other parts of the aquatic ecosystem. Temperature may influence changes in geographical distributions, through a shifting of species' fundamental niches, changes in the distribution of suitable habitat and variation in the dispersal ability of species. Such a rapid change in the environment results in a strong selective pressure towards adaptation to cope and the inevitable loss of some populations and, potentially, species). Dragonflies regulate body temperature ectothermically by control of solar input and their thermoregulation is achieved by behaviour and physiological responses (Corbet, 1999). Therefore, shade affects the dragon flies thermoregulation and consequently their abundance and distribution.

The Odonata are unique in being the only taxon of aquatic insects which exhibits solely negative relationships between egg development time and temperature (Pritchard et al., 1996). The population model developed by Crowley et al., (1987) considered a direct effect of temperature on development rate only in the egg stage, with indirect effects of temperature via feeding rates in "small" and "large" larval classes (Lawton et al., 1980). Photoperiodic cues are thought to play a role in regulating larval development (Norling 1984b) and, as such, influence the temperature-developmental rate relationships. The increased feeding rates at higher temperatures have also been linked to an increase in the rate of gut clearance at higher temperatures (Gresens et al., 1982). Clearly an increase in feeding rate in a top predator in aquatic ecosystems (e.g. Cordulegaster boltonii, Woodward and Hildrew, 2001) will have knock-on effects at other trophic levels.

It is also tightly linked to temperature, with larger body sizes at lower temperatures being reported in the majority of studies (Atkinson, 1994). Body size in Odonata has been showed to affect to diet breadth (Thompson, 1978b), handling time (Thompson, 1978c) and rate of consumption (Woodward and Hildrew, 2002). However, patterns in odonate body size have been under-studied. Low temperature may also increase stress during development (Chang et al., 2007).Increases in temperature bring increases in evaporation from water bodies with concomitant increases in the concentrations of pollutants (Carpenter et al., 1992). Odonates have been shown to be sensitive to pollutants (Clark and Samways, 1996) and may suffer more than other taxa.

Reproductive Behaviour

From the literature study it reveals that there is variation in reproductive behaviour of damselflies and dragonflies species to species. They exhibit different patterns in site selection, territory formation, oviposition, emergence, habitat preference etc. In odonates, the primary goal of an adult male is to secure mates and therefore in the polygynous mating system, competition for mating opportunities exists.

As Darwin (1859) stated in the "Origin of Species", that sexual selection, "depends, not on a struggle for existence, but on a struggle between the males for possession of females; the result is not death to the unsuccessful competitors, but few or no offspring". Many different reproductive tactics have evolved to optimize the number of opportunities to successfully reproduce with female; the territorial behaviour is exhibited in order to gain access to the female (Brown and Orians, 1970) and the territorial behaviour, copulation and oviposition are carried out within or near the territory (Conrad and Pritchard, 1992). Several variation of the ovipositing behaviour exists in Odonata, but the male has become territorial of these oviposition sites respective to its species (Corbet, 1962). Sharma (2010) studies on the reproductive behaviour of Ischnura aurora (Brauer) and highlighted the unique behavioural aspects of damselflies which vary from species to species.

Biological indicator

The advantages of using biological indicators include long term assessments and higher sensitivity to detect subtle changes in water quality and low concentrations of chemicals. Also, biological responses tend to integrate the independent and interactive effects of many stressors, resulting in more robust indicators than analysis of individual chemicals (Cairns and Pratt, 1993; Cairns et al., 1993).

Odonata is a good biological indicator of habitat integrity especially on fluvial environment (Asaithambi and Manickavasagam, 2002) because of its sensitivity to structural habitat and landscape change (DiSalvo et al., 2003). Several species of Odonata are stenotopic and require specialized habitat conditions (Oertli, 2008) and indicator of quality of the biotope is now being increasingly recognised. Larval Odonate diversity and abundance was positively correlated with macroinvertebrates diversity and abundance and it was efficient bioindicator of intactness and diversity of overall macroinvertebrates (Foote and Rice, 2005).

In addition, dragonflies and damselflies play important ecological roles as both predators and prey. They typically eat mosquitoes, midges, and other small insects which make them valuable in controlling populations of harmful insects. On the other hand, birds (such as the egret and Mississippi kite), frogs, spiders, fish, and even other large dragonflies eat them. Thus, loss of dragonflies and damselflies could have a ripple effect on food webs.

