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Migratory behaviour of two butterfly species (Lepidoptera: Nymphalidae) amidst agriculture ecosystems of South-Western Karnataka, India

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Abstract
Migratory behavior of *Tirumala septentrionis* and *Euploea* species was conducted by employing Visual Count Method amidst agriculture ecosystems at the foot hills of Western Ghats of south-western Karnataka, India during 2013 and 2014. Observations were made on periodicity and pattern of migration, swarm size during different hours of the day. *T. septentrionis* and *Euploea* species showed bi-directional *viz*., north-east and south-west migration respectively during March-April and September to November months. The flight pattern has indicated significant variation between different hours of the days. *T. septentrionis* swarm was more than that of *Euploea* species and there existed a significant difference between them. Monsoon become a key factor, influenced the migration of these species. Moreover, local climate and vegetation also played a major role by providing congenial stopover sites during bi-directional migration. Hence, agriculture ecosystems should be taken care to protect the migrating butterfly species.

Keywords: Migration, *Tirumala septentrionis*, *Euploea* species, south-western Karnataka

1. Introduction
Migratory behavior is well-known among Rhopalocera family members of butterflies [1, 2]. It is a seasonal activity for non diapausing Lepidopterans [3] which moved from one habitat to another for specific cause and flying at same time in the same direction as if they guided by a compass [4]. Pence (1998) and Anderson (2009) have reported the migration of monarch butterfly, *Danaus plexippus* which travel more than 5000 kilometers from the great lakes region, east of the Rocky Mountains in southern Canada and the United States to overwinter sites in central Mexico. It is considered as second largest migration of all known insect species. *D. plexippus* migration is well known since last two decades [7]. In India, butterfly migration has been documented since 19th century. It was held at small scale level with short distance and occurred in north-south direction. Evershed (1910), Williams (1930), French (1943), Fisher (1945), Briscoe (1952), Chathurvedi and Satheesan 91979), Chathurvedi (1993), Bharos (2000), Mathew and Biony (2002) and Ramesh *et al*. (2010) have reported different butterfly species migration namely: *Catopsilia pomona*, *C. pyranthe*, *Appias indra*, *A. wardii*, *A. albino*, *Euploea core*, *Papilio demoleus*, *Cepora nandi* and *Graphium sarpedon* at different parts of India. Larsen (1978) and Kunte (2005) have recorded east-west migration of butterflies in southern India. Moreover, [17] has conjectured about east-west migration of Nymphalidae family members such as *Tirumala limniace*, *T. septentrionis*, *Euploea sylvester* and *E. core* with their large swarms. These species were migrated amidst evergreen and semi evergreen forests, but they were forced to migrate towards eastern plains during late April and May, and Nilgiris, Annamalai and Palani hills during October and November months. It was a longitudinal migration, covered a distance of 300 to 500 Kilometers from east to west and influenced by south-west and north-east monsoon patterns of south India [17]. Further, [17] has estimated the sex ratio and swarm number that was restricted for a day and estimated the migration period only for three days. However, there are skewed reports on the butterfly migrating swarm for a complete migratory phase in southern Karnataka. Quantitative estimation of migrating butterfly species, their swarm size and period of migration occurs at agriculture ecosystems is fragmentary. Hence, the present study was undertaken.

2. Material and Methods

2.1 Study area: To record butterfly migration, Jyothigowdanpura village of Chamarajanagar Taluk was selected. The village is located at 2261ft MSL in Deccan plateau at southern tip of Karnataka state (Fig. 1) [18]. The Jyothigowdanapura village ($11^{0}57^{1}$ 03.84^{11}N and $77^{0}02^{1}43.75^{11}$E) boundary is located at the foot hills of Biligiri Rangan (BR) Hills at the point of hill ranges between Eastern Ghats and Western Ghats [19]. The area experiences highest temperature (40 ^{0}C) during March and April months, while December and January indicate lowest temperature (9^{0}C). The relative humidity (RH) ranged between 60 and 80% during morning hours and 20 to 70% in the evening hours with an average annual rainfall 816.1mm [20]. The wind speed ranges from 8.4 to 14.1Km/hr. Moreover, the area is drained by the water from Bellatha small water collecting check dam constructed at the foot hills of BR Hills. The cereals, pulses, oil seeds producing plants, vegetables, commercial crops, horticultural plantations along with flowering plants are grown in this region. Since, agriculture is the main occupation for the farmers of this region, they depend on both Rabi (monsoon) and Kharif (autumn) crops [20, 21]. Interestingly, BR Hills range is connected with Bandipura Tiger Reserve (BTR), Cauvery River Forest Area (CRFA) and Male Mahadeshwara Protected Area (MMPA) in Chamarajanagar District. Moreover, these mountain ranges have connectivity with Mudumalai and Niligiri Mountain Ranges (MNMR) in Tamil Nadu and Wayanad Mountain Ranges (WMR) in Kerala [22].

