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Seasonal variation in spider abundance in Kuttanad rice agroecosystem, Kerala, India (Araneae)

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Abstract: The present study attempts to improve the understanding of resident spider population and seasonal variations in their diversity in the rice agroecosystem of Kuttanad, one of the "Rice Bowls of Kerala". The investigation was carried out for a period of 2 years from June 2001 to February 2003. Fortnightly sampling was done in four cropping seasons viz., Rabi 1 (June 2001 to September 2001), Kharif 1 (November 2001 to February 2002), Rabi 2 (June 2002 to September 2002) and Kharif 2 (November 2002 to February 2003). Spiders were collected from quadrates in 8 sites by hand-picking method. Different indices were calculated using the SPDIVERS.BAS programme. Spider population in Rabi and Kharif seasons exhibited slightly different species abundance and composition. Among the 94 species of spiders collected during the study, 70 species of 17 families were recorded in the Rabi season and 94 species of 20 families in the Kharif season. All families except Amaurobiidae, Pisauridae and Pholcidae were present in both seasons. A total of 68 species had common occurrence in both crop seasons. Results indicate that the interaction of seasons on spider abundance/assemblage was significant for Shannon, Richness and Evenness indices, but non-significant for Simpson's index. Population fluctuation of spiders showed insignificant difference between the two seasons.

Key words: diversity, abundance, spiders, rice agroecosystem, Kuttanad, India

Introduction

Spiders are potential biological control agents in agroecosystems (Riechert, Lockley 1984, Tanaka 1989, Bishop, Riechert 1990). Many researchers have provided descriptions of spider species abundance or composition in a variety of agroecosystems (Wisnieswka, Prokopy 1997). Other researchers provided quantitative observations on the abundance of spiders (Carroll, Hoyt 1984) or recorded spider predation events (Riechert, Bishop 1990). A rice (*Oryza sativa* L.) field is a complex agroecosystem, containing many aquatic, semi-aquatic, and terrestrial species (Oraze *et al.* 1988). Spiders are well represented among the many predators found in this habitat. Numerous surveys of spiders have been conducted in the rice growing regions of Asia (Heong *et al.* 1991, Barrion, Litsinger 1995, Kim 1995, Barrion, Schoenly 1999). The spider fauna of the rice fields in India has been studied by many authors. Basic studies were carried out by Pathak, Saha (1999) and Bhattacharya (2000). However, it is a less common practice among workers to compare spider abundance at different stages of crop growth with the exception of the work of Banerji *et al.* (1993). Anbalagan, Narayanaswamy (1999) also analyzed the population fluctuation of spiders in paddy fields. Most of these studies were just limited to the identification of spiders and investigation of the dominant spider species. There has been no study on their seasonal variation and their ecological impact. Here we present the data that compare the abundance and richness of spiders between two cropping seasons and during different stages of the crop growth.

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Materials and Methods

Study Area: Kuttanad is rightly called one of the "Rice Bowls of Kerala", contributing nearly 20% of the total rice production of the Kerala state of India. This wetland rice agroecosystem extends from 9° 17' – 9° 40' N and 76° 19' – 76° 33' E. It is a low lying area of costal Kerala situated 0.6 – 2.2 m below mean sea level and formed by the confluence of 4 major river systems viz., Meenachil, Manimala, Pamba and Achancoil draining into the Vembanad Lake. It measures approximately 25 km east to west and 60 km north to south on the west coast of Kerala, in which about 53,639 hectares are used for rice cultivation. This is a warm, humid region and the seasonal variation in the temperature ranges from 21°C – 38°C. Humidity is also showing seasonal fluctuation and the average annual rainfall received is around 300 cm of which about 83% is received during monsoon period, from June to October.

Study Period: The investigation was carried out for a period of 2 years from June 2001 to February 2003. Sampling was conducted in four seasons; Rabi 1 (June 2001 – September 2001), Kharif 1 (November 2001 – February 2002), Rabi 2 (June 2002 – September 2002) and Kharif 2 (November 2002 – February 2003) at the following randomly selected 8 sites located in the same altitude: Krishnapuram, Vellisrakka, Edathua, Champakulam, Pallikoottuma, Pallathuruthy, Nedumudy and Moncompu. Rabi season is characterized by heavy rain (South-West Monsoon) and high humidity. More than 80% of the total annual rainfall is received during this season. Kharif season is characterized by low rainfall and dry weather (MENON *et al.* 2000).

