Journal of Threatened Taxa

Building evidence for conservation globally

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

COMMUNICATION

MOULTING PATTERN AND MORTALITY DURING THE FINAL EMERGENCE OF THE COROMANDEL MARSH DART DAMSELFLY *CERIAGRION COROMANDELIANUM* (ZYGOPTERA: COENAGRIONIDAE) IN CENTRAL INDIA

Nilesh R. Thaokar, Payal R. Verma & Raymond J. Andrew

26 October 2019 | Vol. 11 | No. 13 | Pages: 14672–14680
DOI: 10.11609/jott.4954.11.13.14672-14680

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 October 2019 | 11(13): 14672–14680

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Moulting pattern and mortality during the final emergence of the Coromandel Marsh Dart Damselfly *Ceriagrion coromandelianum* (Zygoptera: Coenagrionidae) in central India

Nilesh R. Thaokar [1], Payal R. Verma [2] & Raymond J. Andrew [3]

[1–3] Centre for Higher Learning and Research in Zoology, Hislop College, Civil lines, Nagpur, Maharashtra 440001, India.
[1] nilesh.thavkar@gmail.com, [2] payalrverma@gmail.com, [3] rajuandrew@yahoo.com (corresponding author)

Abstract: The final emergence of the Coromandel Marsh Dart Damselfly *Ceriagrion coromandelianum* was studied for 50 days (22 January–12 March, 2011) from the botanical garden of Hislop College, Nagpur, India, (a semi controlled site) where small underground cement tubs/tanks are used to grow macrophytes by the Botany department. In *C. coromandelianum* emergence is asynchronous, diurnal and occurs between 07.00h and 18.00h. Stage-I starts when the ultimate instar nymph of *C. coromandelianum* leaves the water body, searches for a suitable place and then begins to shudder its body to detach the trapped pharate from the nymphal exuvia. The pharate exerts pressure on the thoracic tergites to split the cuticle. Stage-II starts when the head and thorax of the pharate emerges out of the split exuvia. The pharate struggles to remove its trapped body from the nymphal exuvia. During Stage-III, the wings expand but are opaque; pigmentation of the body occurs simultaneously all over the body. Soon the whole body develops its species specific coloration while the expanding wings gain transparency, unfold and separate out and now the imago is ready for its maiden flight. Stages I, II, and III occupy 31.66%, 11.73%, and 56.60% of the total moulting period, respectively. A total of 243 emergences occurred during the observation period, 158 emergences occurred in tanks containing *Pistia stratiotes,* while 65 emergences in tubs containing *Nymphaea nouchali* indicating that *C. coromandelianum* prefers *P. stratiotes* over *N. nouchali* for oviposition. Twenty deaths were recorded during the present observation. Failure to moult (15%) and failure to emerge completely out of the exuvia (85%) were the two reasons for mortality.

Keywords: Dragonfly, emergence, exuvia, instar, metamorphosis, moulting, pharate.

DOI: https://doi.org/10.11609/jott.4954.11.13.14672-14680

Editor: K.A. Subramanian, Zoological Survey of India, Chennai, India. **Date of publication:** 26 October 2019 (online & print)

Manuscript details: #4954 | Received 15 March 2019 | Final received 12 June 2019 | Finally accepted 02 October 2019

Citation: Thaokar, N.R., P.R. Verma & R.J. Andrew (2019). Moulting pattern and mortality during the final emergence of the Coromandel Marsh Dart Damselfly *Ceriagrion coromandelianum* (Zygoptera: Coenagrionidae) in central India. *Journal of Threatened Taxa* 11(13): 14672–14680; https://doi.org/10.11609/jott.4954.11.13.14672-14680

Funding: Self funded.

Competing interests: The authors declare no competing interests.

Author details: Dr. Nilesh R. Thaokar is presently teaching at the Post Graduate Department of Zoology as an assistant lecturer. Dr. Payal R. Verma is actively engaged in research in the area of odonatology. She has completed her PhD from Rashtrasant Tukadoji Maharaj Nagpur University, and currently is an assistant professor lecturer at the Post Graduate Department of Zoology. Dr. R.J. Andrew has been studying various physiological, morphological, ethological, and ecological aspects of dragonflies of central India for the last 30 years and has more than 100 research papers to his credit. He serves as the director of the P.G. Dept. of Zoology, and Vice Principal, Hislop College, Nagpur. He has published two books on odonates and has organized one international, three southern Asian, six national, and two state level symposia.

Author contribution: NRT and PRV contributed in field work and documentation of the oviposition behaviour. RJA set up the project and evaluated the findings.

Acknowledgements: We thank the Principal Dr. Ms. Dipti R. Christian and Management of Hislop College, Nagpur for providing us laboratory facilities.

INTRODUCTION

In Odonata, moulting during the final emergence when the aerial imago is released from the exuvia of aquatic nymph is a fascinating event involving many different types of rhythmic movements. It is also a very vulnerable period since the helpless individual is exposed to various antagonistic factors of the environment. This process was documented by various workers (Tillyard 1917; Corbet 1957; Pajunen 1962; Trottier 1966; Ubukata 1981; Banks & Thompson 1985; Gribbin & Thompson 1990, 1991; Haslam, 2004; Andrew & Patankar 2010) and was evaluated by Corbet (1999) who divided it into four observable stages. Later, Andrew & Patankar (2010) modified this division and proposed only three stages taking into consideration the time-lag and attainment of morphological characters of the freshly moulted imago. Eda (1963), reported two major types of posture during emergence- horizontal emergence commonly found in Zygoptera and Gomphidae and the vertical, found in the remaining groups, though inverted emergence has also been reported in some species of Zygoptera (Rowe 1987). Mortality during emergence can be caused by three observable factors: failure to moult, failure to harden body/wings, and predation (Thompson 1991; Bennett & Mill 1993; Andrew 2010). It can range from 0% to 100% and is dependent upon factors like temperature, rain, wind, oxygen level, lack of suitable emergence support, overcrowding and predation (Corbet 1957, 1999; Pajunen 1962; Kurata 1974; Inoue 1979; Thompson et al. 1985; Gribbin & Thomas 1990; Bennett & Mill 1993; Jacob & Suhling 1999; Purse & Thompson 2003; Andrew 2010). Most studies on the final emergence in Odonata are confined to species of the sub-tropical and temperate regions, while only a few attempts have been undertaken to study this process in detail in the tropical region mostly covering only the anisopteran species (Mathavan & Pandian 1977; Andrew 2010, 2012; Andrew & Patankar 2010).