2.2 Methods

To record the migrating butterflies at agriculture ecosystems, field survey was conducted by selecting ten meters wide line at the middle of butterfly swarm as per [17, 2]. Butterflies passing through the line for a period of 10 minutes at every hour time intervals were recorded by Visual Count Method (VCM) during migration period. Migrating butterflies were observed during Morning (0600 to 1200), Noon (1200 to 1400) and Evening (1500 to 1800) hours and recorded for two consecutive years i.e., 2013 and 2014 during March to April (east to west) and October to November (west to east) for complete migrating days. Further, migrating butterflies were observed from the beginning of migratory activity in the morning and till the end of the day. The direction, periodicity and daily pattern of the migrating swarm were estimated by following standard methods as per [16, 17, 2, 23]. The swarm size was estimated for 50 meters as follows. Butterfly flying in one hour in a belt of 10 meters = Mean number of butterflies in 10 meters for ten minutes × 6 as per [17]. Flying butterflies during migrating days in each season in 50 meters belt = Mean number of individuals for one hour × Average flying hours in a day × 5. However, *Euploea sylvester* and *E. core* look almost alike and very difficult to distinguish during their flight; they were together considered as *Euploea* species alone as per [17].

2.3 Statistical analysis

The collected data was analyzed by using windows based statistical package mainly MS EXCEL and ANOVA as per [24].

3. Results

3.1 Butterfly species Migration

The bi-directional, annual migration of *Tirumala septentrionis* and *Euploea* species is shown in Table 1. Altogether 53,605 individuals were recorded during 83 days of migration. The migrating swarm was with 39,184 individuals of *T. septentrionis* that accounted 73% and 14,421 individuals of *Euploea* species that accounted 27% (Table 1). These species showed their migrating activity for 33 days during March and October in 2013 and it was progressed upto 50 days in April, September, October and November in 2014 (Table 1). Further, abundance was considerably varied during different months in 2013 and 2014. Around 5,058 butterflies in March 2013, around 33,836 butterflies in October 2013 and 8,247 butterflies in April 2014 and 6,464 butterflies in September, October and November, 2014 were recorded during migration period (Table 1). Further, butterflies were traveled towards south-west direction for 24 days during October and nine days migrated towards north-east direction during March, 2013. The swarm was with 40,300 individuals, traveled towards south-west direction, which included 29,035 individuals of *T. septentrionis* and 11,265 individuals of *Euploea* species (Table 1). In 2014, butterflies migrated towards south-west direction for 36 days during October and 14 days towards north-east direction during April, 2014 (Table 1). Altogether 13,305 butterflies were traveled towards north-east direction which included 10,149 *T. septentrionis* and 3,156 individuals of *Euploea* species. Interestingly, migrating butterfly swarm size was high during 2013 compared to 2014 (Table 1). The swarm was with 40,300 individuals which have traveled to south-west direction and which was three times more (i.e., 75%) than the north-eastwardly directed migration that included only 13,305 individuals (Table 1). Per cent occurrence of butterfly migration during different seasons in 2013 and 2014 is shown in Figure 2.

3.2 Daily pattern of Migration

Flight pattern of migrating *T. septentrionis* and *Euploea* species did show considerable variation during different hours of the day. The migrating butterfly swarm size was more during afternoon hours compared to morning and evening hours (Fig. 2). However, *T. septentrionis* and *Euploea* species activity was recorded in between 9000 to 1600hrs in March, 2013 and there existed a significant variation (F= 4.745; $p>0.05$) between different hours of the day (Table 2). The migrating swarm size reached to >2000 individuals during afternoon hours, but it was less during morning and evening hours (Fig. 4). Further, during October migrating activity was recorded between 9000 to 1530hrs and showed significant variation (F= 7.107; $P>0.05$) between different hours of the day (Fig. 4).

3.3 Bi-directional Migration

T. septentrionis and *Euploea* species have migrated towards north-east direction between 8000 to 1730hrs during April, 2014, but on 9th and 10th April, they showed migration between 0600 to 1830hrs and there existed a significant variation (F= 4.038; $p>0.05$) between different hours of the day (Table 3). Interestingly, during April, 2014 the migrating activity was completely absent between 1200 to 1400hrs (Table 3). However, the migrating swarm density was more during morning and evening hours (Fig. 5). The south-west migration during 2014 was recorded for three months i.e., September, October and November between 9000 to 1530hrs and there existed a significant variation (F= 7.107; $p>0.05$) between different hours (Fig 6). Interestingly, migrating swarm density was more during the morning and afternoon hours compared to evening hours of the day (Fig. 6).

