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Cover: Ponmudi Bush Frog *Raorchestes ponmudi* before emerging from its egg. © Abhijith, A.V.

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COMMUNICATION

Mammalian fauna in an urban influenced zone of Chandaka-Dampara Wildlife Sanctuary in Odisha, India

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Abstract: A camera trapping survey to estimate the species richness and relative abundance of different mammalian fauna and various anthropogenic activities was carried out for four months within an urban influenced zone of Chandaka-Dampara Wildlife Sanctuary, Odisha. The survey extended over 120 days in January–April 2019 over 10% of the total sanctuary area. With nine cameras and a total effort of 771 trap days, 2,855 independent photographs including 14 species of wild mammals and birds, human traffic, and movement of stray animals were captured. Among the mammalian fauna, Golden Jackal was the most photographed species whereas the Asian Elephant, Striped Hyaena, and Common Palm Civet were the least photographed species. Various anthropogenic activities like intensive movement of departmental vehicles, staff, feral livestock, and stray dogs and cats were also recorded and these activities need to be addressed in management activities for long term conservation of the area and its mammalian fauna. In order to enhance biological connectivity and improve movement of wildlife between the main part of the Chandaka Sanctuary and its near-detached reserved forests in Jagannathprasad-Bharatpur, the study recommends removal of feral cattle, extensive plantations, and construction of a fly-over for vehicular traffic.

Keywords: Bhubaneswar, camera trap survey, eastern India, Odisha, relative abundance, urbanization.

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INTRODUCTION

Information on the presence and distribution of species within a region is important for planning and evaluating conservation strategies (Tobler et al. 2008) and it is particularly vital if the area is experiencing threats from adjoining urban development. Globally around half of the human population are currently living in urban areas and it is predicted that it may cross 70% by the year 2050 (United Nations 2011, 2012). So, the increasing pressure for urban development will lead to continued urban expansion resulting in loss, degradation, fragmentation and isolation of the remnant natural habitats (Biamonte et al. 2011). This changing environmental condition affects biodiversity at local, landscape and regional scales (Jokimaki & Kaisanlahti-Jokimaki 2003; Wilby & Perry 2006).

The Chandaka-Dampara Wildlife Sanctuary (CDWS) covering an area of 193.39km² is situated in Khurda District adjoining Bhubaneswar, the capital city of Odisha, eastern India. The sanctuary exists in two different parts; the major part contains an area of 172.12km² while the other part, Bharatpur-Jagannathprasad sector is 19.27km² (Image 1). Out of the 19 wildlife sanctuaries in Odisha CDWS experiences severe biotic interference out of the growth and development of Bhubaneswar City. For the last six decades, Bhubaneswar has expanded many times from just 26.09km² in 1951 to 422km² in 2011 (Routray et al. 1996; Naik 2013). In fact, expansion of the northern region of the city has resulted in fragmentation and isolation in the sanctuary. The Bharatpur and Jagannathprasad reserve forests of CDWS have already been isolated from the sanctuary and surrounded by human habitations of Bhubaneswar City. Therefore, it can be predicted that the negative effect of urban growth might have resulted in the local extinction or population depletion of many species particularly the mammalian fauna in this fragmented habitat. Unfortunately, there is sporadic information on the status of different mammalian fauna in this urban influenced zone of CDWS. Therefore, documenting the status of different mammalian fauna and various ongoing anthropogenic activities is important to assist subsequent conservation interventions.

In this study, we carried out a camera trapping survey within the urban influenced and isolated zone of CDWS with the objectives of: (a) documentation of the mammalian species richness, (b) estimation of their relative abundance based on photo-capture rate, and (c) monitoring of various anthropogenic activities. The results obtained from the study can be used as baseline data in future inventories to ascertain the change over time and develop appropriate conservation interventions.

MATERIAL AND METHOD

Study Area

The Bharatpur and Jagannathprasad forest sector of CDWS, Odisha (Image 1) lies between 20.286–20.360 ^{0}N & 85.756–85.810 ^{0}E. This sector covers an area of 19.27km² (Bharatpur 11.88km² and Jagannathprasad 7.39km²) that represents around 10% of the total area of the sanctuary. The climate of the area is tropical and the three distinct seasons—summer (March–June), monsoon (July–October) and winter (November–February)—are experienced here. The annual mean temperature of the area varies between 12°C during January to 42°C during May with an average annual rainfall of 1,542mm. Vegetation of the area is an admixture of mixed deciduous, semi-evergreen and bamboo brakes and the major portion of the area is covered with bushy and shrubby vegetation. As the area is situated adjoining Bhubaneswar City, a major portion of the boundary line is covered with stone wall concertina fencing to check human interference and straying of wild animals. Although currently, there is no human habitation and human activities within the area, it is experiencing severe biotic pressure from the growth and development of Bhubaneswar City.

Data collection and analysis

The study was carried out for four months (1 January–30 April 2019) by using nine automatically triggered camera traps (Cuddeback and Moultrie, USA). The area was first divided into square shaped 1km² grids on map (Image 1) followed by installation of one camera trap in each grid for a minimum of 25 days. Because of limitations from the number of camera traps we could only sample nine grids at a time. Cameras were strapped on to trees approximately 50cm above ground along the motorable roads and forest paths by aiming the censor parallel to the ground. Cameras were set to operate 24 hours-a-day and programmed to take two consecutive photos registering date and time for each exposure with 30 seconds delay for the next exposure. Cameras were checked once a week for photo download and battery replacement. For each station, the date and time of installation and retrieval of each camera trap was recorded to calculate the total number of trap days (Each trap day = 24 hours).

