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Agriocnemis femina (Odonata: Coenagrionidae) and its significance in environmental parameters of rice pests in northern Sumatra-Indonesia

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Abstract: *The pattern movement and age structure influence of rice cultivation phases on A. femina aquatic organisms was investigated in the Manik Rambung rice field (MRRF) ecosystem in North Sumatra. A. femina collections of a buterfly net samples were collected in five cultivation phases (fallow, plough, transplanting-young, tiller, mature atau preharvest). Agriocnemis femina adult (Odonata:Zygoptera), one of the rice pest predators in the adult stage, was dependent on its interactions with rice cultivation phases. There were three age classes of A. femina; teneral, juvenile and mature with sex ratio male and female is 1.7:1. It was important in regulating Agriocnemis femina population in MRRF which determined its successful emergence to a predatory adult. Rice cultivation managements that focus on enhancing the population of Agriocnemis femina would contribute to more effective biological control of rice pests.*

Keywords: *movement, age strucuture, A. femina, rice cultivation phases, Sumatra.*

I. Introduction

All species of Odonata (dragonfly and damselfly) are predators both in the larval and adults stages; hence they are positioned at the higher level in aquatic and teresterial food chains (Bradley *et al.*, 2001; Vashishth *et al.*, 2002). Odonata is one of the main predators in rice fields (IRRI 2013) during the aquatic larval stage (Moore & Townsend, 1998; Yamazaki *et al*., 2003; Leitao *et al*., 2007), and more importantly in the adult stage (Martinez & Rodriquez-Castro, 2007; Ghahari *et al.*, 2009; Prasad, 2010; Norela *et al*., 2013).

Small size coenagrionid Zygopterans are commonly found in many rice fields such as in India (Gunathilagaraj, *et al.*, 1999; Kandibane *et al.*, 2005) and Thailand (Ruay Aree *et al.*, 2000). Some damselflies species, *Ischnura senegalensis, I. delicata, I. rufostigma, Agriocnemis pygmaea* and *Coenagrion coromandelianum* commonly seen fluttering among rice leaves are more useful predators of planthoppers and leafhoppers (Gunathilagaraj, *et al.*, 1999), whilst fast flying anisopterans usually catch bigger preys on flight, such as lepidopteran pests (Krishnasamy, 1984).

Based on their role as important predator of rice pests, investigation of zygopteran population would contribute to better understanding the biological parameters of this species for enhancement of its population in MRRF. The information acquired from this study would contribute to the enhancement of the sustainability of this species in this rice field. *Agriocnemis femina* in MRRF is very important to determine the effective function and useful, especially for formulating control strategies or planning conservation measures in view of their important function as predators of many species of rice pests (Gunathilagaraj, *et al.*, 1999; Bambaredinaya *et al.*, 2004). Then, the age structure useful to determine life cycle of *A. femina* will be grow up in new generations which related management of rice cultivation in MRRF. The environment suchh as temperature, humidity and wind in Simalungun is suitable for Odonata,especially *A. femina* lived.

Simalungun district is one of the major rice producing areas in North Sumatra, Indonesia covering an area of 4386.6 km^2 with an estimated population of 830986 in 2012 (BPS Sumut, 2014). Rice farming is one of the main agricultural activities. Several rice varieties (Ciherang, IR36, IR42, IR 64, IR 66) are grown twice per year in lowland, hilly and terraced rice fields located at altitudes ranging from 20 m asl to 1400 m asl (BPTP, 2010).

II. Material and Methods

Study Sites and Rice Cultivation Phases

This study was carried out at Manik Rambung rice field (MRRF) in the district of Simalungun in North Sumatera. The area is located about 90 km from Medan City, the capital of Sumatra at 594 - 620 m.a.s.l. between the latitude of 2°53’52.8”N to 2°53’60.2”N and the longitude of 98°00’24.4”E to 99°00’24.4”E.

