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Taxocoenosis and Distribution of Nektonic Fauna in the Rice Fields of Kashmir (J and K) India

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Abstract: Present study attempts to identify the taxocoenosis and distribution of nektonic fauna harbouring the rice field ecosystems of Kashmir. The main objective of the study was to provide an overview of the nektonic community composition and physiochemical characteristics of flood waters. 6 sites were selected in Kupwara, Bandipora, Budgam, Srinagar, Pulwama and Anantnag districts of valley Kashmir. A total of 26 taxa belonging to 13 different orders were reported during the study which commenced through 2 consecutive crop cycles. The taxocoenosis was dominated by Coleoptera (10 taxa) followed by Hemiptera (3 taxa), Diptera (2 taxa), Diplostraca (2 taxa), Acarina, Anostraca, Anura, Amphipoda, Basommatophora, Cypriniformes, Cyprinodontiformes, Odonata and Pulmonata (1 taxa each). Diversity was calculated using Simpsons Index (D), Simpsons Index of Diversity (1-D), Simpsons Reciprocal Index (1/D), Shannon-Weiner Index (H'), Margalef Richness Index (d) and Evenness Index (e). Kupwara (34°02'N; 74°16'E) formed the most diverse site registering a total of 2384 individuals belonging to 24 taxa. A perusal of the primary data related to the physicochemical attributes of flood waters exhibited that average water temperature varied between 19-30°C, average air temperature varied between 21 and 33°C. pH depicted a variation between 6.0 and 9.0, Dissolved Oxygen varied between a minimum of 1.0 mg L^{-1} and a maximum of 10 mg L^{-1}. Free CO_2 ranged between 0 mg L^{-1} and 6.1 mg^{-1}. The results pressed the need for recognizing and preserving rice fields as potential habitats for organisms that have successfully adapted to the highly manipulated and eutrophic conditions of rice paddies.

Key words: Community organization, density, distribution, diversity, nekton, rice fields

INTRODUCTION

Irrigated rice fields can be scientifically defined as agro economically managed temporary and seasonal aquatic habitats managed with a variable degree of intensity. These temporary wetlands are the most extensive aquatic ecosystems on earth covering an area of 1.5 million hectare approximately (Fernandez-Valiente and Quesada, 2004). Rice fields are included in the Ramsar Classification System for Wetland Type as a human-made wetland. These typical agricultural landscapes have provided large areas of open water for centuries that support biodiversity including medicinal plants, reptiles, amphibians, fish, crustaceans, insects, molluscs and water birds (Anonymous, 2008). Rice is one of the most important crops that provide food for about half of the world population (Sie *et al*., 2008). The crop production in India has entered the regime of non-sustainability as a consequence of degradation in aerial, edaphic and hydro-environments (Srivani *et al*., 2007).

Rice fields are highly dynamic temporary wetland agro-ecosystems that hold extreme ecologic and economic importance. These form an indispensable component of the landscape and culture of Kashmir valley. The total land area under rice cultivation in the valley of Kashmir is about 374000 acres (Masoodi, 2003). These ecosystems harbour a diverse biota as ponds and have more species than rivers, streams and river flood plains. Rice fields together with their contiguous aquatic habitats and dry land, comprise a rich mosaic of rapidly changing ecotones, harbouring a rich biological diversity, maintained by rapid colonization as well as rapid reproduction and growth of organisms (Fernando, 1995). In the rice agro ecosystem, the core of the unit is the cultivated rice plant. It is part of a biological complex which includes other plants, micro organisms, arthropods and other animals and man. These organisms represent the biotic or living part of the agro ecosystem. Surrounding them is a conditioning environment consisting of abiotic factors such as temperature and

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sunlight. The rice field is an ecosystem whose functioning depends to a great extent on a strong input of nutrients and subsidiary energy through the use of advanced cultivation techniques. The structural peculiarities of the rice field are due to the periods of flooding and drying out related to the cultivation cycle, the shallow depth of water associated with regular fluctuations of water level and the highly developed water-sediment interface (Madoni, 1987). The significance of rice fields in maintaining biodiversity has earlier been stated by Babaradeniya *et al.* (2004), Segers and Sanoamung (2007) and Chittapun *et al.* (2009). Biodiversity is the key component for sustainable environment (Hossain *et al.*, 2008). The changes in biodiversity cause concern for ethical, economical, ecological and aesthetic reasons (Shameem *et al.*, 2010). Currently rice fields are under a serious threat of ecosystem transformation owing to rapid increase in population and accelerated urbanization. This phenomenon has put the biodiversity of rice fields at stake making it necessary to take immediate steps for the conservation of these man-engineered ecosystems. Previous studies on the biodiversity of rice fields deal mainly with agronomic aspects. Comprehensive studies on the ecology and biodiversity of rice fields are scanty (Ghahari *et al.*, 2010).