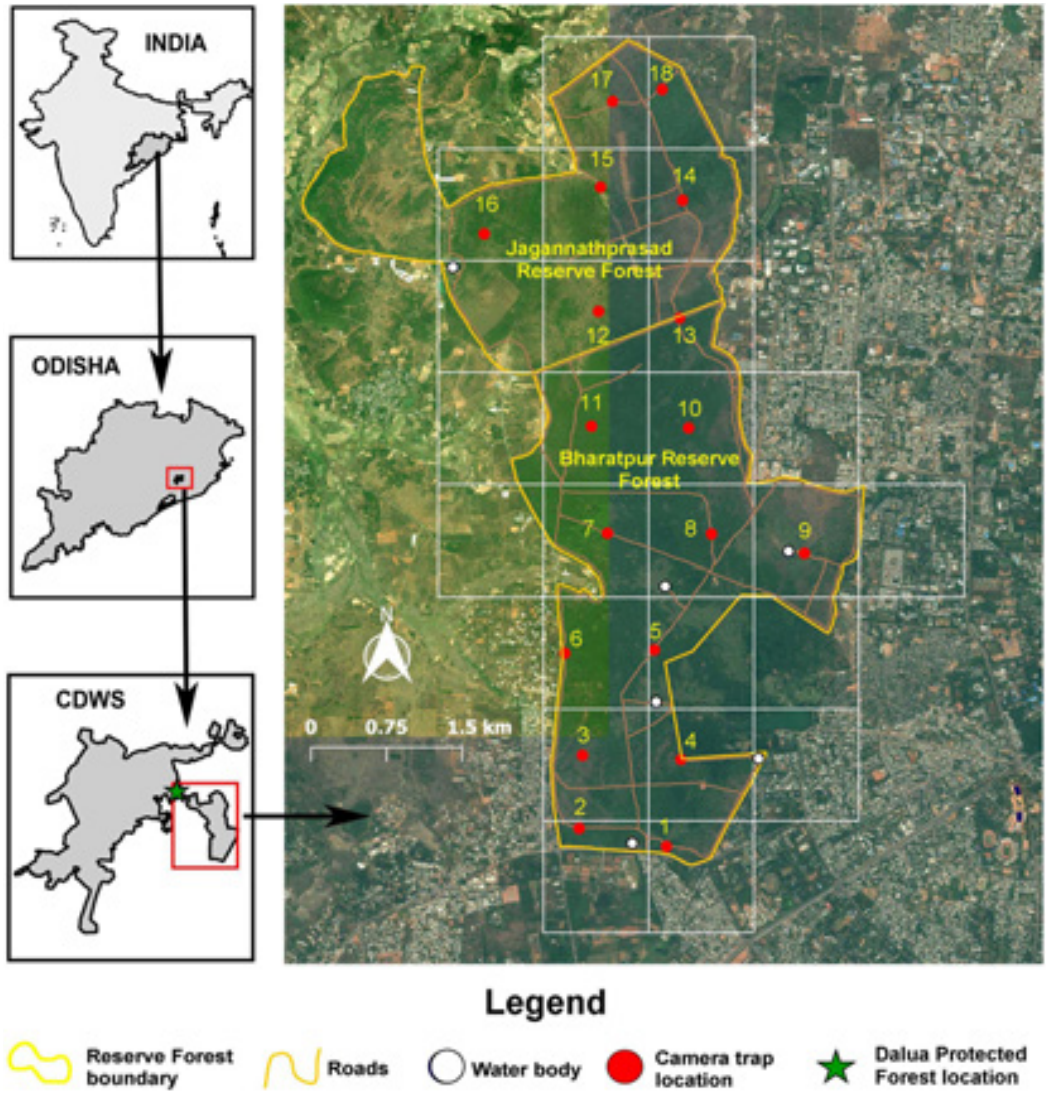

Image 1. Chandaka-Dampara Wildlife Sanctuary (CDWS) showing the study area and camera trap locations.

After retrieving the camera traps, all the photographs were carefully observed and grouped as wild animals, domestic animals and human traffic. Wild animals were identified up to species level following Menon (2014). Each photo was rated as an independent capture, if the time between consecutive photographs of the same subject was more than 30 minutes apart at a particular location (O'Brien et al. 2003). Photos with multiple individuals of the same species in the frame were also counted as single detection for that species. Based on the principles given by Jenks et al. (2011), the relative abundance index (RAI) of each species/ activity was calculated as

$RAI = A/N \times 100$

Where 'A' is the total number of detections of a species/ activity by all cameras and 'N' is the total number of camera trap days by all the cameras.

To understand the impact of various anthropogenic activities on mammalian species detection rate, we calculated the correlation coefficient (r).

RESULTS

During the study period, the camera trapping effort resulted in 771.31 trap days and captured 2,855 independent photographs of which 53.2% were of wild animals followed by movement of departmental vehicle (23.68%), staff (13.27%), and domestic animals (9.84%).

In all, 14 species of wild mammals were photographed (Table 1; Images 2 to 15) and among them, the Asian Elephant is Endangered and Striped

Table 1. Number of independent photographs and relative abundance index (RAI) of different mammalian species and birds in Bharatpur and Jagannathprasad forest sector of Chandaka-Dampara Wildlife Sanctuary in Odisha, eastern India, January–April 2019.

Family	Species	Common name	IUCN status	Number of photos	RAI (%)	Sno. of cameras where animal species recorded
Mammals						
Elephantidae	*Elephas maximus*	Asian Elephant	Endangered	1	0.13	5
Cervidae	*Axis axis*	Spotted Deer	Least Concern	301	39.02	1–14, 17
Cercopithecidae	*Macaca mulatta*	Rhesus Macaque	Least Concern	36	4.67	1–6, 11
	Semnopithecus entellus	Northern Plains Grey Langur	Least Concern	2	0.26	4
Hystricidae	*Hystrix indica*	Indian Crested Porcupine	Least Concern	52	6.74	1–5, 8, 10, 11, 13
Leporidae	*Lepus nigricollis*	Indian Hare	Least Concern	68	8.82	1, 3, 4, 6–10, 14
Suidae	*Sus scrofa*	Wild Boar	Least Concern	110	14.26	1–15, 17
Felidae	*Felis chaus*	Jungle Cat	Least Concern	60	7.78	1–5, 8, 10, 11, 13, 14, 17
Canidae	*Canis aureus*	Golden Jackal	Least Concern	552	71.57	1–11, 13, 14, 17
Hyaenidae	*Hyaena hyaena*	Striped Hyaena	Near Threatened	1	0.13	5
Viverridae	*Veverricula indica*	Small Indian Civet	Least Concern	60	7.78	1–6, 8, 10, 14, 17
	Paradoxurus hemaphroditus	Common Palm Civet	Least Concern	1	0.13	1
Herpestidae	*Urva edwardsii*	Grey Mongoose	Least Concern	6	0.78	1, 2, 9
Mustelidae	*Mellivora capensis*	Honey Badger	Least Concern	2	0.26	5
Birds						
Phasianidae	*Pavo cristatus*	Indian Peafowl	Least Concern	244	31.61	1–13
	Francolinus pondicerianus	Grey Francolin	Least Concern	13	1.68	3–7
	Galloperdix spadicea	Red Spurfowl	Least Concern	4	0.51	13
	Gallus gallus	Red Junglefowl	Least Concern	6	0.77	1–4, 7–11

