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Local movement and feeding pattern of adult *Neurothemis tullia* (Drury) (Odonata: Libellulidae) in a rain fed rice field

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Abstract: The movements of *Neurothemis tullia* (Drury) (Odonata: Libellulidae) adults were studied in a rain fed rice field using the mark-release-recapture technique. Both male and female dragonflies were widely distributed within their home range of approximately 30 m radii. Adult movements were highly localized and the longest distance travelled was about 130 m. Diurnal feeding pattern was studied by examining gut contents. Some individuals had taken preys as early as 0730 hr. Feeding activity however, peaked at 1030 hr and at 1730 hr. Daily food intake was highly variable between sexes and within hours of the day. Females fed more actively in the morning and their body weights were heavier than that of males at all hours of the day. Active feeding activity of both sexes reflected effective predation.

Resumen: Se estudiaron los movimientos de los adultos de *Neurothemis tullia* (Drury) (Odonata: Libellulidae) en un campo de arroz de temporal usando técnicas de marcado-liberación-recaptura. Tanto los machos como las hembras de estas libélulas estuvieron ampliamente distribuidos dentro de sus ámbitos hogareños que tienen radios de aproximadamente 30 m. Los movimientos de los adultos estuvieron muy localizados y la distancia de vuelo más larga fue de unos 130 m. Se estudió el patrón de alimentación diurno por medio del análisis de contenidos intestinales. Algunos individuous habían capturado presas tan temprano como las 0730 hr. La actividad de alimentación, sin embargo, tuvo picos a las 1030 y a las 1730 hr. El consumo diario de alimento fue muy variable entre ambos sexos y entre las horas del día. Las hembras se alimentaron más activamente en la mañana y sus pesos corporales fueron mayores que los de los machos a todas las horas del día. La actividad de alimentación tan activa de ambos sexos reflejo una depredacion efectiva.

Resumo: Os movimentos dos adultos de *Neurothermis tullia* (Drury) (Odonata: Libellulidae) foram estudados num arrozal de irrigação pluvial usando uma técnica de marcação-libertação-recaptura. Quer os machos quer as fêmeas de libélula distribuíram-se largamente num raio de 30 m do seu local de habitação. O movimentodos adultos estava fortemente localizado e a maior distância percorrida foi de cerca de 130 m. O padrão de alimentação diurno foi estudado analisando o conteúdo intestinal. Alguns individuos fizeram presas tão cedo como as 07H30. A actividade alimentar foi altamente variável entre sexos e durante as horas do dia. As fêmeas alimentavam-se mais activamente de manhã e o seu peso corporal era mais elevado do que o dos machos em todas as horas do dia. A actividade alimentar de ambos os sexos reflectiu uma actividade predadora efectiva.

Key words: Feeding pattern, home range, local movement, *Neurothemis tullia*, Odonata, rice field.

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Introduction

Small sized libellulids, *Neurothemis tullia* (Drury) commonly found in tropical rice fields (Asahina *et al.* 1972; Ek-Amnuay 1982; Heckman 1974, 1979) continuously habour around rice plants, thus rendering them a suitable natural enemy of rice pests (Fraser 1936; Maimon *et al.* 1994; Van Vreden & Ahmadzabidi 1986; Yasumatsu 1975). Other rice field species such as *Orthetrum j. japonicum* (Uhler), *Sympetrum* spp. and *Pantala flavescen* (Burmeister) are stronger fliers, bigger in size and usually prefer bigger moving preys (Watanabe 1986; Michiels & Dhondt 1989; Kumar 1984). Although these species can colonize a wider range of habitats, most of the important rice pests are small microlepidopterans and leaf and plant hoppers that live close to the base of the plants (Pathak 1975), hence not easily accessible to them.

This study investigates the movement pattern and home range of *N. tullia* in a rain fed rice field. The gut contents of a dragonfly represent the feeding activity on the day an individual is collected (Mayhew 1994). Thus the feeding pattern and gregariousness of this species would reflect its potential as a predator of rice pests.