Sampling: Sampling was done every 15 days after transplantation (DAT) from quadrates. Spiders were collected from 4 quadrates (1m × 1m) placed at four corners of 10m × 10m area by visual search method between 9.30 – 11.30 hours. A sufficient core area was left to avoid edge effects. All 4 quadrates were searched for a total of one hour. Seven visits were made per site per season. A total of 28 quadrates were studied in each season per site. Spiders were collected from the ground stratum and from the terminals of plants. Specimens from each quadrate were preserved in 75% alcohol in the field and counted under a stereo-zoom microscope (Leica-MS5) in the laboratory.

Identification of Spiders: The adult spiders were identified on species level and others on genus or family level using available literature (TIKADER 1987, BARRION, LITSINGER 1995). Monthly data were prepared for each season with detailed information on the occurrence of mature male, female and juvenile spiders. Voucher specimens were preserved in 75% alcohol and deposited in a reference collection housed with the Arachnology Division, Department of Zoology, Sacred Heart College, Cochin, Kerala, India.

Data Analysis: The diversity indices like the Shannon-Wiener index (H^1), which is sensitive to changes in the abundance of rare species in a community, and the Simpson index (λ), which is sensitive to changes in the most abundant species in a community, Margalef Richness index (R) and Evenness index (E) of spider communities were calculated using the SPDIVERS.BAS program of LUDWIG, REYNOLDS (1988). Shannon-Wiener index is defined as:

$H^1 = -\sum_i \log p_i$

Where: p_i = the observed relative abundance of a particular species (SOLOW 1993).

Simpson index is defined as:

$\lambda = \sum n_i (n_i\text{-}1)/ [N (N\text{-}1)]$

Where: n_i = the number of individuals of species i, and $N = \sum n_i$ (SOLOW 1993).

Margalef richness index is defined as:

R = S-1/In (n).

Where: S = total number of species in a community, and n = total number of individuals observed.

Evenness index is defined as:

$E = \text{In}(N1)/\text{In}(N0)$.

Where: $N1$ = number of abundant species in the sample, and $N0$ = number of all species in the sample. One tailed ANOVA tests were used to test the hypothesis that the crop growth stages and seasons resulted in different abundance and composition of spider assemblages. Feeding guild classification was done following Uetz *et al.* (1999).

Results

Species Composition: A total of 17,717 individuals belonging to 94 species, 64 genera and 20 families were collected during the study (Table 1). In the Rabi season 70 species of 17 families and in the Kharif season 94 species of 20 families were collected. The spider population in the Rabi and Kharif seasons exhibited a slightly different species composition. The family level composition also shows differences between the two seasons. All families except Amaurobiidae, Pisauridae and Pholcidae were present in both seasons and species that commonly appeared in both seasons numbered 68.

Table 1. List of spiders collected from the Kuttanad rice agroecosystem.

Family	No. of genera	No. of species	No. of individuals	Guild
Amaurobiidae	1	1	5	Sheet webs
Araneidae	5	11	2142	Orb weavers
Clubionidae	1	2	19	Foliage runners
Corinnidae	1	1	49	Ground runners
Gnaphosidae	1	1	11	Ground runners
Hersiliidae	1	1	8	Foliage runners
Linyphiidae	2	4	3576	Sheet webs
Lycosidae	4	9	3378	Ground runners
Miturgidae	1	1	11	Foliage runners
Oxyopidae	2	6	429	Stalkers
Philodromidae	2	2	14	Ambushers
Pholcidae	3	3	16	Space builders
Pisauridae	1	1	1	Ambushers
Salticidae	15	17	1625	Stalkers
Scytodidae	1	1	30	Ambushers
Sparassidae	2	3	42	Foliage runners
Tetragnathidae	6	12	4489	Orb weavers
Theridiidae	5	5	1760	Space builders
Thomisidae	6	6	75	Ambushers
Uloboridae	3	3	30	Orb weavers
Total	64	94	17717	