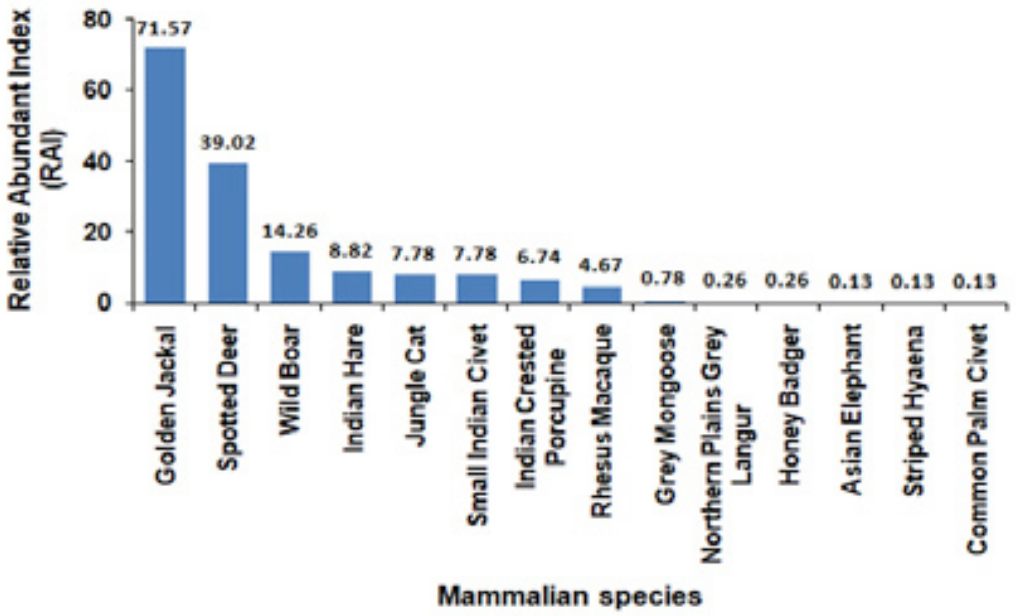

Figure 1. Relative abundance index of mammals in Bharatpur and Jagannathprasad forest sector of Chandaka-Dampara Wildlife Sanctuary, Odisha from January–April 2019.

Hyaena is Near Threatened as per the IUCN Red List of Threatened Species (IUCN 2017). Among the seven species of mammalian herbivores, the Spotted Deer was the highest photographed (RAI = 39.02) and the Asian Elephant was the lowest photographed (RAI = 0.13) species. Similarly, among the carnivorous mammals, the Golden Jackal was the highest photographed (RAI = 71.57) whereas the Striped Hyaena and Common Palm Civet were the lowest photographed (RAI = 0.13 each) species. Overall, the Golden Jackal was the most photographed species whereas Asian Elephant, Striped Hyaena, and Common Palm Civet were the minimally photographed species. The detailed information on the number of independent photographs and RAI of all the mammalian species is given in Table 1. The histogram showing the RAI of different mammalian species is given in Figure 1.

Photographs captured during the study depicting various anthropogenic activities include movement of departmental vehicles, staff, feral livestock, and free ranging dogs and cats. Among these, movement of vehicles was the maximum photographed activity (RAI = 87.64) than movement of staff (RAI = 49.13), stray dogs (RAI = 17.50), feral buffalos (RAI = 15.81), feral cattle (RAI = 2.46), and domestic cat (RAI = 0.65) (Table 2). Among all the sampling grids, the anthropogenic activity was extremely low at the camera trap location in grid number 10 due to no vehicular movement and it might be due to the absence of motorable roads. Detailed information on the number of independent photographs and RAI of all the mammalian species and anthropogenic activities in each sampling grid is given in Table 3. It was observed that the detection rate and RAI of different mammalian species was found to be negatively correlated with level of anthropogenic disturbances ($r = -0.66$, $p < 0.05$).

DISCUSSION

The CDWS is home to 37 species of mammals of which rodents, bats, shrews, and tree-shrews are represented by 14 species (Tiwari et al. 2002). So a comparison of the 14 species of mammals recorded during the present study from Bharatpur and Jagannathprasad forest sector with the rest of the species from the entire sanctuary represents around 61%. Excluding bats, rodents, and shrews, species like Sambar *Rusa unicolor*, Barking Deer *Muntiacus muntjak*, Indian Chevrotain *Moschiola indica*, Leopard *Panthera pardus*, Asiatic Wild Dog *Cuon alpinus*, Bengal Fox *Vulpes bengalensis*, Small Indian Mongoose *Urva auropunctatus*, Sloth Bear *Melursus ursinus*, and Indian Pangolin *Manis crassicaudata* that were earlier reported to occur in CDWS (Tiwari et al. 2002), were not recorded during the present study in Bharatpur and Jagannathprasad forest sector. For non-occurrence of these species, there could be several possible factors. For example, the forest cover of Bharatpur and Jagannathprasad was earlier connected with CDWS, however, with increasing urbanization, development of road network and other anthropogenic activities, it has already been fragmented and isolated. Studies across the world have revealed that fragmentation and isolation of wildlife habitats bring negative effect on abundance and distribution of animal communities (Mullu 2016). It was also observed that the photo-capture rate of various anthropogenic activities accounted for around 47% of all the detections and it was even much higher than Similipal Tiger Reserve (Palei et al. 2015) and Kuldiha Wildlife Sanctuary (Debata & Swain 2018). Furthermore, the presence of domestic animals can have a detrimental effect on the distribution and assemblage of wild animal communities (Palei et al. 2015; Debata & Swain 2018) and movement of feral buffalos, cattle and stray dogs were recorded throughout the study area. Therefore, species like Sambar, Barking Deer, and Indian Chevrotain prefer comparatively large undisturbed forest patches and are highly sensitive to human disturbance and due to livestock pressure might have left the habitat or became locally extinct. Similarly, these factors might be responsible for the absence of Leopard, Asiatic Wild Dog, and Sloth Bear which prefer similar habitat conditions (Srivastava & Singh 2003). Even the current status of these carnivores is uncertain in the entire sanctuary (S. Debata pers. obs. 2020). Other species like the Small Indian Mongoose might have been missed out from the cameras because of small body size. Usually the body size and behavior of individual animals greatly influence the detection probability (Sollmann et al. 2013), however, the photo-capture rate and RAI of Asian Elephant was estimated to be extremely low. It can be inferred that this mega herbivore rarely visit the area during seasonal migration. Although the habitat of the study area is ideal for the Bengal Fox, the presence of the species in the area was not confirmed.