The zygopteran *Ceriagrion coromandelianum* (Fabricius, 1798) is a very common damselfly of the Indian subcontinent. The life history of this species was described in detail by Kumar (1980) and Sharma (2009). Kumar (1980) also described the larval morphology of all the instars. We have used this species to evaluate various aspects of odonate reproductive biology (Andrew et al. 2011a,b; Thaokar et al. 2018a,b). It is found almost throughout the year, ovipositing in various floating and submerged vegetations of small natural and man-made water bodies (Sharma 2009; Andrew et al. 2011a). The present paper describes the pattern and process of emergence of this damselfly with a note on mortality during this event.

MATERIAL AND METHODS

Site: The observation was carried out at the botanical garden of Hislop College, Nagpur, (21.147$^{0\prime}$N, 79.071^{0}E), India, a semi-controlled site, where small underground cement tubs are used to grow macrophytes by the Botany department. The tubs contain floating *Nymphaea nouchali, Lemna paucicostata* and submerged *Hydrilla verticillata* vegetation, while the cement tank contains only *Pistia stratiotes*. These are surrounded by bushes of flowering plants and post-noon, this area is under the shadow of the college building. *Ceriagrion coromandelianum* is found breeding all round the year at this site.

Mature F-0 larvae were collected from this site and kept in a glass tank partially filled with water along with floating vegetation. Natural conditions were maintained by keeping the containers near the large open windows. With the help of an aim-n-shoot Sony (DSC-W30) and Canon (G11) cameras, various stages of the process of moulting during metamorphosis were documented. All movements of the larva/emerging pharate were documented and an electronic stopwatch was used to record the time. Some of the emergences were directly recorded at the collection site. Daily collection of exuviae was undertaken at the study site from 22 January to 12 March, 2011 (Table 1). Details of the weather report of the city were procured from the website https://www.timeanddate.com.

RESULTS

The daily emergence of *Ceriagrion coromandelianum* was recorded for 50 days by collecting the exuviae from the water tubs of the above described site from 22 January to 12 March 2011. The tubs and tank were filled with floating *Pistia stratiotes* and *Nymphaea nouchali* which made a perfect substrate for the final emergence. A total of 243 emergences occurred during the observation period of 50 days at the study site (excluding the ones collected from the study site and reared in the laboratory), 158 emergences occurred in tanks containing *Pistia stratiotes* while 65 emergences in tanks containing *Nymphaea nouchali.* Two peaks of emergences were recorded, the first emergence on 14 February (19) and the second on 21 February (17) (Table 1). Fifty percent of the

Table 1. *Ceriagrion coromandelianum*: Number of emergence and mortality observed during the 50-day study period (mortality in parenthesis).

	Date	*Pistia stratiotes*	*Nymphaea nouchali*	Mortality	Total
1	22.i.2011	0	0	0	0
2	23.i.2011	2	0	0	2
3	24.i.2011	1	0	0	1
4	25.i.2011	2+(1)	0	1	3
5	26.i.2011	1	0	0	1
6	27.i.2011	3+(1)	0	1	4
7	28.i.2011	0	0	0	0
8	29.i.2011	0	1	0	1
9	30.i.2011	2	2+(1)	1	5
10	31.i.2011	1	0	0	1
11	01.ii.2011	0	1	0	1
12	02.ii.2011	0	0	0	0
13	03.ii.2011	1	2+(1)	1	4
14	04.ii.2011	0	0	0	0
15	05.ii.2011	3	1	0	4
16	06.ii.2011	5+(1)	1	1	7
17	07.ii.2011	2	0	0	2
18	08.ii.2011	2	0	0	2
19	09.ii.2011	1	2	0	3
20	10.ii.2011	1+(1)	0	1	2
21	11.ii.2011	2	0	0	2
22	12.ii.2011	4	0	0	4
23	13.ii.2011	12	4	0	16
24	14.ii.2011	16+(3)	3	3	22
25	15.ii.2011	6	3	0	9
26	16.ii.2011	2	3	0	5
27	17.ii.2011	4	1	0	5
28	18.ii.2011	3+(1)	2+(1)	2	7
29	19.ii.2011	6	0	0	6
30	20.ii.2011	12+(1)	5	1	18
31	21.ii.2011	8	5	0	13
32	22.ii.2011	10+(2)	1	2	13
33	23.ii.2011	4	5	0	9
34	24.ii.2011	5+(2)	1	2	8
35	25.ii.2011	5	3	0	8
36	26.ii.2011	0	0	0	0
37	27.ii.2011	2	4+(1)	1	7
38	28.ii.2011	4	1	0	5
39	01.iii.2011	5	2	0	7
40	02.iii.2011	0	0	0	0
41	03.iii.2011	0	0	0	0
42	04.iii.2011	2	2	0	4
43	05.iii.2011	5+(1)	1	1	7
44	06.iii.2011	4	2	0	6
45	07.iii.2011	1	2	0	3
46	08.iii.2011	3	0	0	3
47	09.iii.2011	5+(1)	3+(1)	2	10
48	10.iii.2011	1	0	0	1
49	11.iii.2011	0	0	0	0
50	12.iii.2011	0	0	0	0
	Total	**158+(15)**	**63+(5)**	**20**	**241**

total emergence of *C. coromandelianum* was observed by the 29th day (19 January 2011) (Fig. 1). The duration of the day was divided as morning (07.00–12.00 h), noon (12.00–16.00 h), and evening (16.00h–dusk). Emergence was not found during the pre-dusk and pre-dawn period. The number of emergence recorded were: morning 58 (23.86%), noon 166 (68.31%), and evening 19 (7.8%) (Table 2, Figure 2a). The highest number of emergence (22) was observed on 14 February 2011 (Max. temp. 34°C, min. temp 20°C, humidity 30% at noon) followed by 18 emergence on 20 February 2011 (Max. temp. 25°C, min. temp. 19°C, humidity 85% at noon) (Figure 2b). Depending upon the type of substrate *C. coromandelianum* can moult in both horizontal (on floating leaves) as well as vertical (on emerging stem) positions. Eleven complete events of metamorphosis leading to emergence of the pharate were observed and recorded. Moulting in *C. coromandelianum* is not time specific since this process occurs throughout the day between 07.00h and 18.00h (Table 3).

