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Differential Diurnal Population Density Ratios of Wet Rice Arthropods in Malaysia

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ABSTRAK

Pemonitoran dilakukan ke atas densiti populasi artropod sawah padi yang berubah dalam kitaran masa 24 jam, di dua lokasi. Dengan menggunakan satu rumpun sebagai unit pensampelan, 22 kategori artropod dibilang melalui pemerhatian secara langsung setiap tiga jam. Bagi setiap satu daripada dua kajian, dan pada setiap gabungan kategori artropod, haribulan dan masa pensamplean, min densiti populasi pada setiap masa pensamplean dikira dan dibahagikan dengan min densiti untuk sepanjang hari (24 jam), bagi memperolehi nisbah densiti setiap masa. Analisis varians ke atas nisbah-nisbah (yang terjelma menggunakan log demi kenormalan reja dan kestabilan varians) ini menunjukkan bahawa hanya masa pensampelan sahaja muncul sebagai faktor yang memberi kesan utama yang bererti (P<0.05). Apabila digabungkan kategori dan haribulan, nisbah bagi jam 2100, 2400 dan 0300 adalah serupa, melebihi nilai 1.0, dan lebih tinggi secara bererti daripada nisbah bagi jangka masa antara jam 0600 hingga 1800. Penelitian corak nisbah setiap kategori artropod menunjukkan bahawa terdapat empat kumpulan yang berbeza berdasarkan kelakuan; yang pertama ialah yang mempunyai nisbah melebihi satu, terdapat lebih banyak populasinya pada waktu malam dan diketahui aktif di sebelah malam: yang kedua ialah yang banyak di sebelah malam tetapi tidak aktif: yang ketiga mempunyai bilangan yang hampir sama siang dan malam: dan yang ke empat ialah yang banyak hanya pada waktu tertentu sahaja terutama sekali disebelah malam dan aktif pada masa tersebut. Penganggaran populasi dengan tepat wajar mengambil kira perubahan densiti mengikuti masa dalam sehari dan perubahan corak kelakuan artropod berkenaan. Justeru disarankan bahawa nisbah yang bersesuaian wajarlah digunakan apabila memperolehi anggaran saiz populasi daripada pensampelan pada masa tertentu dalam seharian.

ABSTRACT

The varying population density of wet rice arthropods in a 24-h period, at two different locations, was monitored. Using one hill as the sampling unit, 22 categories of arthropods were visually counted every 3 h. In each of two separate studies, at each combination of arthropod category, date and time of sampling, the mean density at each sampling time was calculated and divided by the mean density for that day, to obtain the ratio of population density. Analysis of variance on these ratios (log transformed to normalize residuals and stabilize the variance) indicates sampling time as the only significant (P<0.05) main effect. When combined across categories and dates, ratios for 2100, 2400 and 0300 h were similar, higher than 1, and significantly higher than those from 0600 - 1800 h. Examination of each category's ratio pattern indicates four major behaviour groupings: (1) those with night ratios higher than 1, hence present in higher numbers at night and known to be active then; (2) those with ratios higher at night but known to be inactive then; (3) those with relatively constant ratios throughout day and night; (4) those with ratios high at certain hours only, usually at night and known to be most active then. Accurate estimation of population should consider the varying density of individuals corresponding with the time of day and changing activity pattern of the arthropod concerned. Hence it is suggested here that the appropriate ratio should be used for the relevant arthropod category when sampling at a certain time of day.

INTRODUCTION

Nearly all samplings to estimate population densities of arthropods have been done during the day time (e.g. Shepard *et al.* 1985; Hassan *et al.* 1992a; Hassan and Wilson 1993). There is very little information on the numbers of arthropods on crop plants during the night (Browde *et al.* 1992; Hassan *et al.* 1992b). However, there are numerous reports of light trap catches of arthropods, even at hourly intervals (e.g. Hayes 1991). These night studies clearly indicate a much higher density of arthropods during the night than daytime estimates. Consequently, there is justification for questioning the validity of population estimates based solely on daytime sampling.

Apart from intensity of flight activities as shown by light trap catches, there are many indications of a high level of nocturnal activities on various crop plants (Adjei-Maafo and Wilson 1983; Hassan *et al.* 1992b). Some insects, e.g. noctuid adults, perform more activities such as feeding and oviposition during the night than during the day. Many predatory arthropods, such as those in the wet rice ecosystem, were observed to be more active and more abundant during the night (Hassan *et al.* 1992b). Moreover, temporal changes in density can produce shifts in spatial pattern of distribution of arthropods, thus distorting sampling statistics (Taylor 1984).