Among all the species, Golden Jackal, Spotted Deer, and Wild Boar were the most frequently photo-captured and widely distributed species compared to others indicating their higher abundance in the study area. These animals are habitat generalists and can tolerate a wide range of anthropogenic disturbances (Prater 2005). Additionally, with the absence of large predators and poaching activities, their population is gradually

Table 2. Number of independent photographs and Relative Abundance Index (RAI) of various anthropogenic activities in Bharatpur and Jagannathprasad forest sector of Chandaka-Dampara Wildlife Sanctuary in Odisha, eastern India, January–April 2019.

Family	Number of photos	RAI (%)	Sno. of cameras where anthropogenic activities were recorded
Vehicles	676	87.64	1–8, 11–14, 17
Human traffic	379	49.13	1–6, 8, 9, 11–15, 17
Feral cattle and buffalos	141	18.28	1–15, 17
Free ranging dogs	135	17.5	1–9, 11, 13, 14, 17
Free ranging cats	5	0.65	3, 14

Table 3. Total number of photographs and relative abundance index (RAI) of different mammalian species and anthropogenic activities in different camera trap locations in Bharatpur and Jagannathprasad forest sector of Chandaka-Dampara Wildlife Sanctuary in Odisha, eastern India, January–April 2019.

Sno. of sampling grids	Total number of		RAI	
	Mammal photographs	Anthropogenic activity photographs	Mammals	Anthropogenic activities
1	154	192	19.97	24.89
2	113	120	14.65	15.56
3	225	54	29.17	7
4	172	147	22.30	19.06
5	204	310	26.45	40.19
6	83	71	10.76	9.21
7	19	17	2.46	2.20
8	68	194	8.82	25.15
9	32	36	4.15	4.67
10	74	2	9.59	0.26
11	36	48	4.67	6.22
12	5	63	0.65	8.17
13	29	16	3.76	2.07
14	31	31	4.02	4.02
15	1	3	0.13	0.39
16	-	-	-	-
17	6	32	0.78	4.15
18	-	-	-	-
Overall	1252	1336		

increasing. Similarly with abundant prey species, particularly the Spotted Deer and no competitor, the Golden Jackal population is thriving well. On the other hand, the increasing Golden Jackal population might be the factor for absence or local extinction of Bengal Fox population as a result of increasing competition for space and food.

Implications for conservation management

Although human disturbances from the peripheral areas in Bharatpur and Jagannathprasad have been completely controlled due to stone wall concertina fencing along the boundary, the area is still experiencing severe biotic pressure from intensive movement of vehicles, feral livestock and stray animals. In the long run if these disturbances continue, it may greatly affect the abundance and composition of the existing mammalian fauna. Therefore, for long term conservation of the area and its wildlife, it is essential that the feral livestock population be removed first. Studies have shown that wild herbivores benefit from the reduction of livestock (Madhusudan 2004). Lethal control and sterilization of stray dogs can be useful in controlling their population. Vehicular movements negatively affect the ranging

Image 2. *Elephas maximus* Asian Elephant; 1 photo from 1 camera, RAI 0.13

Image 4. *Macaca mulatta* Rhesus Macaque; 36 photos from seven cameras, RAI 4.67

Image 3. *Axis axis* Spotted Deer; 301 photos from 15 cameras, RAI 39.02

Image 5. *Semnopithecus entellus* Northern Plains Grey Langur; two photos from one camera, RAI 0.26

behaviour and activity pattern of wild animals (Cole et al. 1997; Samson et al. 2016) and it accounted for 23.65% of the total photo-capture rate in our study area. It should be controlled to a minimum unless required. The forests of Bharatpur and Jagannathprasad area are completely isolated from the sanctuary. To ensure the connectivity of the study area with the sanctuary, the area between Dalua Protected Forest in Chandaka Wildlife Range and Jagannathprasad forest sector in Bhubaneswar Wildlife Range should be considered for extensive plantation activities. Moreover, the road passing through the area may be converted to a flyover to avoid vehicular traffic. These implications may aid movement of wild animals between habitats and thereby ensure biological connectivity.

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Image 6. *Hystrix indica* Indian Crested Porcupine; 52 photos from nine cameras, RAI 6.74

Image 7. *Lepus nigricollis* Indian Hare; 68 photos from nine cameras, RAI 8.82

Image 8. *Sus scrofa* Wild Boar; 110 photos from 16 cameras, RAI 14.26

Image 9. *Felis chaus* Jungle Cat; 60 photos from 11 cameras, RAI 7.78

Image 10. *Canis aureus* Golden Jackal; 552 photos from 14 cameras, RAI 71.57

Image 11. *Hyaena hyaena* Striped Hyaena; one photo from one camera, RAI 0.13

Image 12. *Veverricula indica* Small Indian Civet; 60 photos from 10 cameras, RAI 7.78

Image 13. *Paradoxurus hemaphroditus* Common Palm Civet; one photo from one camera, RAI 0.13

Image 14. *Urva edwardsii* Grey Mongoose; six photos from three cameras, RAI 0.78

Image 15. *Mellivora capensis* Honey Badger; two photos from one camera, RAI 0.26

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COMMUNICATION

Species in peril: assessing the status of the trade in pangolins in Nepal

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Abstract: Pangolins are among the most widely traded taxa in the southeastern Asian illegal wildlife trade because of which they are at great risk of extinction. Yet, little is known of their trade status in Nepal. This research was carried out to unfold the status of pangolin trade in Sankhuwasava District of Nepal. We used mixed methods such as semi-structured questionnaire (n=75) and, focus group discussion (n=4) and key Informant Interview, (n=30) to assess the trade status. Seizure data (2009–2017) were gathered from law enforcement agencies to predict major trade routes. The major threat perceived was hunting especially by unemployed local youth and children. The majority of hunters were opportunistic. Sankhuwasava District has become both source and transit for the illegal pangolin trade rather than for local use. The involvement of non-timber forest product traders was high in the illegal trade business, however, there seems a rapid decline in the seizure of pangolin in the last two years, mainly because of the deployment of the Nepal army in the Makalu Barun National Park, which had long served as a major route to China. Thus, we recommend continuation of strong border security. Our study calls for capacity building of enforcement agencies for detailed investigation of seizure data. For sustainable conservation of pangolin and its habitat we recommend sustained conservation awareness programs in addition to alternative livelihood opportunity. Furthermore, formation of community based anti-poaching units followed by motivation, anti-poaching trainings, security assurance, and incentives for worthy conservation outcomes in pangolin-rich communities might aid in conservation.