The following documentation describes one complete pattern of moulting during the final emergence of the damselfly, *C. coromandelianum* observed on 18 February 2011, which started at 12.55h and ended at 15.38h, (153 minutes) (Images 1–9). This process has been divided into three observable stages (Andrew & Patankar 2010).

Stage- I: At 12.55h the F–0 larva emerged out of water and climbed the floating leaf of *Pistia stratiotes*. It moved 4cm on the dry surface of the leaf, and rested. At 13.24h the larva began to shake the abdomen in the vertical plane. These movements were very slow and later it started moving it in the horizontal plane. This movement continued for 56sec. Then it started pushing the head and thorax against the leaf. The legs were spread while the posterior region of the abdomen was firmly pressed against the base. The larva moved the head sideways

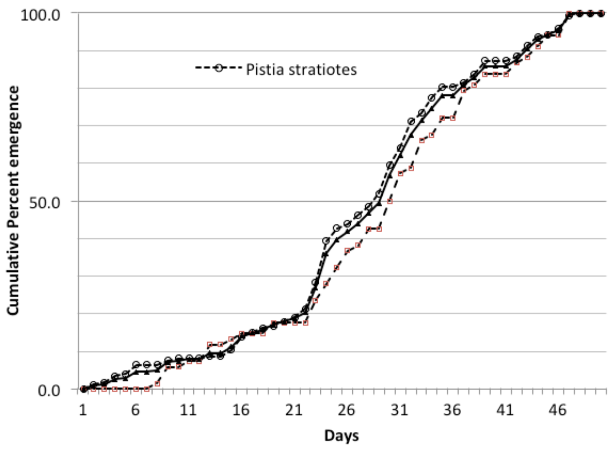


Figure 1. Cumulative percentage emergence of *Ceriagrion coromandelianum* during the 50-day study at Nagpur, India.

Images 1–6. Stages I and II of the final emergence of *Ceriagrion coromandelianum.* © Nilesh R. Thaokar.

and curved up the abdominal tip. It reset the grip of the fore and hind legs and raised the head and thorax. This movement continued interspaced with long intervals of motionless rest. It flexed the legs to elevate the anterior region of the body. At 14.03h, a split appeared along the cuticle of the dorsal region of thorax. This concluded Stage-I of moulting which took 68 minutes.

Stage- II: Within two minutes the head and thorax just elevated from the split exuvia without wriggling, leaving the exuvia on the leaf. The legs were straight sticking along the dorsal side of the body. At 14.07h, half the abdomen along with the head and thorax was outside the exuvia. The legs started flexing slowly. Initially only the forelegs exhibited movement but by 14.09h all the legs started moving and pawing the air without touching the substrate (leaf). The body of the pharate was still supported by the trapped abdomen. The thorax and abdomen formed an angle of 90 degree. The tiny compact wings lay parallel to the abdomen. The pharate now started making feeble movement of the legs trying to grip the leaf surface. As soon as it found a suitable grip for all the legs, the pharate smoothly extracted the remaining part of the abdomen from the exuvia without wriggling. It was 14.14h and the end of Stage-II. This stage took only 11 minutes.

Stage- III: The fore and mid legs of the pharate rested on the leaf while the hind legs now rested on the exuvia. It swayed the body forward and straightened the curved abdomen and swayed back to the original position without moving the legs. Slowly, the telescoped abdomen started expanding. Concomitantly, the wings also started stretching and by 14.42h, the wings were completely stretched but opaque white in colour and still stuck to each other. The pharate was motionless just re-adjusting the legs and re-gripping the leaf at regular intervals. The abdomen continued to expand and by 15.08h it was completely stretched and stiff. While the abdomen was expanding the pharate cleared the gut by forcefully expelling water (23 times) from the rectum at regular intervals. But for the eyes and a slight tinge of green on the thorax, the pharate was un-pigmented (at this stage, pink inter-segmental bands are observed in females which dissipate within a few minutes). Pigmentation of the body took place simultaneously all over the surface along with transparency of the wings and by 15.27h the freshly emerged imago became flight worthy. The imago now exhibited its characteristic species specific color patterning on the adult body. Stage-III took 74 minutes.

A comparative account of 11 complete metamorphoses on site and in the laboratory shows that on an average, the duration of Stage-I is 31.5 minutes (29.35%), Stage-II is 14 minutes (13.04%), and Stage-III is 61.83 (57.61%) in the laboratory. While on the site the average duration of

Table 2. ***Ceriagrion coromandelianum:*** **Number of emergence at different period of the day.**

	Date	Morning	Afternoon	Evening	Total
1	22.i.2011	0	0	0	0
2	23.i.2011	0	2	0	2
3	24.i.2011	0	1	0	1
4	25.i.2011	0	3	0	3
5	26.i.2011	0	1	0	1
6	27.i.2011	1	3	0	4
7	28.i.2011	0	0	0	0
8	29-.i.2011	0	1	0	1
9	30.i.2011	2	3	0	5
10	31.i.2011	0	1	0	1
11	01.ii.2011	0	1	0	1
12	02.ii.2011	0	0	0	0
13	03.ii.2011	2	2	0	4
14	04.ii.2011	0	0	0	0
15	05.ii.2011	1	2	1	4
16	06.ii.2011	2	4	1	7
17	07.ii.2011	0	2	0	2
18	08.ii.2011	0	2	0	2
19	09.ii.2011	1	2	0	3
20	10.ii.2011	0	2	0	2
21	11.ii.2011	1	1	0	2
22	12.ii.2011	1	2	1	4
23	13.ii.2011	3	11	2	16
24	14.ii.2011	6	13	3	22
25	15.ii.2011	2	6	1	9