4. Discussion

Butterflies migrate every year in southern part of Western Ghats and in the plains lying to the east and then moved towards Nilgiri, Annamalai and Palani hills in October-November and towards the plains in April- May [17]. This tendency has apparently evolved to escape the monsoon patterns in southern India. Ramesh *et al*. (2010) and Ramesh *et al.* (2013) have reported north-south bi-directional migration across the plains of Eastern Ghats. During the present investigation, longitudinal bi-directional migration of *T. septentrionis* and *Euploea* species was recorded. Two years observation of *T. septentrionis* and *Euploea* species migratory activity at agriculture ecosystems of Jyothigowdanpura village nearby the foot hills of Western Ghats showed considerable variation in their migratory time. The north-east migration was initiated early in March 2013 but, it was late by one month during 2014 and that was occurred during April. However, these butterfly species migrated towards south-west direction in 2014, but the migration occurred early September and completed in November. Interestingly, it was associated with the monsoon in south India that was slightly varied in 2014. Thus, monsoon becomes one of the key factors that determine the migration of *T. septentrionis* and *Euploea* species in this region. Butterflies migrate mainly due to their non diapausing characters [3] to escape from the unfavorable conditions [17]. It clearly indicated that initiation of migration is directly influenced by monsoon which plays a crucial role in deciding the migration time of certain butterfly species [17].

In India 52 butterfly species showed migratory behavior among 1,501 butterfly species [25, 26]. Migration was reported in Western Ghats ranges by [25, 1, 16, 27, 17]. The spectacular migratory behavior of *D. plexippus* was recorded by [28, 29, 5, 6]. However, during the present study the south-west migrating butterfly swarm size was three times more than that of the north-eastwardly migrating *T. septentrionis* and *Euploea* species swarm. Perhaps, prevailed congenial conditions might have encouraged migrating swarm in large to move for breeding activity that usually occurs more in Western Ghats compared to Eastern plains. As *T. septentrionis* and *Euploea* species are basically migrated from Western Ghats [17] and going back to Western Ghats to breed predominantly instead amidst scrubby and dry deciduous forests of Eastern plains in India. Further, earlier reports revealed that these butterfly species spend most of their life i.e., more than six months in a year in Western Ghats and another six months in plains of Eastern India [17]. Moreover, *T. septentrionis* and *Euploea* species spend most of their life i.e., more than six months in a year in Western Ghats alone and remaining period in migration and at plains of eastern India [17]. Thus, *T. septentrionis* and *Euploea* species exhibited bi-directional migration in this region. Kunte (2005) and Harvel *et al*. 2002) have reported the temperature influence on butterfly's activity. Since, butterflies are poikilotherms their activities are directly influenced by solar radiation [21]. Mathew and Biony (2002), Kunte (2005), Ramesh *et al*. (2010) and Ramesh *et al*. (20013) have reported the peak migratory activity during noon. Similar type of observations was made during the present study. *T. septentrionis* and *Euploea* species activity was high during afternoon i.e., 1200 to 1300hrs at different places. But, it was completely absent between 1130 to 1400hrs during south-west migration during April 2014. Interestingly, during the present study, migrating *T. septentrionis* and *Euploea* species population was less during October 2014 and it was completely absent in September 28th to October 26th due to the cyclone (Hud Hud) [21]. Perhaps, extreme weather conditions accompanied with rainfall might have adversely affected the migrants [31, 32] and reduced the migratory activity [33]. Similar types of observations were made on 14th and 15th March 2013 and 7th October 2013, it has been due to heavy rainfall occurred in this region. Thus, our observations corroborate the published reports of [7, 27, 30, 33]. Thus, agriculture ecosystems possess diversified flora [34], have provided congenial stopover sites for migrating butterflies and it could help support the livelihood of migrating butterflies [35].

5. Conclusion

Under tropical conditions, climate plays a major role while determining the local vegetation. To protect migrating butterflies amidst agriculture ecosystems, proper care should be taken to avoid anthropogenic intereferences during migration. On this direction, further in depth studies on stopover sites of migrating butterflies is required. Moreover, it has necessitated creating awareness on migrating butterflies among agriculturists for their successful conservation.