Keywords: Chinese Pangolin, illegal hunting, Indian Pangolin, *Manis crassicaudata*, *Manis pentadactyla*, opportunistic hunting, NTFP traders, Sankhuwasava District, transboundary.

सालक दक्षिणपूर्वी एसियामा सबैभन्दा बढी अवैध व्यापार हुने वन्यजन्तु हुन, जसको कारण यिनीहरु लोप हुने प्रवल खतरामा छन । यद्यपि, यिनीहरुको व्यापार बारे नेपालमा निकै कम जानकारी छ । यो अनुसन्धान नेपालको संखुवासभा जिल्लामा सालक व्यापारको अवस्था उजागर गर्न गरिएको हो । हामीले अवैध व्यापार स्थिति आकलन गर्नका लागि मिश्रित विधिहरू प्रयोग गऱ्यौं, जस्तै अर्ध संरचित प्रश्नावली (n = ७५) र समूहगत छलफल (n = ४) । व्यापार नाका अनुमान गर्न जफत गरिएका सालक का विवरण हरु कानुनी निकाय बाट प्राप्त गरियो । सालकको लागि प्रमुख खतरा बेरोजगार स्थानीय युवा र बालबालिकाको प्रयोगबाट गरिएको अवैध सिकार रहेको बुझियो । अधिकांश सिकार अवसरवादी रुपमा गरिएको पाइयो । स्थानिय खपत भन्दा पनि, संखुवासभा जिल्ला गैरकानुनी सालक व्यापारको स्रोत र ट्रान्जिट दुवै भएको छ । अवैध व्यापारको कारोवारमा गैरकाष्ठ वन पैदावार व्यापारीहरूको संलग्नता बढी रहेको थियो । मुख्यतया लामो समय देखि चीन को प्रमुख नाकाको रूपमा रहेको राष्ट्रिय निकुञ्जमा नेपाली सेनाको परिचालनका कारण विगत दुई वर्षमा सालक जफतमा द्रुत गिरावट आएको देखिन्छ । तसर्थ हामी सीमा सुरक्षालाई अझ निरन्तरता दिन सिफारिस गर्दछौं । हाम्रो अध्ययनले जफत गरि दायर गरिएको मुद्दाको विस्तृत अनुसन्धानका लागि कानुनी निकायहरुको क्षमता विकासको लागि आह्वान गर्दछ । हामी सालक र यसको वासस्थानको दिगो संरक्षणको लागि, वैकल्पिक जीवनयापनका अवसरको साथसाथै दिगो संरक्षण जागरूकता कार्यक्रमहरूको पनि सिफारिस गर्दछौं । यसबाहेक, समुदायमा आधारित चोरी शिकारी नियन्त्रण तथा युवा परिचालन समूहको गठनका साथसाथै संरक्षण लगाव, सिकार रोक्न प्रशिक्षण, सुरक्षा आश्वासन, र प्रोत्साहन जस्ता कार्यक्रमले संरक्षण गर्न सहयोग गर्न सक्छन् ।

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INTRODUCTION

Illegal wildlife trade is one of the most crucial threats to biodiversity conservation (Nijman & Shepherd 2011; Esmail et al. 2019). Along with increased threats to biodiversity conservation, illegal wildlife trade also impacts the security of the community and their livelihood, living together with wildlife (Riskas et al. 2018). Moreover, it has extended impacts on the governance and economy of the nation (Felbab-Brown 2017).

With dramatic increase, illegal wildlife trade is ranked the fourth most lucrative global crime after drugs, humans, and arms with the transaction approximately between $7 billion and $23 billion each year (World Economic Forum 2016). Moreover, the illegal wildlife trade has risen to $23 billion annually, resulting from increase in environmental crime (Nellemann et al. 2018). Illegal wildlife trade is a large business run by well-coordinated and financially organized groups with international linkages that include a network of traders, smugglers, and supporters (locals, middleman, office staff, politicians, and international contacts) forming an illicit network facilitating poaching (Katuwal et al. 2015; Upadhaya 2017).

Pangolin is an internationally heavily trafficked mammal, as a result both Asian and African pangolins are highly threatened with extinction (Challender et al. 2014; Waterman et al. 2014; Boakye et al. 2015; IUCN SSC Pangolin Specialist Group 2016). In the past few years pangolin trafficking and hunting for local use has peaked up dramatically (Actman 2016; Aisher 2016; Challender et al. 2019; Ullmann et al. 2019). The rate and trend of trafficking of African pangolins to Asia has increased in the last decade (IUCN SSC Pangolin Specialist Group 2016; Challender & Waterman 2017), so that the demand of Asia has been fulfilled by Africa (Challender & Waterman 2017). Pangolin is hunted, poached, and illegally traded mainly due to increase in the demand for meat as a delicacy and for its medicinal importance (Challender et al. 2015; Mohapatra et al. 2015; Sharma et al. 2020).