	Date	Morning	Afternoon	Evening	Total
26	16.ii.2011	1	4	0	5
27	17.ii.2011	1	3	1	5
28	18.ii.2011	2	5	0	7
29	19.ii.2011	3	3	0	6
30	20.ii.2011	4	11	3	18
31	21.ii.2011	4	8	1	13
32	22.ii.2011	5	7	1	13
33	23.ii.2011	1	8	0	9
34	24.ii.2011	3	5	0	8
35	25.ii.2011	3	4	1	8
36	26.ii.2011	0	0	0	0
37	27.ii.2011	2	5	0	7
38	28.ii.2011	2	3	0	5
39	01.iii.2011	2	4	1	7
40	02.iii.2011	0	0	0	0
41	03.iii.2011	0	0	0	0
42	04.iii.2011	0	4	0	4
43	05.iii.2011	1	6	0	7
44	06.iii.2011	1	5	0	6
45	07.iii.2011	0	3	0	3
46	08.iii.2011	0	3	0	3
47	09.iii.2011	1	8	1	10
48	10.iii.2011	0	1	0	1
49	11.iii.2011	0	0	0	0
50	12.iii.2011	0	0	0	0
	Total	**58**	**165**	**18**	**241**

Stage-I is 348 minutes (333.80%), Stage-II is 15 minutes (10.50 %), and in Stage-III it is 79.2 minutes (55.70%). Further, the average time to complete emergence is much higher on site (142.5 minutes) as compared to in the laboratory (107.33 minutes) (Tables 3, 4).

The mortality rate recorded during emergence was 8.2% (N= 20). Failure to moult (15%, Stage-I) and the failure to emerge out of the exuvia (85%, Stage-II) were the two reasons of mortality. During Stage-II, if the pharate is unable to extract the abdomen and wings from the exuvia within the optimal period, it results into a deformed imago (which may step out of the exuvia) with twisted, telescoped abdomen and crumpled, deformed wings ultimately leading to the death of the individual (Images 10–13).

Case of an unsuccessful emergence

On 18 February 2011, one larva was found out of water, preparing for the final emergence. By 12.48h a split was observed on the thorax and slowly the pharate extracted the head and thorax from the exuvia. Half the way it stopped and after a gap of three minutes it again started pulling itself out of the exuvia. At 12.58h, the wing buds along with the cuticle of the exuvia partly separated from the main body of the exuvia. The pharate struggled to pull out the wings from the exuvia wing bud case but with little success. Soon the body of the phatrate was completely out of the exuvia along with a major portion of the wings but the wing tips were still trapped. At 13.10h the part of the wings outside the exuvia started stretching and spreading and soon turned transparent, but the pharate could not release the trapped wing tips. By 14.13h although the complete body stretched but the wings lay trapped in the cuticle resulting in an adult with deformed wings (Images 14–19).

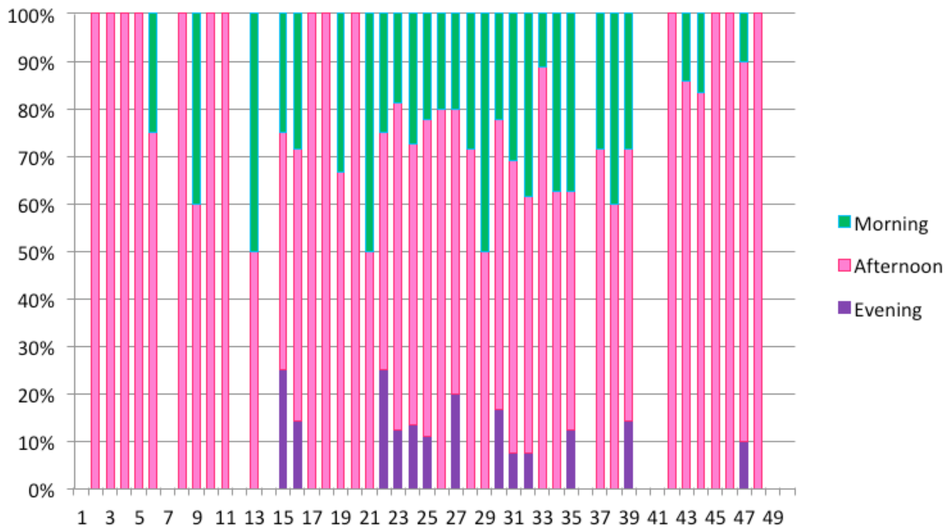


Figure 2a. Emergence of *Ceriagrion coromandelianum* at different periods of the day during the 50-day study at Nagpur, India.