In this district, two crops of rice were planted each year. Cultivation practices followed recommendations by the local agricultural department. Fertilizers were mechanically applied twice yearly.

Herbicide (Ally-XP®) and insecticides (Imidacloprid® and Rhodiamine®) were minimally used to control weeds and rice pests respectively. We defined five rice cultivation phases in MRRF following the descriptions of Mogi & Miyagi (1990) and Stenert *et al.* (2009). They were categorized based on the water level in the field, the amount of surface water shaded by the rice plants, as well as the physical condition of the field.

Fallow phase (F) is defined as uncultivated land area and starts immediately after harvest until the next rice growing season which may last up to two months. In the first part of the phase, the dry field is filled with uniform height rice stumps. Then rice ratoons and aquatic weeds start to grow in the fields which slowly accumulate from 3cm to 5cm of water. The substrate in plough phase (P) is slightly undulated due to the ploughing process and the tyre tracts left by the tractors. Soil depressions contain up to 40 cm of water which remains for 6 to 8 weeks. The transplanting and young field phase (TY) has transplanted rice plants, approximately 30 cm high. The water level may reach up to 10-20 cm. Rice plants in tiller phase (T) have completed tillering but have not eared, growing in less than 10 cm of water. The water surface is half-shaded by the plants. The last phase is the mature and pre harvest phase (MP) which begins when the plants ear continues through the plants bearing flower panicles and developing grains, ending with the yellowing of the grains. The water depth is less than 5 cm and rice leaves have completely shaded the water surface.

Sampling of Agriocnemis femina

Two people captured *A. femina* in each subplot using a butterfly net (400 µm mesh, 60 cm x 90 cm) (Figure 1a) (Kandibane *et al.*, 2005; Sharma and Joshi, 2007; Benazzouz *et al.*, 2009) and give a code with permanent marker (Figure 1b). All of *A. femina* sighted were captured for forty five minutes in each sub plots and placed in an empty cage (60 x 30 x 30 cm) temporarily prior to marking (Figure 1c). Males and females of *A. femina* were assigned into three age categories (classes) which were teneral, juvenile and mature using morphological features adapted from Garrison and Hafernik (1981) and Orr (2005) (Table 1).

Measurements of Physico-Chemical Water Parameters

On each sampling occasion, measurements of physico-chemical parameters, such as air temperature, wind velocity, rainfall and humidity (Figure 2) were recorded. Air temperature at the rice field was recorded by hanging a thermometer on a pole at the centre of the rice plots. Wind speed was recorded using a Davis Anemometer (Figure 2e: Davis Instrument Manufacturing Co., U.S.A) at three randomly selected locations at each sampling site, while rainfall and humidity were collected from BMKG (Metereology and Climatology Society Department).

Data Analysis

Composition of *A. femina* were analyzed using t-test (at $P<0.05$) for normally distributed data to determine differences among sampling occasions, environmental variables and rice cultivation phases. The correlation between *Agriocnemis femina* with environmental variables (are temperature, wind velocity, rainfall, relative humidity). All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 22.00 for Windows®.

III. Results

Abundance of A. femina in Manik Rambung Rice Field

The period of MRR study comprised of two rice growing seasons and was divided according to rice cultivation phases in order to examine affinity of *A. femina* to the rice growth phenology. The population of *A. femina* was lower in the first season than in the second season. The abundance of adults fluctuated gradually from 341 adults in the tiller phase, peaked at 933 adults in the mature phase followed by another peak at 783 adults in the preharvest phase. In the second rice growing season, low abundance of *A. femina* was observed at the beginning of the season especially in the plough phase.Then it dropped abruptly to a very low abundance in tiller phase showing a couple of small peaks in the mature and in the pre harvest phases before it dropped within in the preharvest phase .