6. Acknowledgement

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Table 1: Migration of *Tirumala septentrionis* and *Euploea* species amidst agriculture ecosystems

Sl. No.	Species	Migration								Total of North-east migration	Total of South-west migration	Over all Total
		During 2013				During 2014						
		March (North-east migration)		October (South-west migration)		April (North-east migration)		September, October and November (South-west migration)				
		No. of migrants	Days of migration	No. of migrants	Days of migration	No. of migrants	Days of migration	No. of migrants	Days of migration			
1.	*T. septentrionis*	3902	9	24259	24	6247	14	4776	36	10149	29035	39184
2.	*Euploea* spp.	1156		9577		2000		1688		3156	11265	14421
Total		5058		33836		8247		6464		13305	40300	53605
Mean ± SD		2529 ± 1941.72	-	16918 ± 10381.74	-	4123.5 ± 3003.08	-	3232 ± 2183.85	-	6652.5 ± 4449.78	20150 ± 12565.2	26802.5 ± 17510.00

Table 2: Migration of *Tirumala septentrionis* and *Euploea* species recorded at different time intervals during March 2013

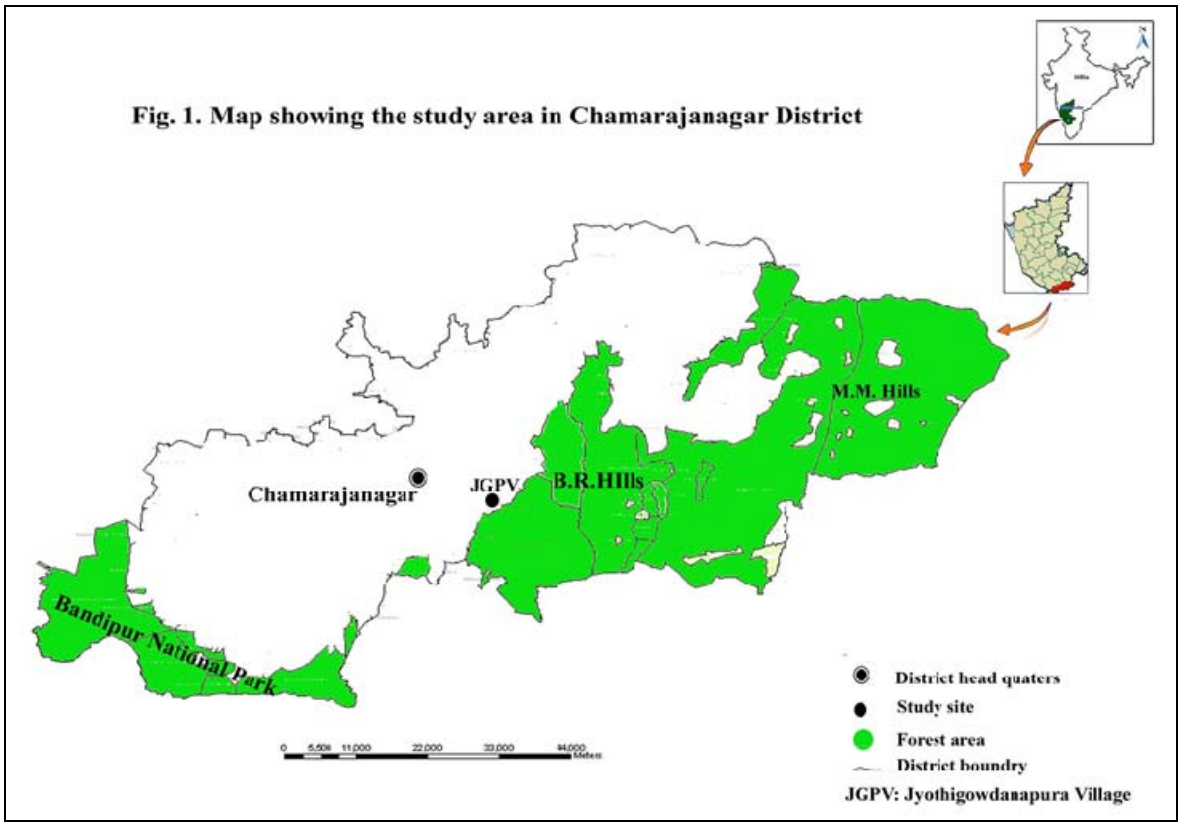
Sl. No.	Time	Species	March 2013									Total	Mean ± SD	'F' value
			11th	12th	13th	14th	15th	16th	17th	18th	19th			
1.	9.00 - 9.10 AM	A	28	42	24	0	0	62	21	18	14	209	23.22 ± 14.02	4.745 (*P*>0.05)
		B	12	18	12	0	0	21	8	7	6	84	9.33 ± 5.70	
2.	10.00-10.10 AM	A	48	97	56	0	0	89	39	22	23	374	41.56 ± 27.51	
		B	13	23	24	0	0	29	11	9	12	121	13.44 ± 7.93	
3.	11.00-11.10 AM	A	97	108	103	0	0	124	61	40	20	553	61.44 ± 41.38	
		B	27	26	33	0	0	36	19	22	9	172	19.11 ± 10.77	
4.	12.00-12.10 PM	A	165	138	192	0	0	173	90	62	21	841	93.44 ± 65.38	
		B	33	38	43	0	0	44	21	28	10	217	24.11 ± 14.54	
5.	1.00-1.10 PM	A	124	122	162	0	0	170	82	42	16	718	79.78 ± 58.02	
		B	27	34	36	0	0	40	20	27	7	191	21.22 ± 12.86	
6.	2.00-2.10 PM	A	102	93	96	0	0	122	62	31	14	520	57.78 ± 41.36	
		B	22	31	29	0	0	31	18	14	6	151	16.78 ± 10.47	
7.	3.00-3.10 PM	A	98	81	78	0	0	70	31	21	18	397	44.11 ± 33.46	
		B	19	24	21	0	0	30	14	11	3	122	13.56 ± 8.94	
8.	4.00- 4.10 PM	A	64	73	61	0	0	48	20	14	10	290	32.22 ± 26.02	
		B	16	19	15	0	0	21	11	8	8	98	10.89 ± 6.12	
Total			895	967	985	0	0	1110	528	376	197	5058	562.00 55.94	-
Mean ± SD			55.94 ± 39.30	60.44 ± 36.12	61.56 ± 40.40	0.00 ± 0.00	0.00 ± 0.00	69.38 ± 41.47	33.00 ± 21.13	23.50 ± 11.13	12.31 ± 4.98	-		-
'F' value			10.653 (*P*>0.05)											