Materials and methods

Study area

A rich source of *N. tullia* was discovered in an 11 ha rice field plot in Bandar Baru District in the northern state of Kedah in Peninsular Malaysia. The rice field depends totally on rain water. Usually 2 rice crops are grown in a year. Rice cultivation is fully mechanized with minimum pesticides usage.

Movement

The movement of *N. tullia* was studied between 17 July 1994 and 3 April 1995 using the mark-release-recapture (MRR) technique. A preliminary observation showed that this species moved less than 35 m from a release point. Thus its home range is within 35 m radii. Therefore 8 points (stations 1 through 8) in the rice field were selected as capture and release stations. There are drainage canals (~2 m wide) around the plots and a canal runs approximately across the centre of the study area near some of the mark and release stations (Fig. 1). The adults were captured from 0900 hr until 1200 hr using a 30 cm-diameter butterfly net. Their wings were marked with ICI Gloss Finish enamel paint (May 1980; Mc Vey 1985; Tan & Jaal 1986) at 4 to 5 day intervals. The sex of individual odonate, marking and recapture stations were recorded. Recaptured adults were categorized into residents and non-residents based on their marking stations. Residents referred to those that were marked and recaptured in the same station whereas non-residents were those that were marked in one station and recaptured in another. The non-residents were further divided into 2 groups; as emigrants, according to their station of capture and mark, and as immigrants according to their station of recapture (Sonleitner & Bateman 1963).

Diurnal feeding pattern

The diurnal feeding pattern of *N. tullia* was

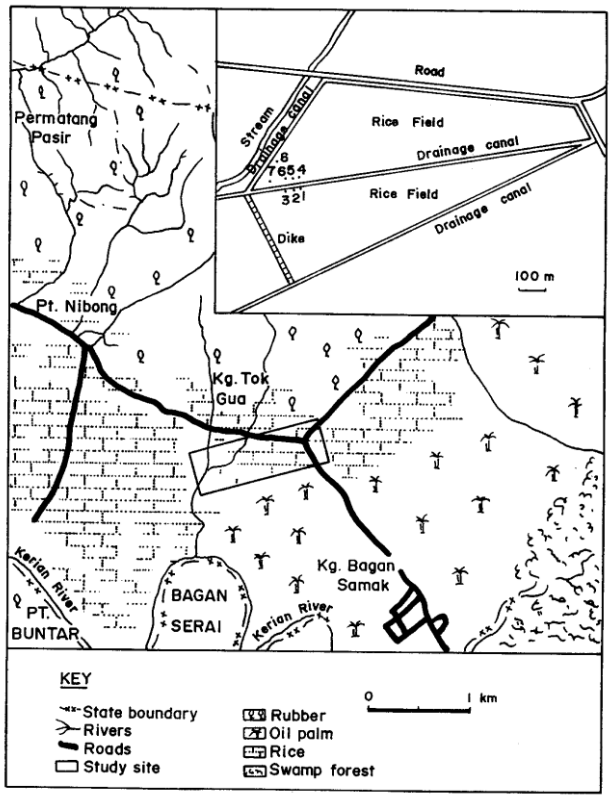

Fig. 1. Vegetational map of the study area. Inset is the study plots. Numbers 1-8 represent mark and release stations.

studied between May and August 1994. Adults of *N. tullia* were collected for 20 minutes hourly from 0730 hr through 1830 hr (approximately half an hour after sunrise and half an hour before sunset) using a 30 cm-diameter butterfly net. Collections of adults were spread within this large interval to avoid excessive disturbance of the dragonfly community during the study period. All captured adults were immediately killed with ethyl acetate, kept individually in paper envelopes and placed in a freezer at -18°C until they were ready to be measured and dissected (Anholt 1992). The dragonflies were thawed at room temperature before weighing using an analytical balance (Denver Instrument AA 200) to 0.1 mg. Collection time and sex of the adults were recorded.

The guts were removed by cutting the abdominal sternites longitudinally using a pair of dissecting scissors. With a pair of fine forceps, they were carefully pulled out of the head regions (Mayhew 1994). Other organs that stuck to the guts especially the gonads were excised. Dissected guts were placed on filter papers and weighed. They were subsequently dried at 40°C in a drying oven for at least 48 hours to constant mass and then reweighed.