The nekton forms an important component of the aquatic fauna of rice fields. It occupies an indispensable position in the rice field biogeocoenosis. Numerous taxa of aquatic insects including odonates, coleopterans, hemipterans and heteropterans are recorded in irrigated rice ecosystems (Kandibane *et al.*, 2007). In order to study the biodiversity of nekton in the rice field ecosystems of Kashmir, 6 spatially variable sites located in different administrative zones were selected and studied for 2 consecutive crop cycles. A rich nektonic taxocoenosis dominated qualitatively and quantitatively by Arthropoda was revealed during the investigation. The present study was carried out with the main objective of exploring the nektonic diversity of the rice fields of Kashmir which have always been ignored by ecologists of the state despite being the largest freshwater ecosystems. The bio-ecological studies on the rice fields of Kashmir are negligible. The diversity of nektonic fauna in the rice fields has not been documented earlier. The present investigation being a maiden one in the region was carried out in the same backdrop.

MATERIALS AND METHODS

During the present investigation, 6 spatially variable study sites were selected in different administrative zones of Kashmir valley. The representative sites included:

- Kupwara (34°02'N; 74°16'E) in north west Kashmir
- Bandipora (34°06'N; 74°44'E) located in north Kashmir
- Budgam (34.63°N; 76.04°E) lying in south west Kashmir
- Srinagar (35°5'N; 74°47'E) in north east Kashmir
- Pulwama (33°53'N; 74°55'E) in south Kashmir and
- Anantnag (33.73°N; 75.15°E) situated towards south east of Kashmir province

The sampling period encompassed 2 consecutive crop cycles between May-Aug (2005) and May-Aug (2006). A metal frame (25×25×5cm) was lowered into the water column and slowly pulled out after 15 min when the disturbance caused due to placing the frame into water had minimized. The orgamisms were sorted manually, placed in separate containers and brought to the laboratory for further investigations. Soft bodied organisms were preserved in 4% formaldehyde while hard bodied forms like adult aquatic insects were dry preserved. Identification was done in accordance with Rajagopal and Rao (1955), Linsenmaier (1972), Pennak (1978) and Edmondson (1989). Simpsons Index (D), Simpsons Index of Diversity (1-D) and Reciprocal Index were performed following Simpson (1949), H' was calculated as per Shannon and Wiener (1949), Margalefs' Richness Index was obtained as prescribed by Margalof (1958), Evenness Index was calculated as per Pielou (1966). The physico-chemical attributes of flood waters were analysed following APHA (1998).

RESULTS

Nektonic fauna in the rice fields of Kashmir included 26 genera belonging to 13 different orders including Coleoptera (*Agabus* sp., *Cybister* sp., *Berosus* sp., *Dytiscus marginalis*, *Gyrinus substriatus*, *Helophorus* sp., *Hydrophilus* sp., *Laccobius* sp., *Laccophilus* sp., *Rhantus* sp.), Hemiptera (*Microvelia* sp., *Plea* sp., *Sigara* sp.), Diplostraca (*Cyzicus* sp., *Eulimnadia* sp.), Diptera (*Chironomus* sp., *Culex* sp.), Acarina (*Atax* sp.), Anostraca (*Branchinecta acanthopenes*), Anura (Tadpole), Amphipoda (*Gammarus pulex*), Basommatophora (*Gyraulus pankongensis*), Cypriniformes (*Cyprinus carpio*), Cyprinodontiformes (*Gambusia* sp.), Odonata (Dragonfly nymph) and Pulmonata (*Lymnaea stagnalis*). Maximum number of taxa was reported from Kupwara (24 taxa) followed by Srinagar (23 taxa), Pulwama (23 taxa), Bandipora (22 taxa), Anantnag (22 taxa) and Budgam (20 taxa). The quantitative dominance pattern was exhibited as: Pulwama