The prolific abundance of arthropods on wet rice plants is well documented (Heong *et al.* 1991a,b). Yet there is no further information available which enables apportioning of abundance as a dynamic parameter varying with time on the actual rice plants. In this paper, the variability of estimates of population density is defined through three-hourly counts of the arthropods in a 24-h period. For each arthropod category, ratios are established for mean density at each time of sampling to that of the mean density for the day. The availability of such ratios for each species enables a more accurate estimation of population density at a given time of sampling, hence enabling a more reliable assessment of pest and predator population size for accurate estimation of numbers for research sampling, and for determining status, especially towards decision-making purposes in pest management.

MATERIALS AND METHODS

Study Areas

Two separate studies were conducted involving plantings of transplanted rice replicated spatially and temporally. Two widely separated sites were chosen: experimental plots at Universiti Pertanian Malaysia (UPM), Serdang, Selangor (3° 2' N, 101° 42' E); and a farmer's plots at Sawah Sempadan, Tanjung Karang (SSTK), Selangor (3° 20' N, 101° 12' E). At UPM, four adjacent plots (each measuring 30 x 26 m) were planted with 21-day-old seedlings of MR 84 variety on 7 January 1992. No insecticides were sprayed during the entire sampling period of 73 days. At SSTK, two adjacent plots (each measuring 67 x 61 m) were established using MR 84 variety; transplanting was done on 17 February 1992, 21 days after seeding in the nursery. The field was sprayed once with a synthetic pyrethrin insecticide (Fastac®), 40 days after transplanting (DAT). At 20 and 40 DAT, a mixed fertilizer with N:P:K:trace elements (15:15:17:2 by weight) was applied. At 60 DAT, another mixed fertilizer N:P:K:trace elements (12:12:17:2 by weight) was applied. At each site, transplanted seedlings were placed at the normal spacing of 0.25 m.

Sampling

At each site, six observers in two separate groups conducted direct visual counting recorded on tape cassettes, on 22 categories of arthropod: *Nephotettix* spp. (Homoptera: Cicadellidae), *Nilaparvata lugens* (Homoptera: Delphacidae), Pyralidae (Lepidoptera), *Recilia dorsalis* (Motschulsky) (Homoptera: Cicadellidae), *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), *Pelopidas mathias* (Fabricius) (Lepidoptera: Hesperiidae), *Cyrtorhinus lividipennis* (Reuter) (Heteroptera: Miridae), Diptera, Orthoptera, Odonata, *Casnoidea* spp. (Coleoptera: Carabidae), *Micraspis* spp. (Coleoptera: Coccinellidae), *Paederus fuscipes* (Curtis) (Coleoptera: Staphylinidae); and the spider families Lycosidae, Oxyopidae, Agriopidae, Clubionidae, Thomisidae, Tetragnathidae, Salticidae, spider nymphs and adult hymenopteran parasitoids.

At SSTK, weekly sampling was conducted from 23 April until 3 June 1992 (7 sampling occasions) using one hill as the sampling unit. Weekly visual examination of 40 hills per plot were conducted, at three-hour intervals, during each 24-h duration. At each site, the manner of walking through the field was varied from diagonal to zig-zag and semi-circular, to ensure a good coverage when sampling each plot. Three border rows in each plot were left unsampled. At UPM, weekly sampling was carried out from 20 February until 2 May 1992 (11 sampling days), with 20 hills examined for each plot. The hourly intervals and manner of traversing the field were similar to those implemented at SSTK. For sampling during the night, heavy-duty waterproof torchlights, with 6V Superheavy Eveready® battery, were used to examine the plants. All the species examined were easily recognized under this light.

Analyses

At each site, for each combination of arthropod category, date and time of sampling, the mean density was calculated and divided by the mean density for that day, to obtain the ratios of population density at 0600, 0900, 1200, 1500, 1800, 2100 and 2400 h.

An exploratory data analysis (EDA) (STSC 1991) was done on the ratios at each site to examine their distribution patterns. Dispersion of residuals versus expected values of the ratios was also inspected. After transforming the data using $\log(x + 2)$ and deleting the outliers $(2.7 > (x + 2) > 4.0)$ which were determined using the interactive outlier rejection technique (STSC 1991), parametric analyses proceeded. The transformation was done to normalize distribution of residuals and stabilize the variance.