The spiders collected in the largest numbers were *Phycosoma martinae* (Roberts, 1983) (8.12% of total collection), *Pardosa pseudoannulata* (Bösenberg, Strand, 1906) (7.13%), *Erigone bifurca* Locket, 1982 (7.07%), *Tetragnatha andamanensis* Tikader, 1977 (7.05%). *Atypena adelinae* Barrion, Litsinger, 1995 (6.75%), *Dyschiriognatha dentata* Zhu, Wen, 1978 (5.97%), *Araneus ellipticus* (TIKADER, BAL, 1981) (5.26%), and *Tetragnatha cochinensis* GRAVELY, 1921 (4.77%). The major component of the spider population found in this ecosystem was the family Tetragnathidae composed mainly of *D. dentata*, *T. andamanensis*, *T. cochinensis* and the family Linyphiidae mainly composed of *Atyepena* and *Erigone*. Besides the above, Lycosidae and Araneidae were found in relatively large numbers. The families Tetragnathidae and Linyphiidae constituted 45%, while Lycosidae and Araneidae constituted 31% of the total collection.

In the Kharif season, Tetragnathidae and Lycosidae were the dominant families. However, in the Rabi season the second dominant family was Linyphiidae. Lycosidae constituted 20% of the Kharif spiders and 16.91% of the Rabi spiders. Eleven minor families constituted 1.163% of the total collected spiders. Theridiidae (9.93%), Salticidae (9.17%), Oxyopidae (2.42%), and Thomisidae (0.42 %) were also represented in the fauna from these sites.

Diversity, Evenness and Richness indices: There were some significant differences in Shannon index, Richness index and Evenness index between the two seasons. But the Simpson index was not significantly different in the two seasons. The highest Shannon index value of the Kharif season was 3.55 and the lowest was 2.95 with a mean of 3.32 ± 0.04. But in the Rabi season, it was 3.34 and 3.02 with a mean of 3.19 ± 0.02. The one way ANOVA showed that the Shannon index showed significant variation ($F_{1, 30} = 7.41$, $P = 0.01$) between the two seasons. In the case of the Simpson index, the maximum value of the Kharif season was 0.61 and the minimum was 0.37 with a mean of 0.46 ± 0.01. In the Rabi season, it was 0.56 and 0.37 and 0.47 ± 0.01. This showed no significant difference between the two seasons ($F_{1, 30} = 0.61$, $P = 0.04$). In the case of the Richness index, the Kharif maximum value was 9.88 and minimum 4.63 and mean 7.61 ± 0.40. However, in the Rabi season, it was 7.75 and 4.40 and 5.80 ± 0.27. This also showed a significant difference between the two seasons ($F_{1, 30} = 34.70$, $P = 0.08$). The average Evenness value of the Kharif season was 0.85 ± 0.01 with a maximum of 0.90 and a minimum of 0.82. In the Rabi season however it was 0.88 ± 0.01, 0.91 and 0.83 respectively. The ANOVA result showed a significant difference ($F_{1, 30} = 18.03$, $P = 0.01$). The above results indicated that the interaction of seasons on spider composition was significant for Shannon, Richness and Evenness indices, but was non-significant using the Simpson index.

Population: The population growth showed a gradual increase in the 15th, 30th and 45th DAT followed by a slight decrease in the 60th DAT. Then it continued to grow up to the 90th DAT and reached the peak and then showed a sudden decline (Fig. 1). The number of species obtained during the sampling showed a gradual increase in number as the growth of the plants advanced and the maximum number of 86 species was collected on the 90th DAT sampling. The number of individuals also increased as the crop growth advanced and the maximum number (5442) was collected in the 90th DAT. A doubling of individuals occurred between 60th and 75th DAT as shown in Table 2. The value of the Shannon index also showed a gradual increase except in the 60th DAT with an average of 3.05 during the entire growth. But the Simpson index value registered an irregularity and the maximum value was reached on the 15th DAT and the minimum on the 90th DAT with an average of 0.60. The richness index value showed the same tendency as number of individuals reached its peak during the 90th DAT. The value of evenness index showed more similarity in the 15th, 30th 45th and 60th DAT than 75th, 90th and 105th DAT. Spiders of the family Corinnidae appeared for the first time on the 45th DAT and Pholcidae with Pisauridae appeared in 75th DAT. No male spiders were collected in the 15th DAT and a peak of M: F ratio occurred in the 45th DAT and then declined. In the case of A: J ratio, peak value was obtained on the 30th DAT and then decreased. The fluctuation in the population density showed a difference between the web builders and the non-web builders. The density of web builders gradually increased and then decreased at the time of harvest. But hunters showed a trend of continuous increase in population density towards harvest (Fig. 1) and some families were present only at the final stage of crop growth. This study reveals that non-web builders outnumbered the web builders in this rice ecosystem.