Table 1: Average population density (individuals m^{-2}) of nektonic fauna at the representative sites

Taxa	Kupwara	Bandipora	Budgam	Srinagar	Pulwama	Anantnag	Composition of nektonic groups (%)
Total taxa	24	22	20	23	2322		
Coleoptera							38
Agabus sp.	-	-	1	1	122		
Berosus sp.	15	11	7	11	15	4	
Cybister sp.	2	-	2	3	13	3	
Dytiscus marginalis	2	2	1	1	5	-	
Gyrinus substriatus	23	18	15	18	26	8	
Helophorus sp.	9	8	4	7	2	7	
Hydrophilus sp.	3	2	1	2	5	1	
Laccobius sp.	11	6	5	6	9	5	
Laccophilus sp.	6	5	3	5	-	2	
Rhantus sp.	4	2	2	3	6	1	
Hemiptera							11
Microvelia sp.	4	4	-	1	3	1	
Plea sp.	10	10	5	11	15	9	
Sigara sp.	9	5	7	-	11	5	
Eulimnadia sp.	2	6	1	-	-	-	
Diplostraca							8
Cyzicus sp.	2	1	-	2	1	2	
Eulimnadia sp.	2	6	1	-	-	-	
Diptera							7
Chironomus sp.	5	5	6	6	12	5	
Culex sp.	15	38	7	17	34	16	
Acarina							4
Atax sp.	6	7	4	4	3	4	
Anostraca							4
Branchinecta acanthopenes	14	27	3	6	13	3	
Anura							4
Tadpole	1	1	-	2	1	1	
Amphipoda							4
Gammarus pulex	1	2	1	1	1	3	
Basommatophora							4
Gyraulus pankongeusis	1	-	-	1	2	1	
Cypriniformes							4
Cyprinus carpio	1	1	-	1	-	-	
Cyprinodontiformes							4
Gambusia sp.	2	-	-	-	1	-	
Odonata							4
Dragonfly nymph	2	2	1	1	2	1	
Pulmonata							4
Lymnaea stagnalis	2	1	1	3	4	2	
Total Nekton	2384	2281	1219	1744	3044	1271	

-: Absent/not recorded from the study site

(3044 individuals)>Kupwara (2384 ind.)>Bandipora (2281 ind.)>Srinagar (1744 ind.)>Budgam (1219 ind.) (Table 1).

The Coleoptera which formed the most dominant component of nektonic fauna was represented by 3 families viz. Hydrophilidae, Dytiscidae and Gyrinidae. Although most of the coleopterans exhibited a cosmopolitan distribution, yet a complete absence was registered by some including *Dytiscus marginalis* (absent at Anantnag), *Laccophilus* sp. (not reported from Pulwama), *Cybister* sp. (absent at Bandipora), *Agabus* sp. (not recorded at Kupwara, Bandipora). The highest average density among coleopterans was exhibited by *Gyrinus substriatus* at Pulwama as 26 ind.m^{-2}. Among the Crustacea, *Branchinecta acanthopenes* and *Gammarus pulex* were registered at all the study sites where as, *Cyzicus* sp. was absent at Budgam and *Eulimnadia* sp. depicted absence at Srinagar, Pulwama and Anantnag. *B. acanthopenes* formed quantitatively the most dominant taxa with an average density of 27 ind.m^{-2}. *Plea* sp. representing Hemiptera depicted a highest average density of 15 ind.m^{-2} at Pulwama forming the most dominant taxa. *Microvelia* sp. and *Sigara* sp. registered complete absence at Budgam and Srinagar sites, respectively. The diptera larvae were registered at all the study sites with the highest average density of 38 ind.m^{-2} depicted by *Culex* sp. at Bandipora site where as, a lowest average density of 5 ind.m^{-2} was exhibited by *Chironomus* sp. at Kupwara, Bandipora and Anantnag sites. *Gyraulus* sp. belonging to Gastropoda registered a peak density of 2 ind.m^{-2} at Pulwama. It depicted a complete absence at Bandipora and Budgam sites. *Lymnaea stagnalis* varied between 1 ind.m^{-2} (Bandipora, Budgam) and 4 ind.m^{-2} (Pulwama). Among the Cypriniformes, *Cyprinus carpio* was registered at