Note: Species A: *Tirumala septentrionis*, B: *Euploea* species

Table 3: Migration of *Tirumala septentrionis* and *Euploea* species recorded at different time intervals during April 2014

Time	Species	April 2014														Total	Mean ± SD	'F' value
		5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th			
6.15- 6.25 AM	A	0	0	0	0	0	48	0	0	0	0	0	0	0	0	48	3.43 ± 12.83	4.038 (*P*>0.05)
	B	0	0	0	0	0	7	0	0	0	0	0	0	0	0	7	0.50 ± 1.87	
7.00- 7.10 AM	A	0	0	0	0	32	107	0	0	0	0	0	0	0	0	139	9.93 ± 29.21	
	B	0	0	0	0	4	12	0	0	0	0	0	0	0	0	16	1.14 ± 3.30	
8.00- 8.10 AM	A	43	32	0	0	52	156	21	68	68	63	83	12	32	12	642	45.86 ± 41.45	
	B	5	4	0	0	8	22	3	33	32	31	41	10	17	16	222	15.86 ± 13.81	
9.00-9.10 AM	A	64	63	43	42	59	136	88	99	88	103	119	16	42	29	991	70.79 ± 35.55	
	B	7	7	6	6	8	19	22	41	42	58	49	12	20	21	318	22.71 ± 17.65	
10.00- 10.10 AM	A	69	82	52	56	63	149	137	134	148	137	141	21	41	21	1251	89.36 ± 49.26	
	B	5	8	5	8	13	20	34	69	77	68	76	17	19	18	437	31.21 ±28.18	
11.00-11.10 AM	A	73	79	48	68	84	93	49	129	122	99	103	34	31	20	1032	73.71 ± 33.95	
	B	8	7	6	7	22	15	16	61	51	48	64	26	17	17	365	26.07 ± 20.80	
12.00-12.10 PM	A	20	70	0	34	0	14	0	48	0	12	39	10	14	12	273	19.50 ± 21.01	
	B	2	9	0	5	0	3	0	24	0	5	18	9	8	9	92	6.57 ± 7.15	
1.00-1.10 PM	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00 ± 0.00	
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00 ± 0.00	
2.00-2.10 PM	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00 ± 0.00	
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00 ± 0.00	
3.00-3.10 PM	A	0	0	30	35	99	63	142	73	48	46	73	2	0	0	611	43.64 ± 43.39	
	B	0	0	12	4	14	8	28	33	21	20	41	0	0	0	181	12.93 ± 13.80	
4.00-4.10 PM	A	0	0	40	48	138	104	72	82	94	66	92	3	0	0	739	52.79 ± 46.68	
	B	0	0	6	6	16	13	10	39	49	38	51	1	0	0	229	16.36 ± 19.25	
5.00-5.10 PM	A	0	0	28	36	142	29	32	42	24	21	21	5	0	0	380	27.14 ± 36.21	
	B	0	0	9	4	17	2	9	23	14	11	13	1	0	0	103	7.36 ± 7.49	
6.00- 6.10 PM	A	0	0	0	0	99	0	0	0	0	0	0	0	0	0	99	7.07 ±26.46	
	B	0	0	0	0	12	0	0	0	0	0	0	0	0	0	12	0.86 ± 3.21	
6.30-6.40 PM	A	0	0	0	0	42	0	0	0	0	0	0	0	0	0	42	3.00 ± 11.22	
	B	0	0	0	0	18	0	0	0	0	0	0	0	0	0	18	1.29 ± 4.81	
Total		296	361	285	359	942	1020	663	998	878	826	1024	179	241	175	8247	-	-
Mean ± SD		10.57 ± 22.34	12.89 ± 26.15	10.18 ± 16.78	12.82 ± 20.32	33.64 ± 42.65	36.43 ± 50.19	23.68 ± 39.86	35.64 ± 40.61	31.36 ± 42.03	29.50 ± 38.05	36.57 ± 42.42	6.39 ± 9.19	8.61 ± 13.55	6.25 ± 9.16	-		
'F' value		14.875 (*P*>0.05)																