The demand for pangolin is increasing because of the belief and use of its scales in medicines (Challender et al. 2015; CITES 2016). In some parts of the world, like Pakistan, pangolins are killed due to wrongly-held beliefs, such as, pangolins eat human dead bodies by excavating the graves and harm the local people. These beliefs have encouraged selling of pangolin, resulting in the biggest threat to pangolin population (Akrim et al. 2017). People also consider pangolin as bush meat (Newton et al. 2008; Zhang et al. 2017). In addition to these reasons, poaching and illegal trade have severely threatened the pangolin population all around the world (Newton et al. 2008; Katuwal et al. 2015; Mohapatra et al. 2015; Challender et al. 2019; Sharma et al. 2020). As trafficking is a major threat to pangolins in the international arena (Challender et al. 2015, 2019) in the national sphere, regions such as eastern Nepal (Thapa et al. 2014; Katuwal et al. 2015) are considered major hotspots in pangolin poaching and trafficking. People around the globe illegally trade to consume the fetuses and various body parts like scales, bones, meat, and claws to increase healing power in different traditional medicines (Katuwal et al. 2013; Thapa et al. 2014; Boakye et al. 2015; Mohapatra et al. 2015; Heinrich et al. 2016). China and Vietnam are the destination countries where most of the illegally traded pangolins from both Asia and Africa reach (Corlett 2007; Challender & Hywood 2012; Heinrich et al. 2016, 2017). Nepal has been a popular trade route for transferring illegally hunted pangolins to the popular and nearest destination, China (Acharya 2015) and traded through different eastern and central borders via the Araniko highway of Nepal (Katuwal et al. 2013).

Pangolins are nocturnal, covered with overlapping scales, and feed on specialized diet comprising of ants & termites. Among eight species of pangolins distributed globally, Nepal supports two, namely Chinese Pangolin *Manis pentadactyla* distributed up to altitude 2,000m and the Indian Pangolin *Manis crassicaudata* distributed below 500m (Baral & Shah 2008; Jnawali et al. 2011; Sharma et al. 2020). Based on the elevation, the landscape of Nepal is more favourable to Chinese Pangolin which is distributed more widely than the Indian Pangolin (Sharma et al. 2020). Besides Nepal, the Chinese Pangolin is also distributed in several Asian nations including Bangladesh, Bhutan, China, Hong Kong SAR, India, Myanmar, Lao PDR, Taiwan, Thailand, and Vietnam (Sharma et al. 2020). Besides poaching and illegal trade, various other anthropogenic activities like deforestation, extensive grazing, forest fire, agriculture accretion, human settlement, and infrastructure expansion, traditional beliefs and road construction are severely responsible for increasing threats to the pangolin population and its habitat (Challender et al. 2015; Katuwal et al. 2017).

The Chinese and Indian pangolins are categorized as Critically Endangered and Endangered, respectively, under the IUCN Red List of Threatened Species (IUCN SSC Pangolin Specialist Group 2016) and are protected under the National Parks and Wildlife Conservation (NPWC) Act 1973 (DNPWC & DoF 2018); however, very little documentation has been done about the illegal

poaching, trade route, hunting, and trading of pangolin in Nepal (Katuwal et al. 2015; Sharma et al. 2020). Though Nepal is a signatory and party to the Convention on International Trade in Endangered Species (CITES) and has provided all legal and institutional instruments to address wildlife trade issues, the illegal pangolin trade has not been investigated in a satisfying manner. Moreover, the traders have a more sophisticated and advanced system for transporting consignments from one place to another. This study aimed to identify the status of pangolin trade by taking account of trade conditions and highlighting the potential routes used for illegal trafficking within the Sankhuwasava District.

STUDY AREA

Forty-three districts, including Sankhuwasava are home to pangolins in Nepal (DNPWC & DoF 2018) which is located in Province-1 of Nepal (27.6142°N & 87.1423°E, 457–8,463 m), however, our study was confined to three major municipalities namely, Khandbari (457–1,500 m), Chainpur (1,200m), and Madi (500–2,900 m). Sankhuwasava District borders with Taplejung and Tehrathum districts in the east, Solukhumbu and Bhojpur districts in the west, Dhankuta district in the south, and Tibet, the autonomous region of China in the north. Sankhuwasava is extended from sub-tropical to alpine with large wilderness forest and agricultural land that provides a suitable habitat for pangolins. Majority of the local communities are indigenous Limbu, Rai, Yakkha, and Gurung (CBS 2012) who are mainly subsistence farmers and belong to a lower socioeconomic status.

METHODS

The primary data comprised survey response from respondents, key informant's survey, focus group discussions and seizure data. These were collected between February–April 2018 in Khandbari, Chainpur, and Madi municipalities of Sankhuwasava District (Figure 1). These municipalities were specifically selected for this study as these are the major markets and due to various anecdotal evidences such as seizure reporting on local and national media showing high illegal trade of pangolins in the area. Katuwal et al. (2015) had also used major markets as key indicators in selecting study area. Purposive sampling method suggested by Boakye et al. (2015) was used to identify the potential respondent within the district. These selected respondents were interviewed using a semi-structured questionnaire. As suggested by Newton et al. (2008), a two-person team conducted semi-structured interviews without precise,

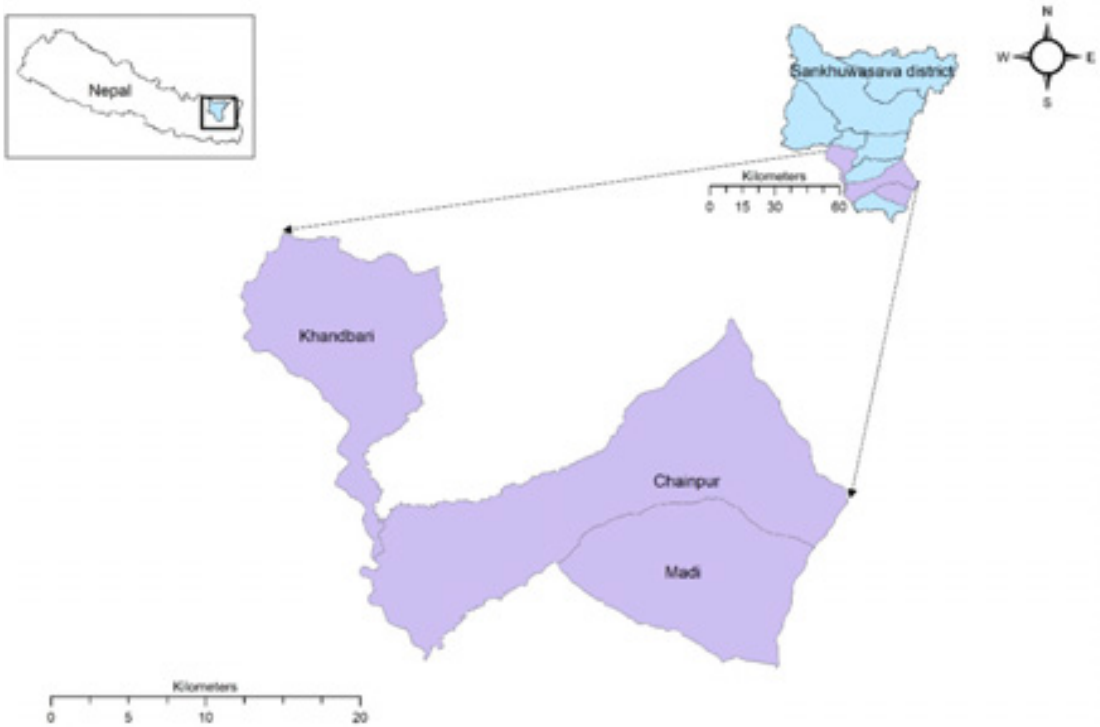

Figure 1. Study area, three different municipalities; Khandbari, Chainpur, and Madi at Sankhuwasava, Nepal.