Since no quantitative and qualitative differences were detected between locations; species of arthropods, rice cultivar, other plants (e.g. weed varieties) and agronomic practices were similar except for one insecticide application at SSTK, the data were pooled in accordance with the central limit theorem accepting locations as spatial replicates. A multi-factor analysis of variance on the transformed ratios, with location, category, date and time of sampling as the major factors, was performed (STSC 1991), and up to three-way interactions were examined. The total number of observations in our data set used in the analysis was 2324. Since the effect of date was found to be not significant, combining data across location and dates, the ratios were plotted against time, for each arthropod category. Combining data across locations, dates and categories, since arthropod category effect was also found not to be significant, the ratios were then compared between the sampling times. The ratios at the various times were also plotted for each category to enable identification of changing patterns in relation to known behaviour of the particular arthropod.

RESULTS AND DISCUSSION

The effects of location, arthropod category and date of sampling are not significant in explaining variation in ratios of population density at the various sampling times. However, sampling time is highly significant ($P<0.001$). This finding is of great significance since it enables focusing of conversion of estimates to mean density to be based largely on time of sampling, without any complication due to interaction of other variables, including that of different taxonomic identity. Consequently, results and inferences on ratio conversion can be applied to all arthropod categories studied.

Comparing mean ratios among times of sampling, combining across all other variables, those of 0600 - 1800 h showed values of less than 1 and the ratios were not significantly different from one another (Table 1). Ratios for 2100, 2400 and 0300 h were similar, but much significantly higher than 1 compared to those at 0600 - 1800 h. Of interest also are the very small standard errors of estimate, ranging from 4.9 to 7.8%, reflecting the low variability of the ratio values at each sampling time. These findings correspond well with earlier findings indicating acceptable reliability and precision of sampling by visual counting of arthropods on a hill basis (Hassan *et al.* 1992b).

In general, the much higher ratios and proportions (63.0% in total) for 2100, 2400, 0300 and 0600 h (Table 1) suggest higher levels of activity of some of the arthropods examined during the night compared to the daytime period.

That the arthropod count at 2100 h was the highest, concurs closely with results of night traps of rice arthropods (e.g. Lim 1977), and of arthropods of other crop ecosystems such as cotton (Hayes 1991). Reasonably high counts were recorded even at midnight and 0300 h, thus indicating the generally higher population density of arthropods on the crop during the night than during the day. There are many possible reasons for this phenomenon. First, in many species of Lepidoptera, for example, life activities such as feeding, mating and oviposition take place mainly at night. During the day, the

TABLE 1
Mean ratios and proportions of population density at sampling time to the overall mean density on sampling day, data combined across location, species and dates. Data from Tanjung Karang and Universiti Pertanian Malaysia, Selangor, 1991/92

Time of sampling	Mean Ratio (% of total)	Standad Error	N
0600	0.76 a (9.5)	0.050	290
0900	0.87 a (11.0)	0.057	290
1200	0.79 a (9.8)	0.053	290
1500	0.77 a (9.6)	0.049	290
1800	0.74 a (9.2)	0.063	262
2100	1.45 b (18.0)	0.077	262
2400	1.32 b (16.0)	0.073	276
0300	1.33 b (16.5)	0.078	276