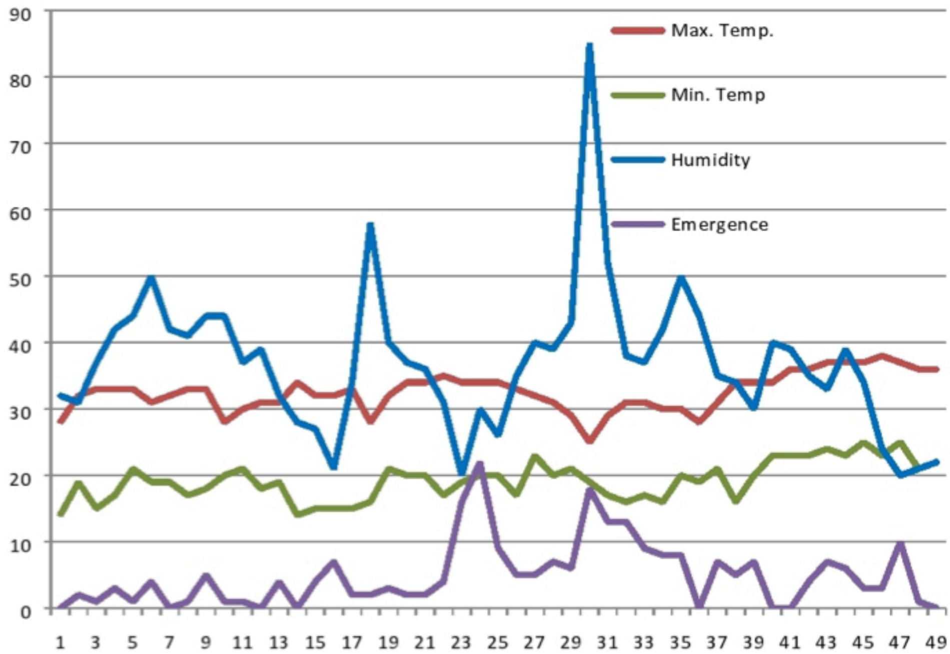


Figure 2b. Graphical representation of the daily weather (minimum temperature, maximum temperature, and humidity (at noon)) and emergence during the 50-day study at Nagpur, India.

DISCUSSION

There are two basic type of postures during emergence, the upright type where the larva completes its moulting at 0° between body and exuvia as found in most Coenagrionidae, Gomphidae, Lestidae, Petaluridae, and the hanging type found in Aeshnidae, Calopterygidae, Corduliidae, and Libellulidae where the larva completes its moulting at an angle which ranges from 90 to 130 degrees and therefore it becomes necessary for the hanging type to climb on a vertical support substrate (Inoue 1964; Trottier 1966). Although horizontal emergence is common in Zygoptera and Gomphidae, inverted emergence occurs in the zygopteran *Xanthocnemis sinclairi* and some *Ischnura* spp. (Row 1987; Corbet 1999). Libellulidae mostly moult in a vertical position (Andrew 2010, 2012; Andrew & Patankar 2010). When the angle of emergence is manipulated, the larva tries

Table 3. *Ceriagrion coromandelianum*—duration and average timing (in minutes) of the three stages of the final emergence recorded in the laboratory.

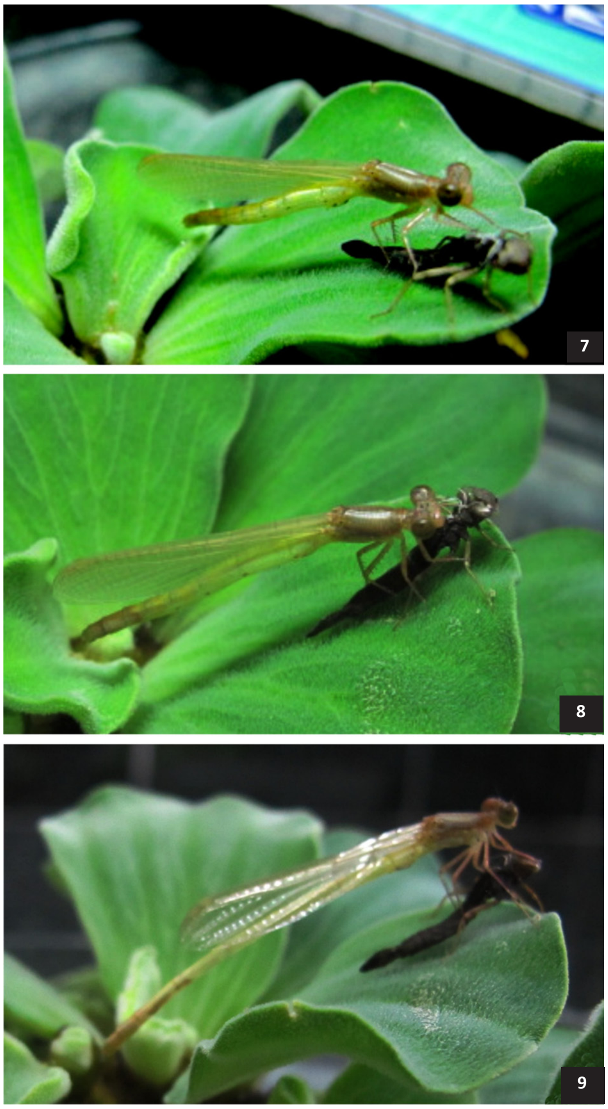
Time (h)	Stage I	Stage II	Stage III	Total
12.37–14.45	36	14	78	128
13.23–14.56	30	15	48	93
14.14–14.44	20	8	62	90
14.16–16.21	41	14	80	135
14.46–16.24	20	18	50	88
14.28–16.18	42	15	53	110
Total	**189** (29.35%)	**84** (13.04%)	**371** (57.61%)	**644**
Average	**31.5**	**14**	**61.83**	**107.33**

Table 4. *Ceriagrion coromandelianum*—duration and average timing (in minutes) of the three stages of the final emergence recorded on site.

Time (h)	Stage I	Stage II	Stage III	Total
12.43–15.08	65	10	70	145
12.56–15.06	47	11	72	130
13.06–15.47	46	13	102	161
14.10–16.30	35	25	80	140
14.23–16.38	47	16	72	135
Total	**240** (33.80%)	**75** (10.50%)	**396** (55.70%)	**711**
Average	**48**	**15**	**79.2**	**142.5**

to regain its original positioning by readjusting its body (*Calopteryx*, Heymer 1972) or by darting towards a vertical substrate (*P. flavescens*, Andrew & Patankar 2010). *C. coromandelianum* appears to be an opportunistic species and can moult in both horizontal as well as vertical position. In *C. coromandelianum,* the spreading of the wings is uniform as found in most libellulids but in most horizontal emergence the spreading starts from the base upwards (Eda 1963). Further in the hanging type of emergence, gravitational force plays an important role in setting the angle of the spreading wings with respect to the linear position of the body (Andrew & Patankar 2010), but in *C. coromandelianum* gravity does not have any influence as it exhibits both vertical and horizontal emergence. In *P. flavescens*, the pigmentation of the body starts from the thorax and terminal end of the abdomen (Andrew & Patankar 2010) but in *C. coromandelianum* pigmentation of the body takes place all over the surface, simultaneously.