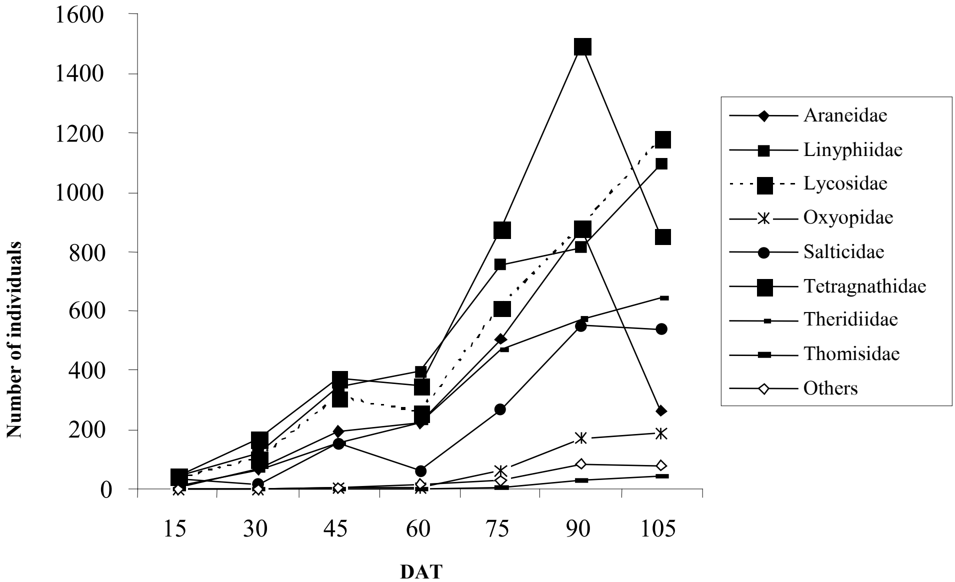

Fig. 1. Population fluctuation of individuals of dominant families during DAT of crop growth.

Table 2. N - Number of individuals, S - Number of species, H[1] - Shannon index, λ - Simpson index, R - Richness index, E - Evenness index, M:F - Male to Female ratio and A:J - Adult to Juvenile ratio during DAT of crop growth in Kuttanad rice agroecosystem during the study.

DAT	N	S	H[1]	λ	R	E	M:F	A:J
15	0178	15	2.53	0.95	2.75	0.92	0.00	12.46
30	0544	19	2.68	0.76	2.95	0.89	6.33	23.81
45	1533	31	2.99	0.57	4.16	0.86	7.00	06.11
60	1542	38	2.96	0.64	5.10	0.80	2.38	02.21
75	3595	64	3.27	0.49	7.74	0.78	2.62	02.25
90	5442	86	3.56	0.37	9.92	0.79	2.21	01.77
105	4883	74	3.38	0.46	8.62	0.78	2.15	01.98
Total	17717	94	3.05	0.60	5.89	0.83	3.24	07.22

Discussion

Twenty spider families recorded from Kuttanad rice agroecosystem represent 43% of the families reported from the country (Platnick 2005). The number of families found here is as high as or higher than the number recorded for other biomes surveyed in India (Jose *et al*. 2006). The numbers of taxa recorded are generally higher than those reported for other surveys of rice ecosystems. Barrion, Litsinger (1984) collected 13,270 specimens belonging to 51 species under 64 genera and 16 families during a 3-year study. This difference in quantity and quality of spider fauna is related to the time of the collection and method of sampling. There are many environmental factors like seasonality, spatial heterogeneity, competition, predation, habitat type, environmental stability and productivity that can affect species diversity (Riechert, Bishop 1990). We found overall significant differences in the diversity, evenness and richness between the two seasons. The results indicate that both seasons show different species composition. It might be expected that climatic changes through seasons would influence the abundance of spiders (Kato *et al*. 1995).