Results

Movement

Of the 6,510 males and 6,438 females captured, marked and released, 2,095 males and 2,050 females were subsequently recaptured. A total of 1428 (68.2%) of the recaptured males and 1437 (70.1%) of the recaptured females had moved to a different station before they were recaptured. Travel distance recorded was only that between released (marked) and recaptured (remarked) stations. Residents ranged from 7.5% to 70.5% for the males and 9.7% to 78.6% for the females.

Figure 2 show the components of residents and non-residents in each station. More residents were recaptured at stations 1, 3, 7 and 8. In stations 7 and 8, majority of the recaptures were residents since these stations were comparatively far from other stations and were densely covered by grasses suitable for dragonfly habitats.

Figure 3 and Tables 1 & 2 show that movements of adults were rather limited as stations 1, 3, 7 and 8 recorded the highest numbers of residents. In station 7 and 8 especially, both male and female residents made up most of the recaptures at the stations. However, 3 males (0.3%) and 4 females (0.4%) released at station 8 were recaptured in station 1, the farthest station apart. Substantial numbers of adults moved from their released stations to other areas. Stations 1 through 6 were less than 20 m apart and about 5% of *N. tullia* released there translocated between these stations. Station 1 was approximately 130 m from station 8. Only 19 adults (out of 3780 males and females released) moved reciprocally between the 2 stations. Therefore it can be assumed that the maximum distance traveled by this species is approximately 130 m.

Diurnal feeding pattern

Figure 4a shows that food material were found in the gut at as early as 0730 hr. A high morning peak especially in females occurred at 10.30 hr (Fig. 4b). A less significant peak was observed at 17.30 hr before feeding declined sharply in males at 18.30 hr. Females fed more than males at any time of the day but feeding trend was remarkably similar in both sexes.

Both body weights and gut weights were greater in females than in males (Table 3). In each sex the body weight was positively correlated with the gut weight ($r = 0.2$ in male, $P<0.05$, $n = 338$; and $r = 0.34$ in female, $P<0.05$, $n = 336$). A 2-way ANOVA show the gut weights were significantly different among sexes and between hours of day ($F_{sex} = 19.93$, $df = 1$, $P<0.05$; $F_{hour} = 3.26$, $df = 11$, $P<0.05$) but the interaction between sex and time of day was not significant.

Discussion

Movement

The majority of *N. tullia* moved considerably within 20 m radii. About 5% of the females and slightly less males released at station 3 were recaptured at station 4, approximately 32 m apart. Less than 3% of individuals translocated between stations that were 46-73 m from each other (stations 7 & 4 and stations 7 & 8). These lower percentages of recovery were also related to the recapture rate (Che Salmah 1996). Nevertheless, it can be concluded that the common home range for *N. tullia* is approximately 30 m. Limited spatial movements resulted in very localized distributions