Variation in the number of emergences during morning, afternoon and evening indicate that photoperiod and temperature have a direct bearing on the initiation of emergence in *C. coromandelianum.* Purse & Thompson (2003) reported that emergence in the damselfly *Coenagrion mercuriale* was positively correlated to the duration of sunlight of the previous day. Positive correlation was found between sunlight and daily emergence in *Lestes eurinus* (Lutz 1968). In *C. coromandelianum* too, maximum emergence is noticed during the afternoon period indicating a link between intensity of sunlight on emergence, but no statistically significant relationship could be established between daily temperature and humidity. Farkas et al. (2012) reported that in gomphid dragonflies, inter year variations found during emergence is due to annual fluctuation in the water temperature which may influence onset



7

8

9

Images 7–9. Stage III of the final emergence of *Ceriagrion coromandelianum.* © Nilesh R. Thaokar

Images 10–13. Incomplete metamorphosis during final emergence of *Ceriagrion coromandelianum.* Imago with twisted and telescoped abdomen and crumpled, warped wings (arrows). © Nilesh R. Thaokar

Images 14–19. Unsuccessful emergence of *Ceriagrion coromandelianum* caused by wings trapped in the wing bud case of the exuvia. © Nilesh R. Thaokar

and synchrony of emergence. A comparative account of the time lag between the three stages of emergence between the anisopteran *P. flavescens* and zygopteran *C. coromandelianum* indicates that the major time of emergence is consumed in Stage-III for the stretching and spreading of the body and wings in both the groups.

Mortality during emergence is classified into three observable events: failure to moult, failure to expand & harden the wings, and predation. The first two are caused by factors such as low temperature, rain, wind, low oxygen level, lack of suitable emergence support and overcrowding (Corbet 1999). Lack of mass emergence results in little competition for support and eliminates overcrowding as a cause of mortality in *Onychogomphus uncatus* and *Orthetrum coerulescens* (Jakob & Suhlingg 1999) and a similar situation is also found in the observation. In the northern range margins of Britain, Purse & Thompson (2003) reported a low mortality rate of 4.9% including deformed individuals during the emergence of the damselfly *Coenagrion mercuriale.* In the damselfly *Pyrrhosoma nymphula* in Yorkshire, England the mortality during emergence ranged 3–5% and was mainly due to incomplete ecdysis, failure to expand wings and predation by spiders (Bennett & Mill 1993). In southern India, Mathavan & Pandian (1977) reported that the mortality rate of most libellulid dragonflies varied between 8% and 14% during emergence, whereas in central India the mortality rate of *P. flavescens* was 10.93% (Andrew 2010). In the Indian subcontinent predation rate is very less, and ranges from zero to 0.78% (Mathavan & Pandian 1977; Andrew 2010, 2012). Failure to moult at Stage-I indicates that there may be some endogenous (genetic) factors or injuries or dehydration which can be responsible for mortality at this stage, whereas failure to emerge out of the exuvia occurs in Stage-II and could be caused by loss of energy during moulting or difficulty in removing the trapped abdomen or wings from the exuvia (Jakob & Suhling 1999; Andrew & Patankar 2010). Strong winds are a major cause of mortality in Stage-III (Corbet 1999). In *P. flavescens*, 56% of the total mortality was found in Stage-III at an open drain in central India (Andrew 2010). In this study, we did not observe a single case of mortality at Stage-III probably because the site is well sheltered against strong winds by the surrounding building of the institution. In the present study, predation was not observed probably due to a lack of major predators at the semi controlled study site. Further, it couldn't be ignored that mortality will be more in natural habitats in and around areas where nesting density of predatory birds is high or where the pharate is more exposed to extreme physical factors (Corbet 1999). Jakob & Suhling (1999) found that the predatory rate during moulting in odonates is mostly less than one in most natural conditions. Nevertheless, we (Thaokar et al. 2018a,b) earlier reported that *C. coromandelianum* displays a refined hierarchy of preferences for oviposition and chooses floating leaves of *Nymphaea nouchali* over *Lemna paucicostata* and submerged *Hydrilla verticillata* but with the addition of *Pistia stratiotes* at the site, *C. coromandelianum* prefers *P. stratiotes* over *N. nouchali* for oviposition.

REFERENCES

Andrew, R.J. (2010). Mortality during emergence of *Pantala flaves*cens Fabricius in central India (Anisoptera: Libellulidae). *Odonatologica* 39: 57–62.

Andrew, R.J. (2012). Field notes on emergence of *Pantala flaves*cens (Fabricius) in central India (Anisoptera: Libellulidae). *Odonatologica* 41: 89–98.

Andrew, R.J. & N. Patankar (2010). The process of moulting during final emergence of the dragonfly *Pantala flavescens* (Fabricius). *Odonatologica* 39: 141–148.

Andrew, R.J., K.A. Subramanian & A.D. Tiple (2008). *A Handbook of Common Odonates of Central India.* Pub. S. Asian Council of Odonatology, India for 18th International Symposium of Odonatology Nagpur, India.

Andrew, R.J., N. Thaokar & A.A. Dhamani (2011a). Oviposition and details of egg shell fine structure in *Ceriagrion coromandelianum* (Fabricius) (Zygoptera: Coenagrionidae). *Odonatologica* 40: 169–178.

Andrew, R.J., N. Thaokar & A.A. Dhamani (2011b). Sentinel position of the male during oviposition in the damselfly *Ceriagrion coromandelianum* (Fabricius) (Insecta: Odonata). *Hexapoda* 18: 24–32.