In general, the population of *A. femina* was high during in the mature, pre harvest and tiller phases of both rice growing seasons at the period of active growth of the rice plants. The population decreased sharply immediatly after all peaks. The trend of estimated population size of *A. femina* follows the patterns of its captured adults depicted in Figure 5.10. Over the study period, 30 to 398 adults of various ages were captured. The number of captured adults fluctuated closely following stages in rice phenology, the lowest abundance of *A. femina* was recorded during the plough phase and more individuals were captured in the young until tiller phases of rice growth.

A total of 8105 individuals of *A. femina* were marked and 1192 individuals (14.71%) were subsequently recaptured. The encounter rate of the female (36.75%) was significantly lower than the male (63.25%) during the 50 marking occasions (Table 2). Using the number of estimated males and females, the sex

ratio (male to female) was calculated to be 1.7:1 (nearing 2:1) which reflected higher abundance of males compared to the females in the rice field.

Influence of Environmental Factors on Movement of A. femina

Environmental factors, such as air temperature, rainfall, wind velocity and relative humidity were described into Table 3. There was significant different of rice cultivation phases (X=0.175, p<0.000), air temperature (X=0.289, p<0.000), rainfall (X=0.168, p<0.000) and relative humidity (X=0.106, p<0.000) to density of *A. femina*, exception wind velocity. Based on analisis Anova One Way showed the rice cultivation phases was influence to distribution and movement of *A. femina* in MRRF ($F_{(249,40)}$=1.826, p<0.004).

IV. Discussions

Abundance of A. femina in Rice Cultivation Phases

The biological data presented in this study suggest several interesting attributes of *A. femina.* The population of this damselfly species was generally lower compared to other damselflies (Hannon and Hafernik, 2006; Rouquette and Thompson, 2007b), dragonflies (Che Salmah, 1996; Cambas and Rodriquez, 2011) and fruitflies or mosquitoes (Serit, 1987; Jaal and MacDonald, 1992).

In this estimation, the population of *A. femina* was much higher than the population of *Ischnura gemina* (Garrison and Hafernik, 1981); *Coenagrion aequabilis* (Conrad and Herman, 1990); *Lestes disjunctus* (Anholt, 1997); *Agrocnemis pygmaea, Ischnura senegalensis, Diplocoides trivialis, Crocothemis servilea* (Gunathilagaraj *et al.*, 1999); *Symptrum obtrusum* (Forbes *et al*., 2004)*; Agriocnemis femina, A. pygmaea, Pantala flavescens, Orthetrum sabina* (Kandibane *et al*., 2005) and *Coenagrion mercuriale* (Watts *et al.*, 2007), but smaller than *Neurothemis tullia* (Che Salmah *et al*., 2000) recorded in rice fields from various countries.

Abundance of *A. femina* adult depended on riparian vegetation (Wissinger, 1988) and food sources (Stock *et al.*, 1999; Anna and Bradley, 2007) that supported its life in the rice field. Very few adults of *A. femina* (30 individuals) were captured during the fallow phase until the end of the plough phase. The number of adult began to pick up during the young phase and increased drastically to slightly high peak at the beginning of the tiller phase. Then it dropped sharply to a very low number at the end of the tiller phase after which the population slowly picked up its size and reached a low peak at the beginning of the preharvest phase. The richness and diversities of adults insects and pests which served as food source for *A. femina* were higher in the tiller phase, but lower during fallow and mature phases which could influence its abundance in MRRF.

Estimated population abundance and percentage of recaptured males was much higher than females. Higher male than female populations were also observed in *Ischnura graellsii* (Cardero-Rivera, 1990), *C. tenelum* (Andreas and Rivera, 2001), and *I. gemina* (Hannon and Hafernik, 2006), but in *I. gemina* (Garisson and Hafernik, 1981) and *C. merculiale* (Watts *et al*., 2007) populations, a much lower percentage of recapture was recorded.