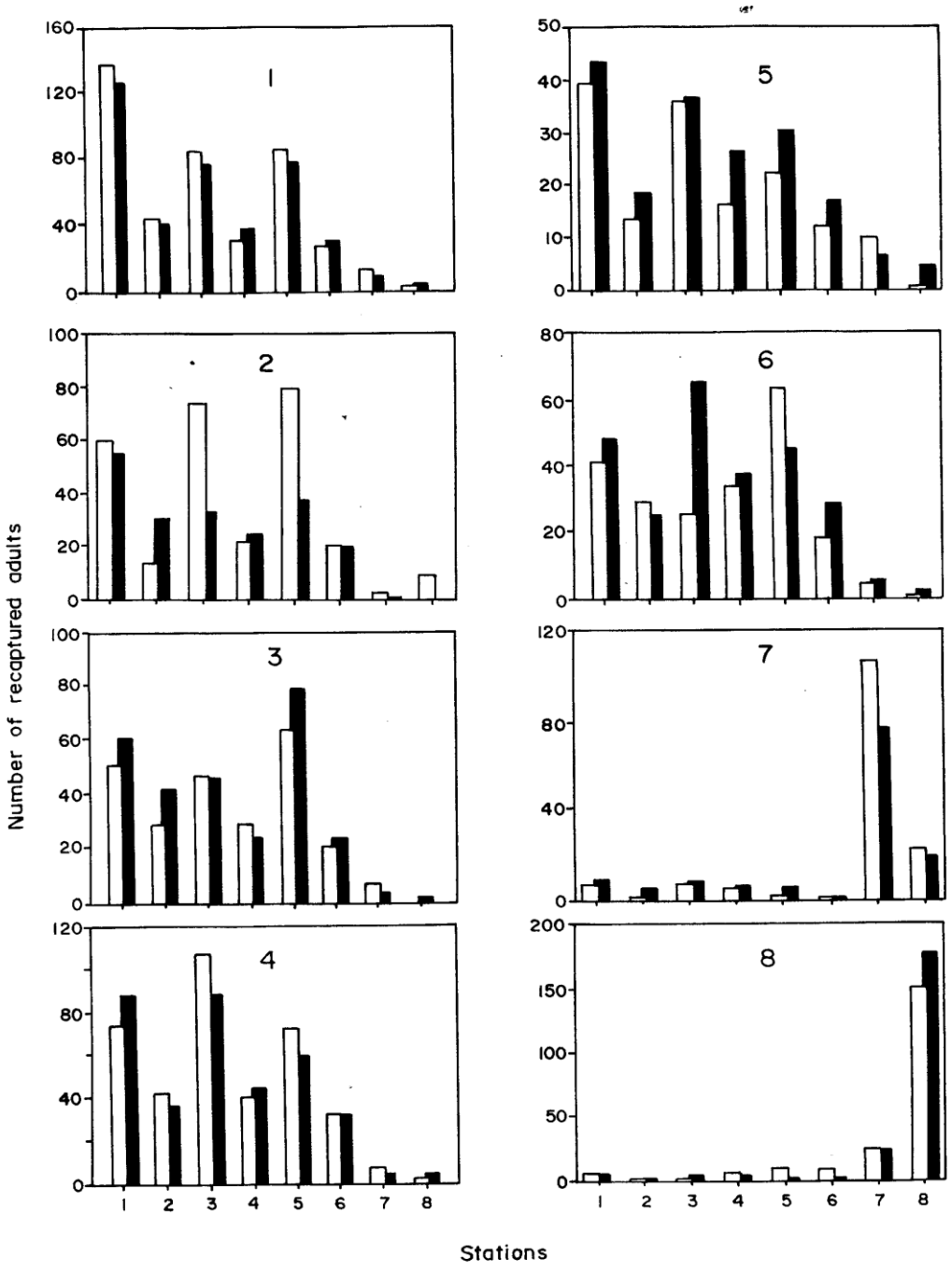

Fig. 2. Compositions of recaptured *Neurothemis tullia* adults (number of individuals) at 8 stations (stations 1-8). Clear bars = males, dark bars = females. Numbers in figures represent mark and release stations.

of *N. tullia* within its breeding habitat. The farthest distance covered in this study was 130 m (stations 1 & 8).

In general, dragonflies are more mobile and more conspicuous (Watanabe & Higashi 1989). *Sympetrum* spp. fly over longer distances beyond their reproductive areas (Watanabe & Taguchi 1988; Michiel & Dhondt 1991). Males of *S. darwinianum* fly over a distance of 569 m and the females could fly a distance of 1.1 km. In contrast, mobility is low in many species of damselflies (Parr & Parr 1979). *Ischnura elegans* (Van der Linden) do not move more than 100 m. About 47 to 71% of males and about 61% of females re-