Arai, Y. (1987). Dragonfly nymphs feigning death. *Insectarium* Tokyo 24: 358–361.

Banks, M.J. & D.J. Thompson (1985). Emergence, longevity and breeding area fidelity in *Coenagrion puella* (L.) (Zygoptera: Coenagrionidae). *Odonatologica* 14: 279–286.

Bennett, S. & P.J. Mill (1993). Larval development and emergence in *Pyrrhosoma nymphula* (Sulzer) (Zygoptera: Coenagrionidae). *Odonatologica* 22: 133–145.

Corbet, P.S. (1957). The life history of the emperor dragonfly, *Anax imperator* Leach (Odonata: Aeshnidae). *Journal of Animal Ecology* 26: 1–69.

Corbet, P.S. (1999). *Dragonflies- Behaviour and ecology of Odonata*. Harley, Colchester.

Eda, S. (1963). Emergence of *Epiophlebia superstes* Selys. *Tombo* 6: 2–7.

Farkas, A., T. Jakab, A. Tóth. & A. F. Kalmár (2012). Emergence patterns of riverine dragonflies (Odonata: Gomphidae) in Hungary: Variation between habitats and years. *Aquatic insects* 34: 1–13. https://doi.org/10.1080/01650424.2012.643030

Gribbin, S.D. & D.J. Thompson (1990). A quantitative study of mortality at emergence in the damselfly *Pyrrhosoma nymphula* (Sulzer) (Zygoptera: Coenagrionidae). *Freshwater Biology* 24: 295–302. https://doi.org/10.1111/j.1365-2427.1990.tb00710.x

Gribbin, S.D. & D.J. Thompson (1991). Emergence of the damselfly *Pyrrhosoma nymphula* (Sulzer) (Zygoptera: Coenagrionidae) from two adjacent ponds in northern England. *Hydrobiologia* 209: 123–131. https://doi.org/10.1007/BF00006924

Haslam, C. (2004). Chronological patterns of emergence of dragonflies in Carver Pond, Bridgewater, MA. *Bridgewater State University., Undergraduate Review* 1: 62–72. Available at http://vc.bridgew.edu/undergrad_rev/vol1/iss1/15

Inoue, K. (1964). On the type of emergence behavior of dragonflies. *International Journal of Kansai Shizenkagaku* 16: 19–23.

Inoue, K. (1979). Review of Japanese Dragonflies part 6 (Concluded). Families Coenagriondae, Platycnmididae, Lestidae and Megapodagrionidae. *Journal of Gracile* 24: 1–20.

Jakob, C. & F. Suhling (1999). Risky times? Mortality during emergence in two species of dragonflies (Odonata: Gomphidae, Libellulidae). *Aquatic Insects* 21: 1–10. https://doi.org/10.1076/aqin.21.1.1.4537.

Kumar, A. (1980). Studies on the life history of Indian dragonflies, *Ceriagrion coromandelianum* (Fabrcius) (Coenagrionidae: Odonata). *Records of the Zoological Survey of India* 76: 249–258.

Kurata, M. (1974). Alpine dragonflies: a survey and an account of a pursuit of *Aeshna juncea*. *Seibundo-shinkosha,*Tokyo.

Lutz, P.E. (1968). Life history studies on *Lestes eurinus* Say (Odonata). *Ecology* 49: 576–579.

Heymer, A. (1972). Comportements social et territorial des Calopterygidae (Odon. Zygoptera). *Annales de la Société entomologique de France* (N.S.) 8: 3–53.

Mathavan, S. & T.J. Pandian (1977). Patterns of emergence, import of egg energy export via emerging dragonfly populations in a tropical pond. *Hydrobiologia* 56: 257–272. https://doi.org/10.1007/BF00014293

Miller, P.L. (1995). *Dragonflies*. Richmond, Slough.

Pajunen, V.I. (1962). Studies on the population ecology of *Leucorrhinia dubia*. V. d. Lind. (Odonata: Libellulidae). *Annales Zoologici Societatis Zoologicae-Botanicae Fennicae 'Vanamo'* 24: 1–7.

Purse, B.V. & D.J. Thompson (2003). Emergence of the damselflies, *Coenagrion mercuriale* and *Ceriagrion tenellum* (Odonata: Coenagrionidae), at their northern range margins in Britain. *European Journal of Entomology* 100: 93–99. https://doi.org/10.14411/eje.2003.018

Rowe, R.J. (1987). *The Dragonflies of New Zealand*, Auckland University Press, Auckland.

Sharma, G. (2009). Life history and reproductive behaviour of *Ceriagrion coromandelianum* (Fabricius) (Odonata: Insecta). *Annals of Forestry* 17: 298–310.

Thaokar, N.T., P.R. Verma & R.J. Andrew (2018a). Breeding behaviour of the Coromandel Marsh Dart Damselfly (Zygoptera: Coenagrionidae: *Ceriagrion coromandelianum* (Fabricius) in central India. *Journal of Threatened Taxa* 10: 11443–11449. http://doi.org/10.11609/jott.3537.10.3.11443-11449

Thaokar, N.T., P.R. Verma & R.J Andrew. (2018b). Breeding behaviour of the damselfly *Ceriagrion coromandelianum* (Fabricius) (Zygoptera: Coenagrionidae) in central India: I. Copulation. *Journal of Threatened Taxa* 10: 12203–12209. http://doi.org/10.11609/jott.3529.10.9.12203-12209

Thompson, D.J. (1991). Size-biased dispersal prior to breeding in a damselfly: conflicting evidence from a natural population. *Oecologica* 87: 600–601. https://doi.org/10.1007/BF00320427

Thompson, D.J., M.J.Banks, S.E. Cowley & J. Pickup (1985). Horses as a major cause of mortality in *Coenagrion puella* (L.) (Zygoptera: Coenagrionidae) *Notulae Odonatologicae* 2: 104–105.

Tillyard, R.J. (1917). *The Biology of Dragonflies*. Cambridge University Press, Cambridge.