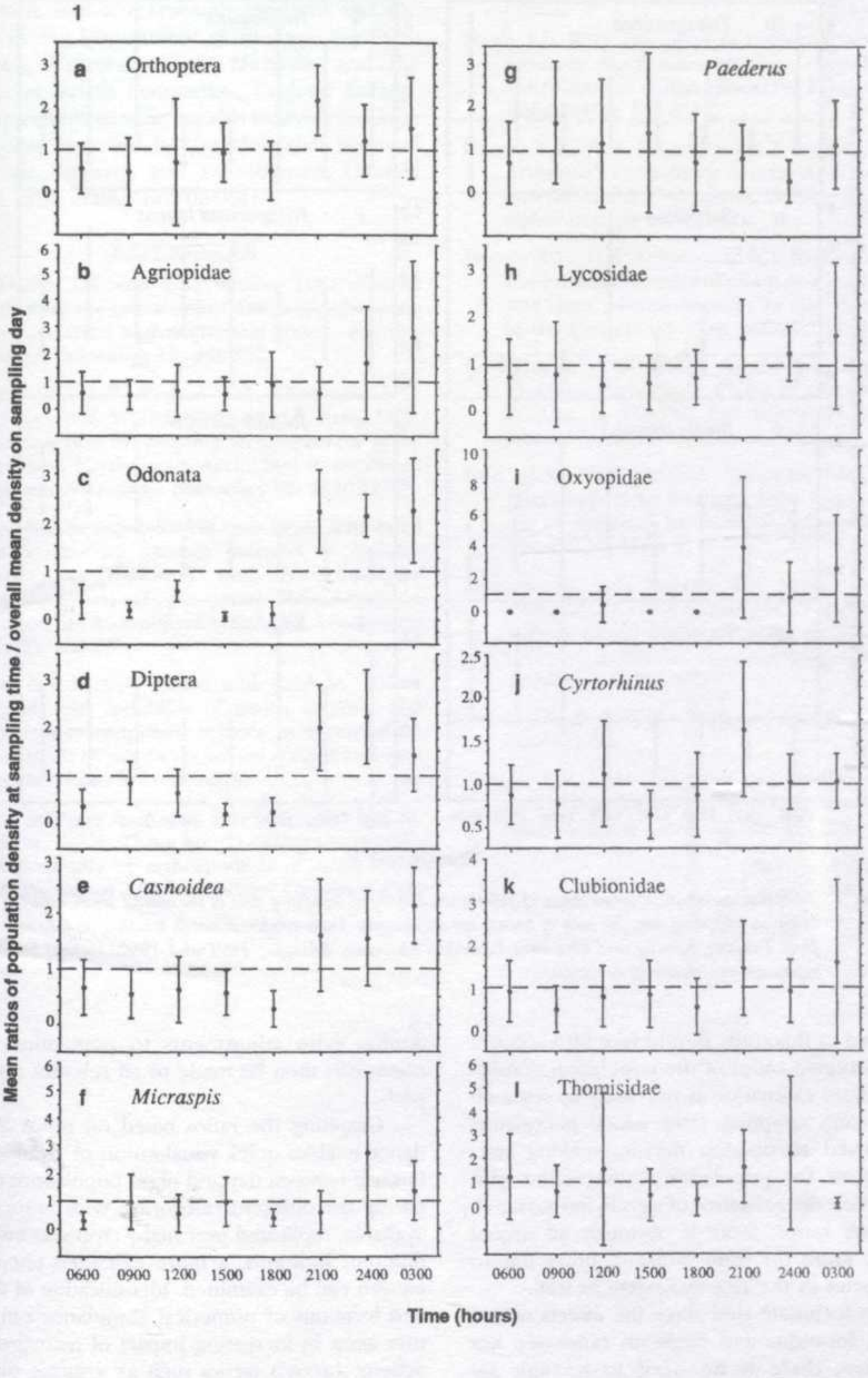
Numbers followed by the same letter are not significantly different at the 5% level

adults may reside on plants and weeds outside the rice crop. They then move into the crop at night. Second, there are arthropods that actively fly during the day, and settle down on the crop plants at night. Examples are the Odonata and the Diptera. Third, there is migration into the crop of some arthropods such as *Nilaparvata* (the Brown Planthopper). Such migration is known to occur at varying levels of population density (Kisimoto 1979). Fourth, natural enemies, especially predators such as spiders and *Cyrtorhinus*, tend to be present in higher numbers when their prey (the pests) are numerous.

Examination of the ratio pattern of each arthropod category indicates four major behaviour-based groupings; (1) those with night ratios higher than one, hence present in higher numbers at night and known to be active then, (2) those with ratios higher at night but are known to be inactive then, (3) those with ratios relatively constant throughout day and night, and (4) those with ratios high at certain hours only, usually at night and are known to be most active then.

The first group consists of many predator species including *Casnoidea, Micraspis*, Lycosidae, Oxyopidae, *Cyrtorhinus*, Clubionidae, Thomisidae, Tetragnatidae, parasitoids, and the pest species *Nilaparvata, Recillia* and Lepidoptera (Pyralidae) (*Fig. 1d-f, h-m, p-s*). The second group comprises other Orthoptera, Agriopidae and Odonata (*Fig. 1a-c*). The adults of these groups are mostly in flight during the day, and settle on the crop at night thus resulting in an increase in their numbers. The third group comprises *Paederus*, spider nymphs, *Nephotettix* and *Sogatella* species (*Fig. 1g, o, q and t*). The fourth group, the spider family Salticidae and the pest species *Nephotettix* and *Nilaparvata* showed obvious increase in numbers around 1800 and 2100 h, and *Sogatella* at 1200 h (*Fig. 1n, o, r, t*).