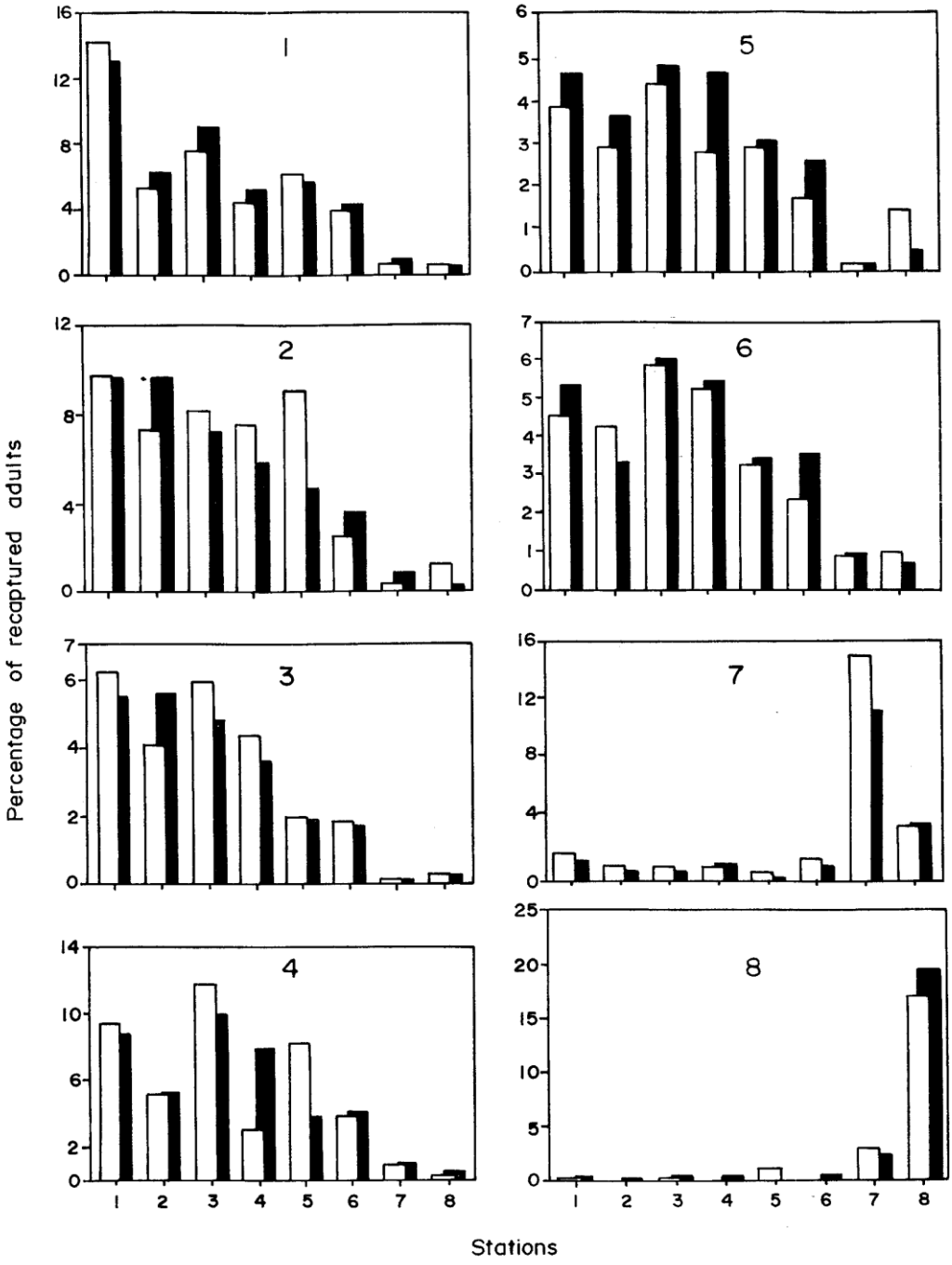

Fig. 3. Movements of recaptured *Neurothemis tullia* adults (percentage of released individuals) to various stations (stations 1-8). Clear bars = males, dark bars = females. Numbers in figures represent mark and release stations.

main within the immediate surrounding of their emergence sites (Parr 1973). Males of *Calopteryx aequabilis* move an average distance of 35 m while females travel only about 50 m in a day (Conrad & Herman 1990). Due to short distances and weak fluttering flight (Fraser 1936), the movement of *N. tullia* resembles that of the damselflies.