Studies of RUSSELL-SMITH (2002) established the importance of rain fall in the regional spider diversity. In the tropics, a continuum of species with extended seasonal ranges has been found (BASSET 1991), which would give rise to variable samples at different times of the year. Most spiders are limited to a certain extent by environmental conditions. In general, different species have varying humidity and temperature preferences and are limited to those seasons which offer a microclimate within the range of their physiological tolerances. So the difference in species diversity between the two seasons is likely to be due to the difference in the amount of rainfall and temperature in the two seasons.

Diversity analysis determines the significance of observed differences in community structure between different crop growth stages and two seasons based on the species abundance distributions (SOLOW 1993). A diversity index incorporates both species richness and evenness in a single value (MAGURRAN 1988). Two diversity indices used here are Shannon-Wiener index (H^1), which is sensitive to changes in the abundance of rare species in a community, and Simpson index (λ), which is sensitive to changes in the most abundant species in a community. In the present study, the value of H^1 increased as crop growth advanced. This indicates the presence of some rare species in the spider community as crop growth advanced. A decline in the value of λ as crop growth in the present study indicates the dominance of some spiders like tetragnathids and lycosids in the initial period of crop growth. A diversity index allows comparisons to be made between two conditions. This index is more easily interpreted than other diversity indices. If values for diversity indices are often difficult to interpret, species richness and evenness are often presented as separate values. In this form they provide important insights into the ecological changes that occur over time or the differences between ecological communities (BISBY 1995). It would appear that an unambiguous and straight forward index of species richness would be Richness index (R), the total number of species in a community. Species richness examines the number of species occurring in a habitat. Overall species richness is the most widely adopted diversity measure. However, since R depends on the sample size, it is limited as a comparative index. Hence, a number of indices have been proposed to measure species richness that is independent of the sample size. They are based on the relationship between R and total number of individuals observed, n, which increases with increasing sample size. When all species in a sample are equally abundant an evenness index will be at its maximum, decreasing towards zero as the relative abundance of the species diverges away from evenness. Probably the most common evenness index used by ecologists is E. An evenness index should be independent of the number of species in the sample. It has shown that the addition of a rare species to a sample that contains only a few species greatly change the value of E.

Additionally, there are many factors that determine the species composition. This may be related to the changes in the vegetation structure of the habitat. KAJAK (1965) found that relative spider and prey densities were related to the structural diversity of the habitat, and TURNBULL (1966) attributed similar relative predator and prey densities to environmental conditions operating in both groups. According to TURNBULL (1973), most webs have specific attachment and space requirements. CHERRETT (1964) found that adult orb weavers in a grass land habitat needed a vertical space of at least 25-30cm^2 for web placements, a factor which strongly limited those spiders to certain habitats. Other workers have also found the availability of specific structural features to limit the habitats occupied by various web-builders (DUFFEY 1962). Structurally complex crops, providing a wider assortment of resources, would be predicted to support a more diverse spider assemblage, thus increasing the chances of the "best" match between spiders and insect pests. The results of this study also indicate the influence of vegetation structure on the diversity of resident spider community. The web building and plant wandering spiders rely on vegetation for some part of their lives, either for finding food, building retreats or for web building. The structure of the vegetation is therefore expected to influence the diversity of spiders found in the habitat. Studies have demonstrated that a correlation exists between the structural complexity of habitat and species diversity (Uetz 1979, Andow 1991). Uetz (1991) suggests that structurally more complex plants can support a more diverse spider community. Downie *et al*. (1999) and New (1999) have demonstrated that the spiders are extremely sensitive to small changes in the habitat structure; including habitat complexity and microclimate characteristics. Thus the physical structure of the environments has an important influence on the habitat preferences of spider species especially web-building species (Hurd, Fagan 1992). Vegetation structure seems to influence the spider composition on family level because similar families cluster within a similar habitat type. The result also indicates that similar species are present at specific stage of crop growth. Thus, vegetation structure may be a more important determinant than the seasonal variation alone. This provides valuable insights as to why certain species may dominate at different times of the season. Vegetation architecture plays a major role in the species composition found within a habitat (Greenstone 1984, Scheidler 1990), and vegetation which is structurally more complex can sustain higher abundance and diversity of spiders (Hatley, Mac Mahon 1980). The final stage of the crop results in a habitat that is more complex and can support higher diversity. Surveys have demonstrated that spiders respond numerically to the diversity and complexity of the vegetation (Rypstra 1983, Halaj *et al*. 1998). Difference in vegetation architecture during crop growth accounts for the different community structure of spiders in the present study. In addition, the difference in the seasonal abundance of spiders may be due to the variation in patterns of activity of individual spiders and the phenology of total spider community (Corey *et al*. 1998).