Trottier, R. (1966). The emergence and sex ratio of *Anax junius* Drury (Odonata: Aeshnidae) in Canada. *The Canadian Entomologist* 98: 794–798. https://doi.org/10.4039/Ent98794-8

Ubukata, H. (1981). Survivorship curve and annual fluctuation in the size of emerging population of *Cordulia aenea amurensis* Selys (Odonata: Corduliidae). *Japanese Journal of Ecology* 31: 335–346.

Journal of Threatened Taxa

www.threatenedtaxa.org

PLATINUM OPEN ACCESS

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

October 2019 | Vol. 11 | No. 13 | Pages: 14631–14786
Date of Publication: 26 October 2019 (Online & Print)
DOI: 10.11609/jott.2019.11.13.14631-14786

Communications

Camera trap survey of mammals in Cleopatra's Needle Critical Habitat in Puerto Princesa City, Palawan, Philippines
– Paris N. Marler, Solomon Calago, Mélanie Ragon & Lyca Sandrea G. Castro, Pp. 14631–14642

Habitat suitability modeling of Asian Elephant *Elephas maximus* (Mammalia: Proboscidea: Elephantidae) in Parsa National Park, Nepal and its buffer zone
– Puja Sharma, Hari Adhikari, Shankar Tripathi, Ashok Kumar Ram & Rajeev Bhattarai, Pp. 14643–14654

Current population status of the endangered Hog Deer *Axis porcinus* (Mammalia: Cetartiodactyla: Cervidae) in the Terai grasslands: a study following political unrest in Manas National Park, India
– Alolika Sinha, Bibhuti Prasad Lahkar & Syed Ainul Hussain, Pp. 14655–14662

A food spectrum analysis of three bufonid species (Anura: Bufonidae) from Uttarakhand region of the western Himalaya, India
– Vivekanand Bahuguna, Ashish Kumar Chowdhary, Shurveer Singh, Gaurav Bhatt, Siddhant Bhardwaj, Nikita Lohani & Satyanand Bahuguna, Pp. 14663–14671

Moulting pattern and mortality during the final emergence of the Coromandel Marsh Dart Damselfly *Ceriagrion coromandelianum* (Zygoptera: Coenagrionidae) in central India
– Nilesh R. Thaokar, Payal R. Verma & Raymond J. Andrew, Pp. 14672–14680

Diversity of parasitic Hymenoptera in three rice-growing tracts of Tamil Nadu, India
– Johnson Alfred Daniel & Kunchithapatham Ramaraju, Pp. 14681–14690

Mapping octocoral (Anthozoa: Octocorallia) research in Asia, with particular reference to the Indian subcontinent: trends, challenges, and opportunities
– Ghosh Ramvilas, Kannan Shalu, Rajeev Raghavan & Kutty Ranjeet, Pp. 14691–14721

SEM study of planktonic chlorophytes from the aquatic habitat of the Indian Sundarbans and their conservation status
– Gour Gopal Satpati & Ruma Pal, Pp. 14722–14744

Is cultivation of *Saussurea costus* (Asterales: Asteraceae) sustaining its conservation?
– Chandra Prakash Kuniyal, Joel Thomas Heinen, Bir Singh Negi & Jagdish Chandra Kaim, Pp. 14745–14752

Short Communications

A first photographic record of a Yellow-bellied Weasel *Mustela kathiah* Hodgson, 1835 (Mammalia: Carnivora: Mustelidae) from western Nepal
– Badri Baral, Anju Pokharel, Dipak Raj Basnet, Ganesh Bahadur Magar & Karan Bahadur Shah, Pp. 14753–14756

Mammal diversity in a montane forest in central Bhutan
– Tashi Dhendup, Kinga Thinley & Ugyen Tenzin, Pp. 14757–14763

Notes

First record of Otter Civet *Cynogale bennettii* (Mammalia: Carnivora: Viverridae) kept as a pet in Indonesia, representing a possible new threat to the species
– Jamie Francis Bernard Bouhuys, Pp. 14764–14766

An observation of the White-bellied Sea Eagle *Haliaeetus leucogaster* preying on Saltwater Crocodile hatchlings *Crocodylus porosus* in Bhitarkanika Wildlife Sanctuary, India
– Nimain Charan Palei, Bhakta Padarbinda Rath & Bimal Prasanna Acharya, Pp. 14767–14769

Elusive, rare and soft: a new site record of Leith's Softshell Turtle *Nilssonia leithii* (Reptilia: Testudines: Trionychidae) from Bhadra Tiger Reserve, Karnataka, India
– H.S. Sathya Chandra Sagar, M. Mrunmayee, I.N. Chethan, Manish Kumar & D.V. Girish, Pp. 14770–14772

A new distribution record of the Pentagonal Sea Urchin Crab *Echinoecus pentagonus* (A. Milne-Edwards, 1879) (Decapoda: Brachyura: Pilumnidae) from the Andaman Islands, India
– Balakrishna Meher & Ganesh Thiruchitrambalam, Pp. 14773–14776

First records of the ghost moth genus *Palpifer* Hampson, [1893] (Lepidoptera: Hepialidae) from the Indian subcontinent south of the Himalaya
– Siyad A. Karim & John R. Grehan, Pp. 14777–14779

First record of longhorn beetle *Calothyrza margaritifera* (Cerambycidae: Lamiinae: Phrynetini) from western India
– Vishwas Deshpande & Hemant V. Ghate, Pp. 14780–14783

Extended distribution of *Ceropegia mahabalei* Hemadri & Ansari (Apocynaceae) to the state of Gujarat, India
– Mukta Rajaram Bhamare, Hemantkumar Atmaram Thakur & Sharad Suresh Kambale, Pp. 14784–14786

Publisher & Host

WILD
ZOOREACH
Threatened Taxa

Partner

صندوق محمد بن زايد
للمحافظة على
الكائنات الحية
The Mohamed bin Zayed
SPECIES CONSERVATION FUND

Member

FJN