Most implementation of sampling assignments occur during the day 0600 - 1200 h and 1300 - 1700 h, the so-called "office hours". Between these times, density ratios change from 0.87 to 0.79 and 0.77 respectively. Although this study relied on visual inspection, relative evaluation of ratios by other sampling methods would also perhaps produce similar ratios. It is the relative index of abundance that was measured, not the absolute sampling efficiency. It is proposed here that future accurate estimations of population density of the arthropod category


1
a Orthoptera
b Agriopidae
c Odonata
d Diptera
e Casnoidea
f Micraspis
g Paederus
h Lycosidae
i Oxyopidae
j Cyrtorhinus
k Clubionidae
l Thomisidae
Mean ratios of population density at sampling time / overall mean density on sampling day
0600 0900 1200 1500 1800 2100 2400 0300
Time (hours)

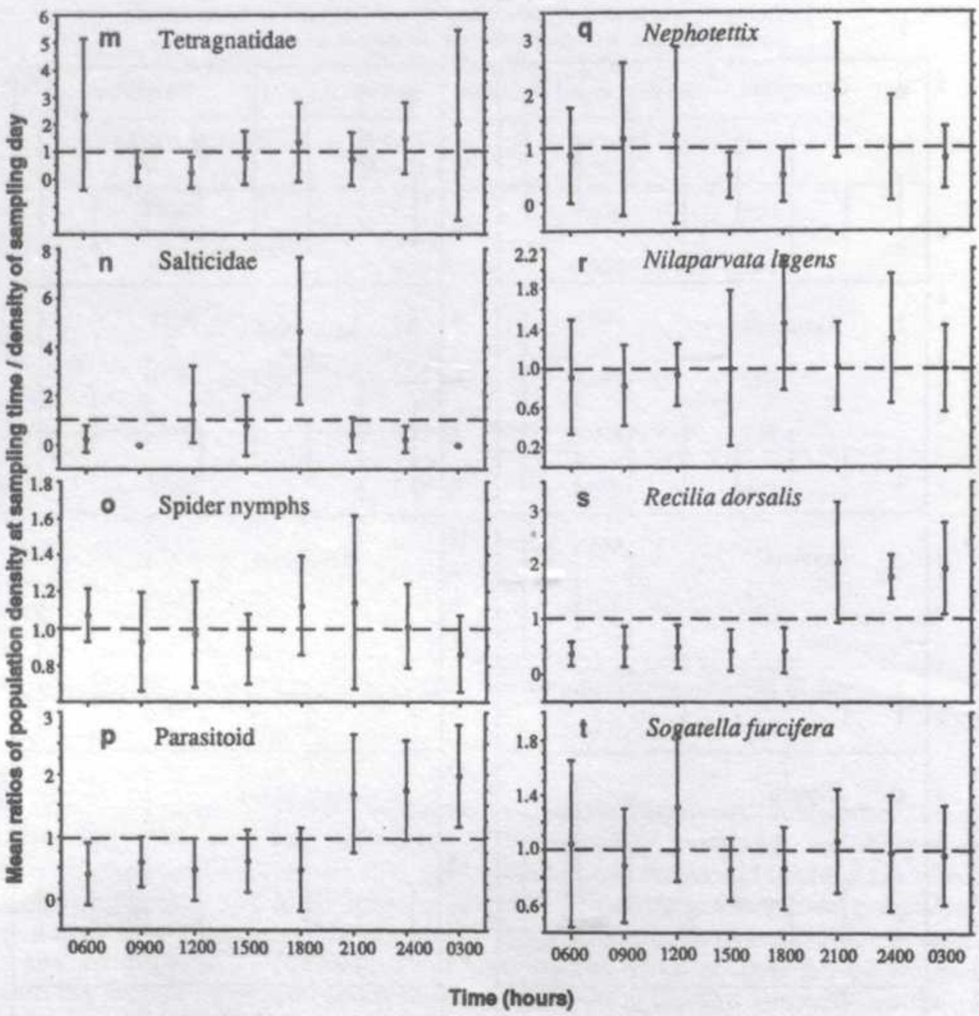


Fig. 1. Temporal variation in mean ratios of population density at sampling time to the overall mean density (one) on sampling day, for each of twenty species category. Data combined across location and dates, from Tanjung Karang and Universiti Pertanian Malaysia, Selangor; 1991 and 1992. Vertical bar represents one standard deviation.

examined in this study should take into account these changing ratios of the population density. An accurate estimation is necessary in research (parameter) sampling, from which parameters are derived to develop decision-making sampling plans for population management purposes. With the existence of significant variation in density ratios, there is obviously an urgent need to know the ratio values of other important species in the rice ecosystem as well.

It is fortunate that since the effects of categories, locations and dates on ratios are not significant, there is no need to account for differential ratio value due to these variables. Similar ratio adjustments to population estimates can then be made to all relevant arthropods.

Graphing the ratios based on mean abundance enables quick visualization of relative difference between day and night populations comparing the different categories. With more data available, replicated over many crop seasons and different locations, a more extended temporal pattern can be examined. Identification of times and locations of numerical abundance can further assist in increasing impact of management actions through tactics such as strategic timing and placement of various kinds of traps.

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