In MRRF, the sex ratio of male and female of *A. femina* was very close to 2:1. Similar male: female ratio with *Lestes sponsa* was recorded by Stock (2001), but there were more males of *Ischnura ramburi* (3:1) in USA (Sirot and Brockmann, 2001). In general, sex ratio male and female damselfly was 1:1. Equal abundance of male and female adults were observed in *Argia chelata* (Hamilton and Montgomerie, 1989); *I. graellsii* (Cordero, 1990); *Enallagma boreale* (McPeek and Peckarsky, 1998) and *Coenagrion puella* (Conrad *et al.*, 2002) which influenced by survival rate in the ecosystem population (Johannson *et al.*, 2002).

Furthermore, harvester and ploughing machine (Roxas *et al.*, 2005) removed the grass and paddy plant which remove shelter for *A. femina* in the rice field of MRRF. Otherwise, chemical application (Suhling et al., 2000; Stenert and Maltchik, 2007; Stenert *et al.*, 2009), such as H Ally-XP, imidacloprid and rhodiamine often used in the rice field often assumed influenced on the abundance of *A. femina* population in MRRF.

Interaction Environmental Factors on Movement of A. femina in MRRF

Banks and Thompson (1985) and Thompson (1978a) show positive relationship between weather (temperature, wind speed, humadity) and abundance of Odonata. In this study, temperatures were never below 28^0C, while the wind velocity ranged from 14.7 to 57. 8 per min. There was no marked difference observed in the movemnet of *A. femina* based on the proportion of recaptures during subsequent marking occasion in MRRF. The species of *A. femina* had adopted some life history strategies to survive the adverse conditions of the rice fields. There were survival in environment, especially changing availability food such as aquatic organisms in the rice field to supported the larvae and adults of *A.femina*.

V. Conclusions

The abundance of *Agriocnemis femina* varied in different rice cultivation phases influenced of movement and age distribution in MRRF. The three age classes of *A. femina* consits of teneral, juvenile and mature with sex ration male and female is 1.7:1.

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Appendices

Table 1. Age structures

Age Class	Male	Female
I (Teneral)	Soft bodies, pale colors, enclosed and possessed legs light brown and. Thorax is green with shades of black, bright red.	Very soft body and wings, thorax greenish cream. Proximal halves of wings, pale brown. Pleural lines brown. Middle abdominal sterna brown and wings very shining.
II (Juvenile)	Hardened cuticle. Prothorax green-black, thorax brownish black, and yellowish abdomen. Dark brown line along pleura and wings hard and shining	Hardened cuticle, bronze colored female. Brownish yellow on thoracic terga, prothorax greenish. Abdomen and sterna were brown colour. Proximal halves of wings dark brown.
III (Mature)	Thorax greenish yellow, ventral abdominal segments dark brown up to pleural lines. Blackish yellow pleural lines, crisp wings.	Thorax dark green colour. Very dark proximal halves of wings. Tough cuticle, crisp wings.

Noted: Adopted from Garrison and Hafernik (1981); Anguilar (1994) and Orr (2005).

Table 2. Comparison population sexes (males and females) of *A. femina* in rice field

Sex	N	R	% R
Males	5121	754	63.25
Females	2984	438	36.75
Total	8105	1192	100.00

Noted:N=total marked individuals, R= number of individuals recapture, %R=proportion of number of individuals recapture during May 2009 until December 2009