Table 1. Socio-economic characteristics of respondents.

Respondent characteristics		Percentage
Gender	Male	72
	Female	28
Age	<16 yr. (Child).	9
	16–35 (Youth)	56
	>35	35
Education	Illiterate	11
	School level	66
	College level	23
Occupation	Agriculture	48
	Hotel	12
	Shopkeeper	13
	Forest guard	2
	Travel agent	5
	Driver	4
	Teacher	11
	Private service	5

pre-determined questions so that interesting lines of discussion could be pursued. The team tried to pose open questions wherever possible, to avoid leading the interviewee into a response (Newton et al. 2008). Semi-structured interview was directed toward information of trade and its triggering factors. A process of chain referral was followed where other potential respondents were referred to by the respondent (Newing et al. 2011). Seventy-five respondents, including seven children were interviewed. The surveyor checked the respondent for species identification by providing well illustrated pictures of both the Indian and Chinese pangolins as well as videos showing the behavior of both the species. Interviews were conducted in Nepali languages and were translated to English. Literature about pangolin distribution has only mentioned Chinese Pangolin distribution in Sankhuwasava District (Baral & Shah 2008; Jnawali et al. 2011). But we cannot omit the fact that some trade might be of Indian Pangolin from outside the study area with the district acting as a transit zone. So, both the Indian and Chinese pangolin trade were taken into account.

Trade information was obtained from the seizure report of the district forest office (DFO), district police office (DPO), and Makalu Barun National Park (MBNP) from 2009 to 2017 (Figure 5).

Information from 30 key informants (KI) including DFO staff (n=7), district court office (n=4), police personnel (n=9), the Federation of Community Forestry Users Nepal (FECOFUN) staff (n=3) & community forestry user committee members (n=7), and four focus group discussions (FGDs), one in each of the three municipalities and one with law enforcement agencies, were used to identify the major trade routes and market hub for pangolin trade. Various seizure hotspot were supporting evidence for predicting the trade route. FGD and KI were the main source of information in identifying the trade route map which was prepared with the help of GIS.

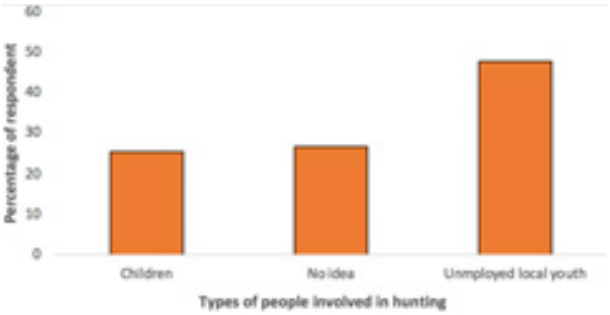

Figure 2. Respondents' (n = 75) response on types of people involved in hunting.

Purposive sampling was used to identify the respondents who were aware of the pangolin, which they had either seen live or heard about from someone else. Out of total respondents, some 36% (n=27) had seen the pangolin alive, and a few (10.67%; n=8) had seen dead pangolins; while most others (53.33%; n=40) were just familiar with the species through indirect means like photographs, newspaper, television, and radio programs. Solitary and nocturnal nature of the species might be the potential reason for lower number of respondents seeing the species live (Jnawali et al. 2011). Identifying pangolin to species level (whether *Manis pentadactyla* or *M. crassicaudata*) was difficult since most (69.33%; n=52) of the respondents had no idea about the species of pangolin, as in nature both the pangolins are solitary, nocturnal, and burrow-dwelling (Baillie et al. 2014; Challender et al. 2014); however, the remaining 30.67% respondents had claimed the presence of Chinese Pangolin which was validated by showing the photo of both the species of pangolin. A detailed discussion with respondents revealed hunting by humans (88%; n=66) as the major threat to pangolin, and thus, the types of people involved in hunting, their hunting manner, and purpose were explored.

Types of people involved in hunting

Forty-eight percent (n=36) of respondents stated that a majority of the unemployed youths (16–35 years old) are involved in illegal hunting; 25.33% (n=19) of

respondents stated that children (<16 years old) are also involved, while 26.67 % (n=20) were not sure about exact participation of the age group (Figure 2). Similar results were reported by Katuwal et al. (2015), where they claimed that youth, especially the unemployed, were encouraged in illegal hunting by traders. From group discussion, it was revealed that the children were mostly lured to hunting as there is less likelihood of security personnel to suspect children, and also the pay rate for them is low. This was verified by security officials during investigation of seizure data too.

Identifying the manner of hunting can help to predict the intensity at which pangolin is hunted. Out of the total respondents surveyed, the majority (44%; n=33) had no idea about how often and by what method pangolins are being hunted, while some (32%; n=24) of them reported opportunistic hunting of pangolins, some (17.33%; n=13) reported of rare hunting and the rest (6.67%; n=5) reported intentional hunting. We concluded that the existence of community forest, that are strongly guarded by local communities have hindered the hunting of pangolin in forest area. So, people are found to be more engaged in opportunistic hunting. Chin & Pantel (2009) also recorded the same in their study. Similarly, D'Cruze et al. (2018) reported opportunistic hunting in tribal communities in Assam. Harrison et al. (2016) explored impacts of hunting on tropical forests in southeastern Asia and highlighted the importance of opportunistic hunting as it does not require much skill.