Note: Species A: *Tirumala septentrionis*, B: *Euploea* species



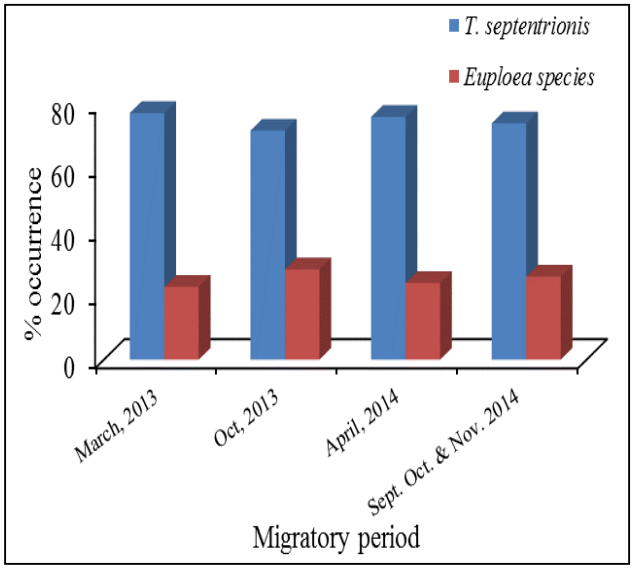


Fig 2: Per cent occurrence of *T. septentrionis* and *Euploea* species migration during 2013 and 2014

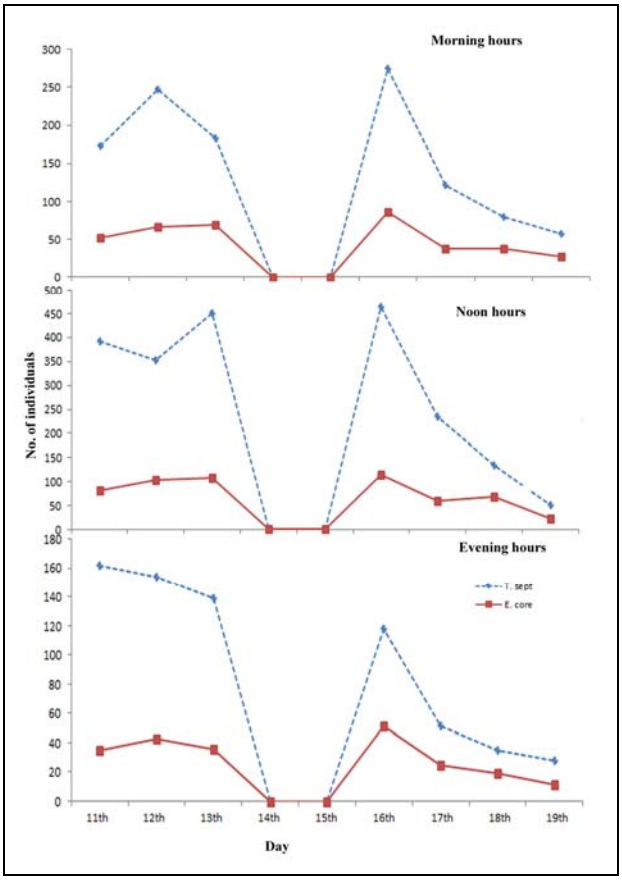


Fig 3: Migration of *T. septentrionis* recorded during different hours in March 2013