An increase in the spider population according to the plant growth tends to depend on prey availability and, if the density of prey becomes higher, spiders are expected to increase proportionally to some extent. The peak of population density of spiders coincides with an increase of insect pests (Kiritani *et al*. 1972). It has already been pointed out by Kobayashi (1961) that the values of correlation coefficients between the population density of insect pests and that of spiders tend to increase from negative to positive form as crop growth advanced. As no quantitative evaluation was done on the insect pest density during this study, further investigations should be carried out to reveal the influence of insect pests on the resident spider community. The amount of preys alone does not affect the density of spiders. What can be cited as other important factors is the number of surviving individuals after hibernation and other repair works related to agriculture. The halter often deals a heavy blow up on spiders because it destroys the vegetation on the ground surface. The growth of weeds quickens the time of draining water from paddy fields and this is considered to promote migration of spiders from dikes to paddy fields and dikes can act as an over wintering place of pests and as a source of spiders (van den Bosh, Telford 1964)

The changes noted in spider association with specific crop stage at different sampling times were related to the flowering state of the crop. A multiple regression analysis of prey density versus various conditions of the physical environment and habitat features revealed the presence of a significant relationship between high insect density and the presence of flowering herbs and shrubs in the vicinity of the web (Riechert 1981). Although it is reasonable to expect a significant influence of crop characteristics on structuring the resident spider community, the importance of adjacent habitats must also be considered (Duelli *et al*. 1990). Selective forces of the crop environment can act only on “what is available” i.e., sets of species colonizing in the fields from the neighbouring habitats. Neighbouring habitats may also influence the composition of crop spider fauna indirectly by modifying the dispersal of potential spider prey and predators in the patchy agricultural landscapes (Polis *et al*. 1998). The quality of the adjacent habitats influences the spider composition of the focal habitat via multitudes of direct and indirect channels. Since no data were collected from the adjacent habitats and bunds, more studies should be carried out to reveal the influence of these habitats on the occurrence of spiders in the rice field proper.

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References

ANBALAGAN G., P. NARAYANASWAMY 1999. Population fluctuation of spiders in the rice ecosystem of Tamil Nadu. - *Entomon*, **24**: 91-95.

ANDOW D. A. 1991. Vegetational diversity and arthropod population response. - *Annual Review of Entomology*, **36**: 561-586.

BANERJI D. K., P. K. NANDA, P. K. BERA, S. C. SEN 1993. Seasonal abundance of some important spider groups in rice agro-ecosystem. - *Records of Zoological Survey of India*, **93**: 275-281.

BARRION A. T., J. A. LITSINGER 1984. The spider fauna of Philippine rice agroecosystems. II. Wetland. - *Philippine Entomologist*, **6**: 11-37.

BARRION A. T., J. A. LITSINGER 1995. Riceland spiders of South and Southeast Asia. CAB International, Wallingford, England, 736 p.

BARRION A. T., K. SCHOENLY 1999. Advances in biological control in tropical rice agroecosystems. - *DFID/CPP Rice Crop Protection Workshop*, *BRRI*, *Gazipur*, *Bangladesh*, **1**: 36-41.

BASSET Y. 1991. The seasonality of arboreal arthropods within an Australian rainforest tree. - *Ecological Entomology*, **16**: 265-278.

BHATTACHARYYA S. 2000. Biodiversity of spiders in the rice fields of Kalyani, West Bengal, India. - *Research Journal of Chemistry and Environment*, **4**: 75-76.

BISBY F. A. 1995. Global Biodiversity Assessment. London, Cambridge University Press, 318 p.

BISHOP L., S. E. RIECHERT 1990. Spider colonization of agroecosystems: mode and source. - *Environmental Entomology*, **19**: 1738-1745.

CARROLL D. P., S. C. HOYT 1984. Natural enemies and their effects on apple aphid *Aphis pomi* Degeer (Homoptera: Aphididae), colonies on young apple trees in central Washington. - *Environmental Entomology*, **13**: 469-481.