Habitat availability influences the movement of insects in their ecosystems. In fruit flies for example, availability of fruits is the main factor influencing their movements around an orchard (Sonleitner & Bateman 1963; Tan & Serit 1994).

Table 1. Movement of male *Neurothemis tullia* (30 August 1994 to 3 April 1995).

	Stations								Total
	1	2	3	4	5	6	7	8	
Adult captured, marked and released	965	706	904	688	878	719	734	916	6510
Recaptures									
Residents	137	29	107	36	80	12	113	153	667
Emigrants	279	147	278	151	325	133	72	43	1428
Immigrants	290	219	269	195	204	135	52	64	1428
Total	706	395	654	382	609	280	237	260	3523
%Capture*	44.2	35.1	41.6	33.6	32.3	20.4	22.5	23.7	32.2

*%Capture = Residents + Immigrants/(Marked adults) x 100.

Table 2. Movement of female *Neurothemis tullia* (30 August 1994 to 3 April 1995).

	Stations								Total
	1	2	3	4	5	6	7	8	
Adult captured, marked and released	963	746	876	736	816	654	711	936	6438
Recaptures									
Residents	126	42	88	40	38	17	82	180	613
Emigrants	313	134	275	170	304	142	58	41	1437
Immigrants	280	240	267	237	148	159	57	49	1437
Total	719	416	630	447	490	318	197	270	3487
%Capture*	42.2	37.8	40.5	37.6	22.8	26.9	19.5	24.5	31.8

*%Capture = Residents + Immigrants/(Marked adults) x 100.

In the rice fields, harvesting of rice removes a large area of suitable habitats for *N. tullia*. The odonates then resort to ratoon crops and grasses around the fields. Stations 1 through 6 for instance, were delimited by small bunds that formed the edge of a drainage canal. After ploughing, only grasses along the bunds were available in the area. Consequently, less odonates found their shelters there. In contrast, stations 7 and 8 were bordered by a drain and bunds densely covered by grasses. Thus very little movements out of these stations were observed.

Diurnal feeding pattern

In many species of dragonflies, their feeding activities begin 15 minutes to about 2 hours after sunrise and stop approximately an hour before sunset (May 1977; Mayhew 1994). Besides exhibiting crepuscular response, *N. tullia* adults fed actively throughout the day. The females were more active in the morning than in the afternoon. However active feeding continued in the afternoon before declining about half an hour before sunset.

Most dragonfly species feed actively after 1000 hr up to midday although the first feeding could have started much earlier (Higashi *et al.* 1979; May 1980). *Neurothemis tullia* had an earlier morning feeding peak (at 1030 hr) possibly due to the higher morning temperatures in the tropics. Interestingly, some of the adults had full guts at 0730 hr. When feeding occurs very late in the afternoon, some undigested portion could remain in the gut until the next morning. For instance, 18% and 26% of maximum gut contents lingers in the guts of *Calopteryx splendens* (Harris) and *Erythroma najas* (Hansemann) respectively up to 16 hours (Higashi *et al.* 1979; Mayhew 1994). In *N. tullia*, there was about 47% of the maximum gut weight at the time when most prey species were still inactive. Based on long food retaining hours in the guts of *C. splendens* and *E. najas*, this food could have been that of the last feeding from the previous day. Furthermore *N. tullia* is not active at night and does not come out of its roosting habitat before 0730 hr. Similar to *N. tullia*, adults of damselfly *E. najas* that feed actively during later parts of the day has heavier