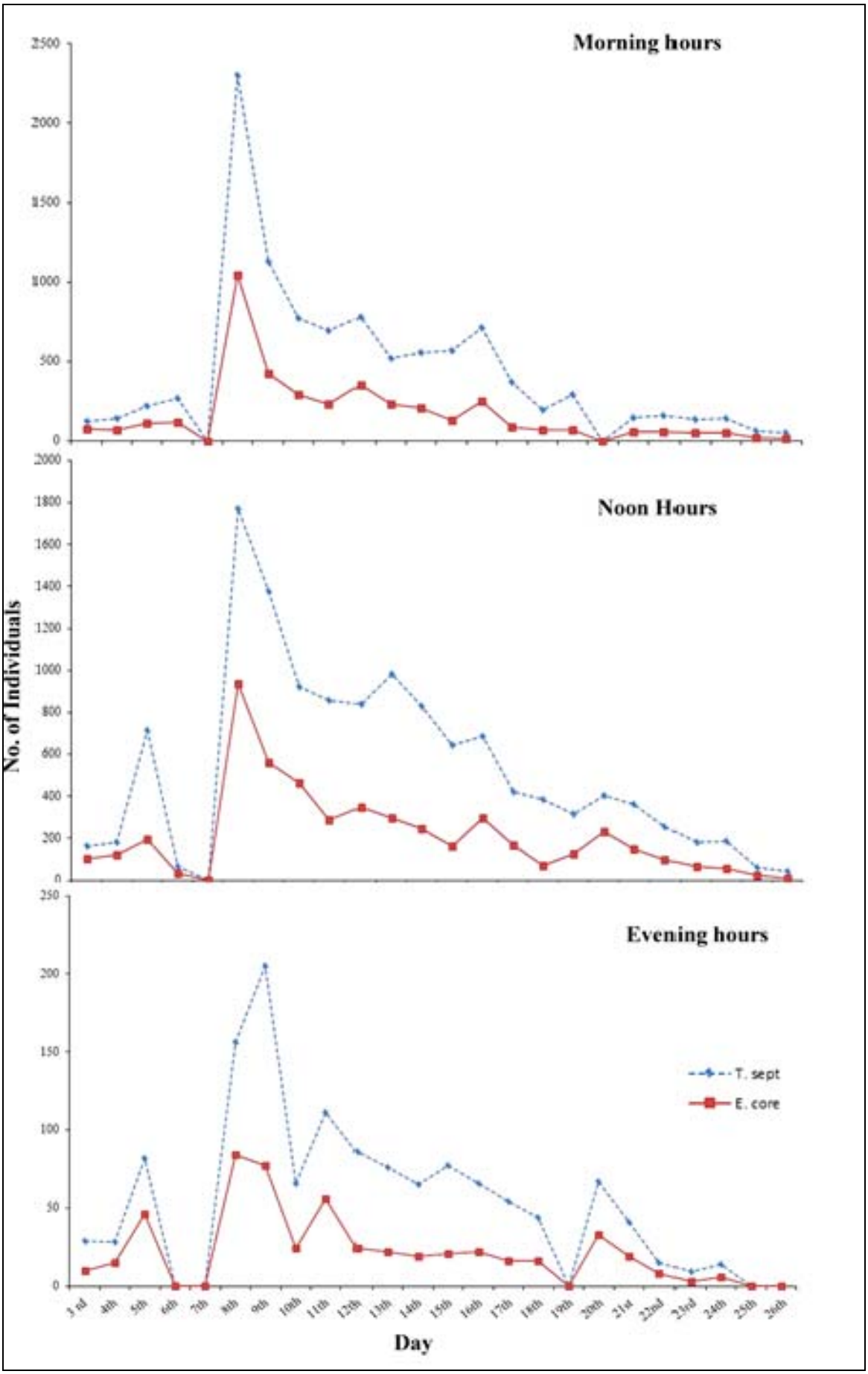


Fig 4: Migration of *T. septentrionis* recorded during different hours in October 2013 (F= 7.107; *P*>0.05 between hours).