CHERRET J. M. 1964. The distribution of spiders on the moor house national nature reserve, Westmorland. - *Journal of Animal Ecology*, **33**: 27-48.

COREY D. T., I. J. STOUT, G. B. EDWARDS 1998. Ground surface spider fauna in Florida sandhill communities. - *Journal of Arachnology*, **26**: 303-316.

DOWNIE I. S., W. L. WILSON, V. J. ABERNETHY, D. I. MCCRACKEN, G. N. FOSTER, I. RIBERS, K. J. MURPHY, A. WATERHOUSE 1999. The impact of different agricultural land use on epigeal spider diversity in Scotland. - *Journal of Insect Conservation*, **3**: 273-286.

DUELLI P., M. STUDER, I. MARCHAND, S. JAKOB 1990. Population movements of arthropods between natural and cultivated areas. - *Biological Conservation*, **54**: 193-207.

DUFFEY E. 1962. A population study of spiders in limestone grass land: The field layer fauna. - *Oikos*, **13**: 15-34.

GREENSTONE M. J. 1984. Determinants of web spider species diversity: vegetation structural diversity vs. prey availability. - *Oecologia*, **62**: 299-304.

HALAJ J., D. W. ROSS, A. R. MOLDENKE 1998. Habitat structure and prey availability as predictors of the abundance and community organization of spiders in western Oregon forest canopies. - *Journal of Arachnology*, **26**: 201-220.

HATLEY C. L., J. A. MACMAHON 1980. Spider community organization: Seasonal variation and the role of vegetation architecture. - *Environmental Entomology*, **9**: 632-39.

HEONG K. L., G. B. AQUINO, A. T. BARRION 1991. Arthropod community structures of rice ecosystems in the Philippines. - *Bulletin of Entomological Research*, **81**: 407-416.

Hurd L. E., W. F. Fagan 1992. Cursorial spiders and succession: Age or habitat structure? - *Oecologia*, **92**: 215-221.

Jose S. K., A. V. Sudhikumar, S. Davis, P. A. Sebastian 2006 (In press). Preliminary studies on the spider fauna (Arachnida: Araneae) in Parambikulam wildlife sanctuary in Western Ghats, Kerala, India. - *Journal of Bombay Natural History Society*, **102** (3).

Kajak A. 1965. An analysis of food relations between the spiders *Araneus quadratus* Clerck and their prey in meadows. - *Ekology Polska*, **13**: 717-764.

Kato M., T. Inoue, A. A. Hamid, T. Nagamitsu, M. B. Merdek, A. R. Nona, T. Hino, S. Yamane, T. Yumoto 1995. Seasonality and vertical structure of light attracted insect communities in a dipterocarp forest in Sarawak. - *Researches on Population Ecology*, **37**: 59-79.

Kim J. P. 1995. Studies of spiders in paddy fields and collecting methods. - *Korean Arachnology*, **11**: 115-122.

Kiritani K., S. Kawahara, T. Sasaba, F. Nakasuji 1972. Quantitative evaluation of predation by spiders on the green rice leaf hopper, *Nephotettix cincticeps* Uhler, by a sight count method. - *Researches on Population Ecology*, **13**: 187-200.

Kobayashi H. 1961. Studies on the effect of insecticides sprayed for the control of rice stem borers upon the population density of plant- and leaf- hoppers. - *Special report on the forecasting of outbreaks of diseases and insect pests*, **6**: 120-126.

Ludwig J. A., J. F. Reynolds 1988. Statistical Ecology: A primer on methods in computing. New York, John Wiley & Sons, 337 p.

Magurran A. E. 1988. Ecological diversity and its measurement. New Jersey, Princeton University Press, 255 p.

Menon N. N., A. N. Balchand, N. R. Menon 2000. Hydrobiology of the Cochin backwater system – a review. - *Hydrobiologia*, **430**: 149-183.

New T. R. 1999. Untangling the web: spiders and the challenges of invertebrate conservation. - *Journal of Insect Conservation*, **3**: 251-256.

Oraze M. J., A. A. Grigarick, J. H. Lynch, K. A. Smith 1988. Spider fauna of flooded rice fields in northern California. - *Journal of Arachnology*, **16**: 331-337.