Table 2: Average values of physico-chemical variables of flood water

Air temperature (°C)	Water temperature (°C)	pH	Free CO_2 (mg L^{-1})	Dissolved oxygen (mg L^{-1})
21-33	19-30	6-9	0-6.1	1-10

Table 3: Biodiversity indices recorded at various study sites

Biodiversity index	Kupwara	Bandipora	Budgam	Srinagar	Pulwama	Anantuag
Simpsons index (D)	0.078	0.092	0.089	0.091	0.087	0.093
Simpsons index of diversity (1-D)	0.921	0.907	0.910	0.908	0.912	0.906
Simpsons reciprocal index (1/D)	12.680	10.800	11.230	10.980	11.470	10.690
Shannon-Wiener index (H')	2.770	2.650	2.630	2.660	2.700	2.640
Margalefs richness index (d)	2.958	2.716	2.674	2.948	2.743	2.938
Evenness index (e)	0.871	0.858	0.880	0.849	0.861	0.855

Kupwara, Bandipora and Srinagar (1 ind.m^{-2}) depicting a complete absence at the remaining sites. *Gambusia* sp. was recorded at 2 sites viz., Kupwara (2 ind.m^{-2}) and Pulwama (1 ind.m^{-2}). *Atax* sp. from Acarina registered a cosmopolitan distribution varying between 3 ind.m^{-2} (Pulwama) and 7 ind.m^{-2} (Bandipora). Tadpoles were not reported from Budgam where as, maximum average density was recorded at Srinagar site as 2 ind.m^{-2}. The dragonfly nymphs were registered from all study sites exhibiting a variation between 1 ind.m^{-2} (Budgam, Srinagar, Anantnag) and 2 ind.m^{-2} (Kupwara, Bandipora, Pulwama) (Table 1). Among the physico-chemical attributes of flood waters, air temperature showed highest values in early summer (21°C) and lowest values in late spring (33°C), water temperature depicted maximum values during early summer (30°C) followed by a decline depicting lower values during late spring (19°C; Table 2). pH exhibited highest values during early summer and lowest values in mid summer. Free CO_2 depicted absence during second half of late spring and first half of early summer where as, peak values were noticed during late summer. Dissolved oxygen registered highest values in early summer and lowest values in late summer.

Shannon-Wiener (H') index and Margalefs index (d) exhibited Kupwara as the most diverse site with a value of 2.77 and Budgam as the least diverse site registering a lowest value of 2.63. As per Simpsons' index (D), Simpsons' index of diversity (1-D), Simpsons' reciprocal index (1/D), Kupwara was the most diverse site whereas, Anantnag was the least diverse site. According to evenness index (e) Budgam was the most even ecosystem obtaining a value of 0.880 (Table 3).

DISCUSSION

A general overview of the rice field nektonic fauna depicted an increase in the average population density till the first half of early summer and a decline thereafter. The significant build-up of population density during early summer may be a probable consequence of a rich growth of crustaceans (mainly *Branchinecta acanthopenes*). The availability of food materials in surplus quantities coupled with high air and water temperatures also seemed to favour a luxuriant growth of nekton. Sufficient sources of food along with warm water conditions aid in the growth and development of nektonic fauna during the warmer months which is in accordance with Pandit (1992).

Insecta formed the most dominant group including 8 orders viz., Coleoptera, Anostraca, Diplostraca, Amphipoda, Hemiptera, Diptera, Acarina and Odonata. The dominance of insects may be attributed to their successful adaptation to diverse kinds of aquatic ecosystems including both lotic and lentic habitats (Dehghani *et al*., 2007). Hydrophilidae or the water scavenger beetles were registered in significant numbers during both the cultivation cycles. The adult forms mostly live on decaying organic matter found in ample quantities rice fields during aquatic phase. Maximum numbers were registered during the open water phase. However, as the canopy grew thick and the crop cycle advanced towards harvest, population density showed a decline. This could be probably in response to the increasing acidity of flood water and sediments which in turn slows down the decomposition of organic matter. Dytiscidae (Predaceous diving beetles) were recorded in lesser numbers in comparison to the Hydrophilidae. Among these, *Dytiscus marginalis* which showed large populations some years ago (as per reports by local farmers) were on a decline which may be a probable consequence of continuous use of agrochemicals in rice fields. Gyrinidae or the whirligig beetles were recorded in significant numbers. These largely feed on other insects found in flood waters. As a result of rich supply of food, these insects grow successfully in the rice fields. Hemiptera was also represented by 3 families viz, Corixidae, Pleidae and Velidae which in turn were represented by a single genus each.