Table 3. Environmental Parameters vs density of *A. femina*

Marking Ocacsions	Time Sampling	Air-Temperature (°C)	Wind velocity (m/min)	Rainfall (mm)	Relative humidity (%)	Total captured
1	21-5-09	36.0	57.8	97	80	179
2	24-5-09	36.0	48.5	99	80	198
3	28-5-09	35.5	36.5	102	81	240
4	31-5-09	35.8	34.5	105	81	209
5	04-6-09	36.0	25.8	108	82	195
6	07-6-09	36.5	27.9	100	80	211
7	11-6-09	37.5	41.5	104	81	126
8	14-6-09	36.0	29.7	101	79	191
9	18-6-09	36.5	41.8	99	78	181
10	21-6-09	37.5	42.5	103	80	189
11	25-6-09	35.5	39.6	102	80	193
12	28-6-09	37.0	43.6	99	76	211
13	02-7-09	36.5	28.5	128	79	196
14	05-7-09	37.0	44.6	135	79	160
15	09-7-09	36.5	43.7	142	81	195
16	12-7-09	35.5	54.4	130	78	176
17	16-7-09	35.5	53.6	155	80	192
18	19-7-09	37.0	56.4	140	79	181
19	23-7-09	35.5	45.8	138	79	161
20	26-7-09	36.5	39.6	156	80	174
21	30-7-09	35.5	43.7	160	80	176
22	02-8-09	37.0	52.6	220	80	54
23	06-8-09	36.0	43.8	245	81	111
24	09-8-09	35.5	34.5	256	81	61
25	13-8-09	36.0	41.5	260	82	35
26	04-10-09	35.5	36.9	275	83	80
27	08-10-09	33.0	58.7	320	85	78
28	11-10-09	29.0	45.5	286	84	76
29	15-10-09	33.7	38.9	298	84	193
30	18-10-09	36.5	35.6	225	82	212
31	22-10-09	34.6	56.4	248	83	242
32	25-10-09	36.0	37.8	330	85	214
33	29-10-09	35.5	32.2	275	82	244
34	01-11-09	33.0	29.8	290	81	394
35	05-11-09	28.0	35.6	280	82	239
36	08-11-09	31.5	37.4	265	81	161
37	12-11-09	35.5	28.7	295	82	160

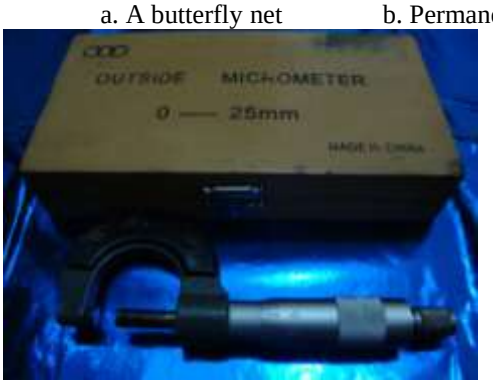
38	15-11-09	32.0	36.5	310	84	88
39	19-11-09	29.0	47.8	335	85	140
40	22-11-09	35.5	57.3	296	83	156
41	26-11-09	34.5	49.6	256	82	100
42	29-11-09	29.0	46.3	195	79	117
43	03-12-09	28.5	39.8	320	83	114
44	06-12-09	34.0	14.7	295	82	137
45	10-12-09	29.5	52.6	310	83	156
46	13-12-09	31.0	56.8	340	84	227
47	17-12-09	32.0	49.5	315	83	174
48	20-12-09	28.0	38.6	295	83	172
49	24-12-09	33.5	42.7	280	82	117
50	27-12-09	28.5	56.4	275	81	98

Figure 1. Equipments used for collecting and marking of *A. femina*

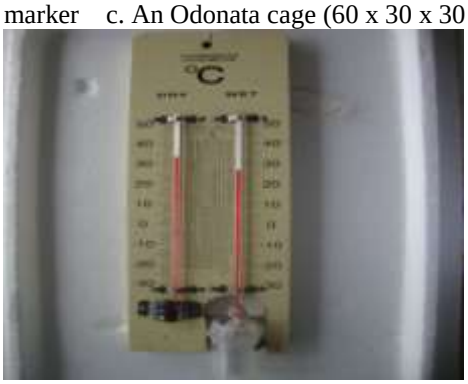
a. A butterfly net

b. Permanent ink marker

c. An Odonata cage (60 x 30 x 30 cm)



d. A micrometer



e. A Davis anemometer