Pathak S., N. N. Saha 1999. Spider fauna of rice ecosystem in Barak valley zone of Assam, India. - *Indian Journal of Entomology*, **2**: 211-212.

Platnick N. I. 2005. The world spider catalog, version 6. American Museum of Natural History, online at http://research.amnh.org/entomology/spiders/catalog/index.html

Polis G. A., S. D. Hurd, C. T. Jackson, F. Sanchez-Pinero 1998. Multifactor population limitation: variable spatial and temporal control of spiders on Gulf of California islands. - *Ecology*, **79**: 490-502.

Riechert S. E. 1981. The consequences of being territorial: Spiders, a case study. - *American Naturalist*, **117**: 871-892.

Riechert S. E., L. Bishop 1990. Prey control by an assemblage of generalist predators: Spiders in garden test systems. - *Ecology*, **71**: 1441-1450.

Riechert S. E., T. Lockley 1984. Spiders as biological control agents. - *Annual Review of Entomology*, **29**: 299-320.

Russell-Smith A. 2002. A comparison of the diversity and composition of ground-active spiders in Mkomazi Game Reserve, Tanzania and Etosha National Park, Namibia. - *Journal of Arachnology*, **30**: 383-388.

Rypstra A. L. 1983. The importance of food and space in limiting web- spider densities: a test using field enclosures. - *Oecologia*, **59**: 312-316.

Scheidler M. 1990. Influence of habitat structure and vegetation architecture on spiders. - *Zoologischer Anzeiger*, **225**: 333-340.

Solow A. R. 1993. A simple test for change in community structure. - *Journal of Animal Ecology*, **62**: 191-193.

Tanaka K. 1989. Movement of the spiders in arable land. - *Journal of Plant Protection*, **43**: 34-39.

Tikader B. K. 1987. Handbook of Indian Spiders. Calcutta, Zoological Survey of India, 251 p.

Turnbull A. L. 1966. A population of spiders and their potential prey in an overgrazed pasture in eastern Ontario. - *Canadian Journal of Zoology*, **44**: 557-583.

Turnbull A. L. 1973. Ecology of the true spiders (Araneomorphae). - *Annual Review of Entomology*, **18**: 305-348.

Uetz G. W. 1979. The influence of variation in litter habitats on spider communities. - *Oecologia*, **40**: 29-42.

Uetz G. W. 1991. Habitat structure: the physical arrangement of objects in space. London, Chapman and Hall, 348 p.

Uetz G. W., J. Halaj, A. B. Cady 1999. Guild structure of spiders in major crops. - *Journal of Arachnology*, **27**: 270-280.

Wisniewska J., R. J. Prokopy 1997. Pesticide effect on faunal composition, abundance, and body length of spiders (Araneae) in apple orchards. - *Environmental Entomology*, **26**: 763-776.

Van den Bosh R., A. D. Telford 1964. Biological control of insect pests and weeds. London, Chapman and Hall, 128 p.

Сезонна изменчивост на паяците (Araneae) в оризова агроекосистема в Кутанад (Керала, Индия)

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(Резюме)

Проучен е видовият състав и сезонната динамика на паяците в оризова агроекосистема в Кутанад. Изследването е проведено от юни 2001 до февруари 2003 г. Материалът е улавян чрез ръчен сбор два пъти в месеца по време на четири жътвени сезона – Раби 1 (юни - септември 2001), Кариф 1 (ноември 2001 - февруари 2002), Раби 2 (юни - септември 2002) и Кариф 2 (ноември 2002 - февруари 2003). От събраните 94 вида паяци, 70 вида от 18 семейства са установени през сезона Rabi, а 94 вида от 21 семейства през сезона Кариф. Наблюдават се незначителни разлики в плътността и видовия състав на популациите в сезоните Раби и Кариф. Всички семейства, без Amaurobiidae, Pisauridae и Pholcidae, или общо 68 вида паяци, са установени и в двата сезона. Резултатите, анализирани чрез програмата SPDIVERS.BAS и индексите на Shannon, Richness и Evenness показват, че влиянието на сезона върху плътността на популациите и видовото разнообразие е значително, докато прилагането на индекса на Simpson показва обратното. Авторите стигат до извода, че флуктуациите в популациите през двата основни сезона са незначителни.