Among the various genera of Crustacea, *Gammarus pulex* was observed only during few initial observations coinciding with high concentrations of dissolved oxygen and high pH. The crustacean *Branchinecta acanthopenes* was registered in large numbers from all the study sites. Along with *Eulimnadia* sp. it was noticed only during early summer coinciding high temperature, pH, dissolved oxygen and electric conductivity. Similar observations have earlier been reported by Jehangir and Bhat (2004). The crustaceans *Eulimnadia* sp. and *Cyzicus* sp. were reported for the first time in the rice fields of Kashmir. Among Diptera, *Culex* sp. and *Chironomus* sp. appeared to exhibit themselves as rich populations during the earlier stages of crop cycle. However, the population declined with the development of thick canopy of the rice plants drawing support from the findings of Roger *et al.* (1991). Chironomus larvae were reported during the initial weeks of crop cycle. Populations declined thereafter which may be probably due to the hardening of the soft sediments as a result of decreased anthropogenic disturbance post transplantation in accordance with Simpson *et al.* (1994). The peak populations of diptera larva coincided with the formation of algal blooms. This was probably in response to the availability of abundant food supply in the form of algae. Similar conclusions have earlier been drawn by Simpson *et al.* (1993). As the algal blooms started decomposing, the diptera larval populations also declined. This is in agreement with the reports of Clement *et al.* (1977) and Roger and Bhuiyan (1990). Gastropods showed peak populations during early summer and but declined thereafter. The decrease in population density seemed to be influenced markedly by the decline in phytoplankters which serve as a potential source of food to these grazers as has been reported by Brown (1985). Mollusks prefer waters with higher levels of calcium which forms a prerequisite for shell formation. Their occasional occurrence during the latter phase may be attributed to their introduction along with the irrigation water. The widespread distribution of gastropods *Gyraulus pankongensis* and *Lymnaea stagnalis* in the rice fields of Kashmir has earlier been reported by Rajagopal and Rao (1955). *Gambusia* sp. and *Cyprinus* sp. were also recorded occasionally. They may also have found entry into the study plots along with irrigation water.

The water mites belonging to the group Acari depicted marked fluctuations in population density. Considerable densities were registered during the initial stage of aquatic phase. Their distribution and density may be attributed to higher water temperatures as previously reported by Butler and Burns (1995) coupled with rich food reserves. The odonate nymphs colonized the rice fields between late spring and mid summer. This period provided them all the congenial growing conditions like high temperature, high oxygen concentration, abundant food supply and a favourable refuge among the emergent vegetation. This explanation draws support from Wetzel (2001) and. The flood water temperature closely followed air temperature up to tillering phase with a considerable difference registered between the two after the development of a thick canopy showing an agreement with the findings of Roger and Kurihara (1991). pH varied between slightly acidic to alkaline conditions (Table 2). Alkalinity prevailed prior to tillering probably in response to high O_2 concentration coupled with low levels of CO_2 as a consequence of high photosynthetic activity. These observations are in accordance with Wetzel (1957) and Golterman and Meyers (1985). Acidic conditions registered towards harvest may be attributed to low O_2 and high CO_2 concentration as a result of increase in zooplankton density. Peak levels of dissolved oxygen were a probable function of high photosynthetic activity due to development of algal blooms and a decline during the later phase was in response to decline in phytoplankton density showing a complete agreement with Fores and Comin (1992).

CONCLUSION

In order to study the nektonic fauna of the rice fields of Kashmir, 6 study sites were selected in different parts of the valley. The study revealed the presence of 26 taxa of nekton with Coleoptera as the most dominant group represented by 10 taxa. The overall interpretation of the results indicated towards the significance of rice fields as potential habitats for a diverse array of opportunistic nektonic fauna that have adapted to the harsh and highly disturbed environment of these shallow ecosystems that remain fallow for almost one-third of the year. The general community composition was fairly similar at all the representative sites which could be a probable consequence of existence of a similar agro-climatic zone. Further, the rice fields are interconnected through continuous corridors which make the taxocoenosis fairly homogenous. Slight variations were evident in the community organizations of different study sites which could be a probable function of micro-climatic variations.

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