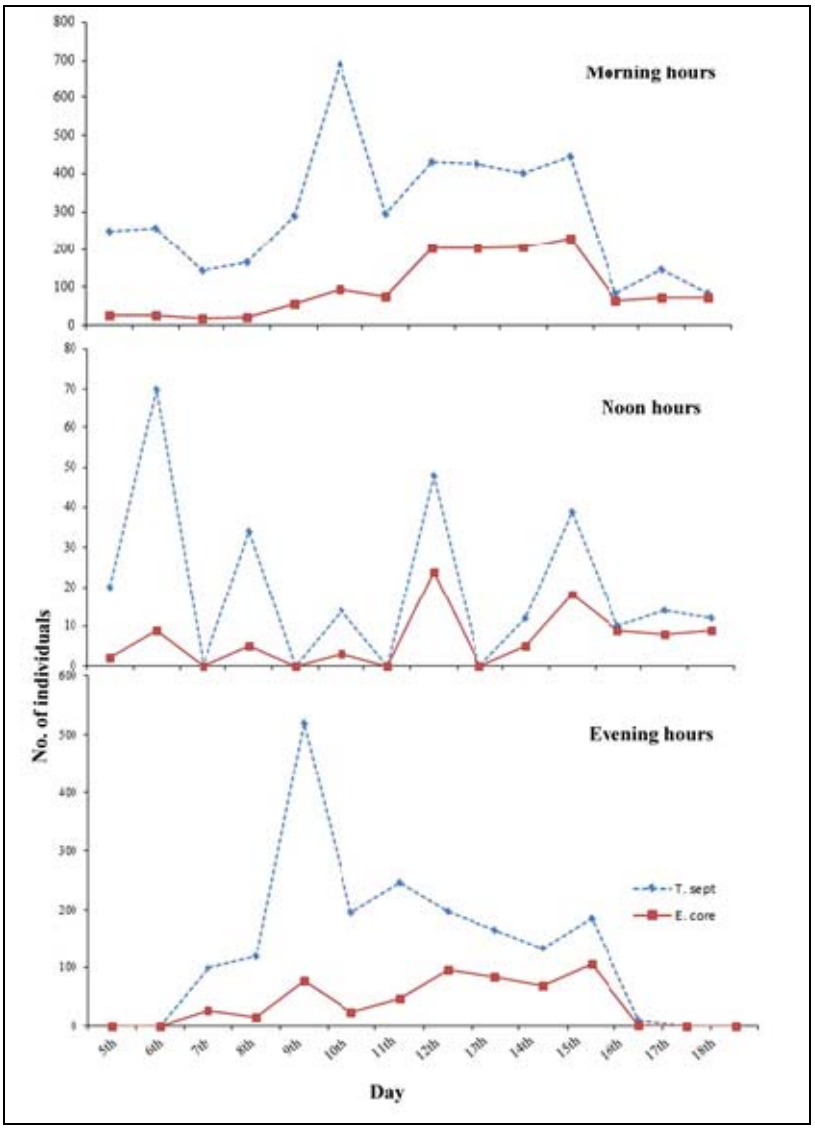


Fig 5: Migration of *T. septentrionis* recorded during different hours in April 2014

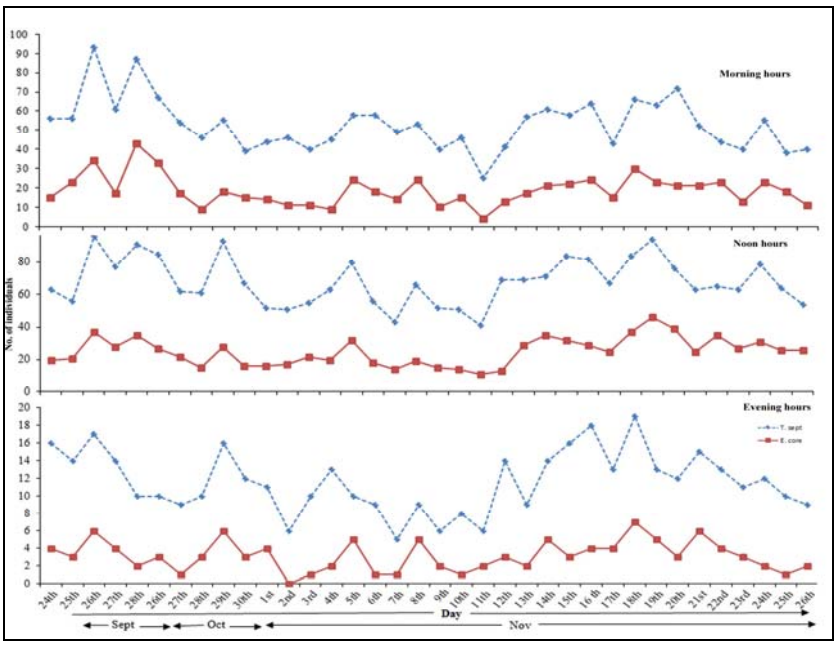


Fig 6: Migration of *T. septentrionis* recorded during different hours during September, October and November, 2014 (F= 4.038; *P*>0.05 between hours).

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