Diversity

About 5,000 species of Odonates are found throughout the world. In India about 500 species and subspecies are reported and of this, about 200 species are found in the peninsular India. The life history of Odonates is closely associated with wetlands. According to scientists, there are about 6000 species of dragonflies in all over the world. At present, the Odonata have about 5,680 species worldwide although the actual no. of species may total 7000 and the rate of new descriptions is currently approximately 200 Odonata species per decade out of which Subramanian (2009) revealed 470 species in 139 genera and 19 families exist in India.

Table I. Various studies on Odonata at various places

Sampling area	Dominating family	Recorded species	Remark	Reference
Narmada Valley, Jabalpur, M.P.	*Libellulidae*	25	Low diversity high anthropogenic disturbances,	Sharma et al., (2015)
Barpeta district, Assam.	*Libellulidae*	45	Loss of water bodies	Baruah and Saikia (2015)
The Padmatola wetland of Balasore, Odisha.	*Libellulidae*	51	Rapid degradation, human activities	Boruah et al., (2015)
Deepor beel bird sanctuary	*Libellulidae*	39	-	Kalita and Ray (2015)
Kolkata and Howrah, West Bengal.	*Libellulidae*	80	Lack of aquatic vegetation	Dawn, 2014
Wetland of Cagayan de Oro and Bukidnon, Philippines.	*Libellulidae*	38	Urbanization and disturbed areas	Dexter et al., (2013)
Sindhudurg district, Maharashtra.	*Libellulidae*	23	-	Bharamal et al., (2014)
Tropical Forest Research Institute, Jabalpur, M.P.	*Libellulidae*	48	Dense shrub and tree vegetation attracts Odonata	Tiple et al., 2012
Kolhapur, M.H.	*Libellulidae*	36	Crop destruction by insect pests	Dr. Sathe and Shinde (2014)
Gorewada international bio	*Libellulidae*	34	Encourages the	Shende and Patil

park			conservation of Odonata	(2013)

The above table represent the various studies on Odonata at various places but the family *Libellulidae* is dominating at every study area, similarly the anthropogenic activity and disturbance contributed in low species diversity of Odonata.

Agricultural Impact

Kalkman et al., (2008) in tropical countries like the Philippines; diversity of Odonata is highly dependent on the types of aquatic habitats in different forests. Temperature plays a big role in the increase of diversity from the poles to the equator. The tropics hold higher diversity of Odonata where 12 of the 31 families are restricted mostly to lotic waters within tropical forest habitats. This is the reason why the India is recognized for its high number of endemic Odonata and also reported that low endemism of Odonata could be due to the slow detrimental effects of human activities, habitat destruction, eutrophication, acidification, and pollution of aquatic habitats in general, and the canalization of streams and rivers.

Cayasan et al., (2013) revealed that no endemic species was present in the agricultural crop area due to the high level of disturbance in the agricultural crop area and also found low endemism of Odonata in disturbed habitats and the species composition characterized predominantly by Oriental species. Quisil et al., (2003) also recorded low endemism (47%) in agriculture area due to the unsustainable and rapid agricultural expansion that was observed as the main threat to the habitats of Odonata. Quisil et al., (2014) documented low endemism due to mining activities. Low endemism of Odonata is attributed to anthropogenic disturbances (Aspacio et al., 2013).

Only those species that can tolerate high degree of habitat disturbance can thrive in the agricultural crop area. Mabry and Dettman (2010) reported that habitat with dense and diverse vegetation provides a rich site for Odonata. The less-disturbance in the agro forestry sites appears to be the main factor in the higher number of species in the agro forestry compared to the agricultural crop area. Mapiot et al., (2013) found in their study that high presence of on-site disturbances could contribute to low species diversity and endemicity of Odonata. Jomoc et al., (2013) also observed less number of species in areas with existing anthropogenic disturbances. Some factors like percentage cover of macrophytes and tree cover which could provide shade in an area are the most important environmental variables for Anisoptera and Zygoptera (Fulan et al., 2008). According to Jomoc et al., (2013) dragonfly species thrive in exposed areas while damselfly species prefer closed canopy areas. Fraser (1933) and Subramanian (2005) reported that shade and aquatic vegetation could favour Zygoptera more than Anisoptera. Habitat disturbance even for small-scale subsistence farming has tremendous impact on Odonata diversity (Oppel, 2006).

Conclusion

The review suggest multidisciplinary research option on Odonata in future This review will consider various aspects on a range of Odonata biology to investigate how true this intuitive assumption may be. Since most invertebrates are small and inconspicuous their immense importance in nature is grossly underestimated. Therefore large conspicuous insects are of great importance in drawing attention to invertebrates and their conservation needs. Dragonflies have a potential health and economic value which is not yet fully exploited.

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