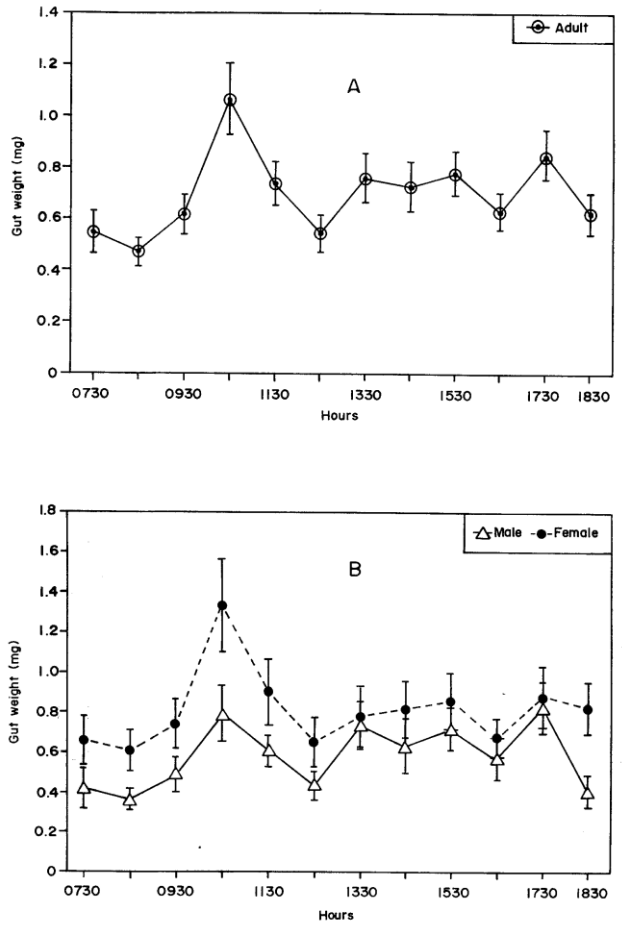

Fig. 4. Diurnal feeding pattern (mean SE) of *Neurothemis tullia* adults. A. males and females combined B. males and females.

gut weight during the fist hour of feeding (Mayhew 1994). Since *N. tullia* is much bigger than either *E. najas* or *C. splendens* (Mayhew 1994), logically they require more food for body maintenance (Dunham 1994) resulting in much heavier undigested portion left in the gut in the morning.

Fried & May (1983) classified *Pachydiplax longipennis* Burmeister as a good thermoregulator based on its long diurnal activities. It was actively feeding approximately 30 minutes after sunrise until 2000 hr, 20 minutes before sunset in late summer. *Neurothemis tullia* then, could also be a good thermoregulator. Its feeding activity started and ended approximately 30 minutes after sunrise and before sunset respectively in the hot tropical weather of about 12 hours daylight.

Females of *N. tullia* had significantly heavier body and the gut weight was greater than that of males at all times of the day. The females are usually heavier than the males because they allocate their reserves to storage products and eggs whereby the males metabolize their resources to meet the high cost of flight in pursuit of reproductive opportunities (Fried & May 1983; Marden 1989; Marden & Waage 1990). The same trend occurs in coenagrionid damselflies where females gain more mass than males (Anholt *et al.* 1991).

Table 3. Body (fresh) and gut (dry) weights (mg) of *Neurothemis tullia*.

Sex		Body	Gut
Male	Mean	496.78	5.83
	S.E.	7.52	0.31
	Min	113	0
	Max	937	42
	n	338	338
Female	Mean	548.59	8.16
	S.E.	8.11	0.43
	Min	99	0
	Max	853	49
	n	336	336

Relationship of body weight and gut weight; Male: R^2 = 4.1%, $P<0.05$; Female: R^2 = 11.5%, $P<0.05$.

Higher body and gut weights of females *N. tullia* implies that the females are active foragers. Consequently they are more exposed to death thus explaining their shorter life span compared to that of the males (Che Salmah 1996). The diffeence in body mass between male and female was at least partly the result of differential foraging effort and success, although variation in resource allocation and metabolic costs may also contribute to the difference (Anholt 1992; Dunham 1994). The divergent relationship between gut fullness and body mass within sexes suggests the possibility that there are intrinsic differences in foraging behaviour among individuals.

Highly localized movement enables the species to be widely distributed within its home range. A small body size enables this odonate species to actively hover around rice plants and prey on pest species including those located in between the leaf blades. Since this species feeds actively throughout the day, most pest species as well as those that are active at different hours will be accessible to it. This study indicates that

N. tullia has a good potential to be an effective predator in the rice field.

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