When it comes to the purpose of hunting, monetary benefits was the most popular response with 66% (n=50) respondents. Following monetary benefits, uses such as traditional medicine, meat, and very few cultural values were some other reasons (Figure 3). In the local context, the use of pangolin and its parts (like its scales) are believed to have healing power to cure wounds. More importantly, the pangolin is believed to cure arthritis and also consumed to increase immunity. Pangolin scales are taken as anti-poisonous reagent, where the belief exists. Moreover, pangolins are perceived to bring extreme bad luck (commonly called 'loddar') and thus, are hunted more often. In addition to these, pangolin claws and scales are used to make rings, bracelets, and other ornaments. All these social and cultural values have collectively added to hunting of the pangolin. However, at present higher monetary values are suppressing these cultural values associated with the species. Similar results were found by Corlett (2007) where he stated that hunters catch pangolins to supply for trade rather than for personal consumption.

Figure 3. Respondents' (n=75) response to the purpose of hunting pangolins.

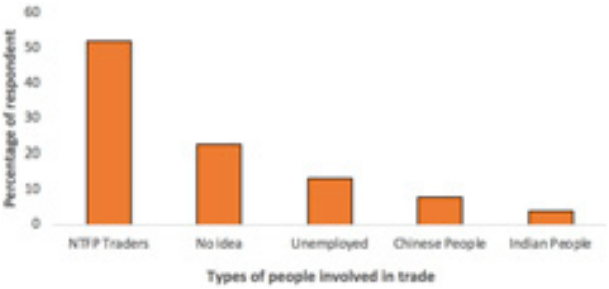

Figure 4. Respondents' (n=75) response on types of people involved in the trade.

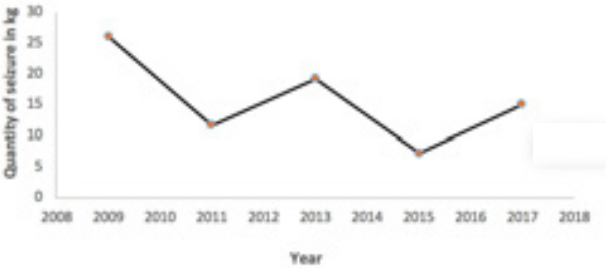

Figure 5. Seizure data showing an overall decreasing pattern of Pangolin trade between 2009 and 2017 (Source: DFO and MBNP seizure report).

Condition of pangolin trade

The status of the pangolin population was assessed where 60% of the respondents had noticed the decrease in pangolin population especially due to high hunting for illegal trade in the past and due to habitat fragmentation. Forty-two respondents (56% of total 75 respondents) identified high profit to be a major reason for trade, followed by low awareness (20%; n=15), poverty (20%; n=15), and poor law enforcement (4%; n=3). Unemployed local youth and children involved in the hunting of pangolins supply its parts to local traders for a small sum of money. It was found during the study, that the price of pangolin rises exponentially at every level of the value chain from local hunters to final traders. The

minimum price of pangolin at local hunter was about Nepali Rupees (NRS) 4,000–5,000 per kg, which increases to NRS 15,000–40,000 per kg in the illegal market. The average price at the Chinese border was higher, ranging from NRS 100,000–150,000 per kg where they were used, especially for preparing bulletproof jackets. Being illegal, prices fluctuate and the difference are site specific. Thus, the actual price may be clear that illegal hunting of pangolin is a serious crime in Nepal. However National Park and Wildlife Conservation Act in Nepal (NPWC Act 1973) has declared both the species of pangolins as protected and any offence regarding them costs a penalty of NRS 100,000–500,000, or imprisonment from 1 to 10 years, or both (1US$= 118.90NRS as per Nepal Rastriya Bank exchange rate on 12 March 2020)

Types of people involved in trade

The majority of the respondents (52%; n=39) claimed that the trade was a side business for most non-timber forest product (NTFP) traders (Figure 4), especially involved in the trade of *Elaeocarpus ganitrus* (Rudrakshya) and *Elettaria cardamomum* (Elaichi), that are the major NTFPs of Sankhuwasava District. Katuwal et al. (2015), however, claimed the involvement of youth, cow herders, local businessmen, and unemployed locals in pangolin trade through coordinated arrangements. The result of this study also identified that the illegal trade of pangolin goes side by side with trade of these NTFPs and finally reach Indian and Chinese markets. Discussion with KI led us to the conclusion that poor people are often lured by NTFP traders for a small sum of money. So, in this process if any seizure occurs, only poor people working as middleman who do not know about the consequences of smuggling the species get arrested. On the other hand, the real traders are mostly free. Most cases registered in the DPO validate these statements.

Fluctuation in pangolin trade

The fluctuations in pangolin trade was assessed, taking into account both the respondents' opinion and the seizure data obtained from DPO, DFO, and MBNP. The seizure data were tallied with the respondents' opinion which also showed a decreasing trend (80%; n=60) in trade. It contradicts with the result obtained by Katuwal et al. (2015) who advocated towards increase in trade. So, further discussion with KI from DFO and MBNP led to the conclusion that the reason for decrease in seizure could be enforcement of more security forces in every transit point of the district. Deployment of Nepal Army forces at the national park area that serves as the main route of trade to China border for two years could also have been the major reason for threatening the smugglers using the route. Various missions of the security forces to control the illegal trade and moreover some personal enmity between traders might be the reason for leaking the information and thus, increase the seizure in some years.

Identification of major trade route through Sankhuwasava District

Sankhuwasava has easy access to China through the Kimathanka border of the district. Majority of the pangolin parts are either directly hunted within the district, or the district serves as the trade route to China. Khandbari municipality appears to have been developed as the main hub for pangolin trade.

As informed by the sectoral police office, Chainpur, previously, the majority of delivery entered the district via Chainpur route from Tehrathum. But after strengthening and increasing of the number of police check posts in this route, the major road to enter the district has become off the road of Legwa, Dhankuta District which has lower number of security check posts due to poor condition of the road. Key informants also suggested that Khandbari and Num are major hotspots where the illegal trade is running and once the pangolin parts reach Khandbari they are transported to the China border (Figure 6).

The route shown in the map was predicted in accordance with the result of focal group discussion, KI interview, and local respondent knowledge. More than 80% of respondents agreed to the route demonstrated in the map. Various seizure hotspots were also used as supporting evidence for developing this map. This route showed some modification from the trade route already proposed by Katuwal et al. (2015) which showed Chainpur as the major entry point. This can be explained from Heinrich et al. (2017) who stated that wildlife trafficking occurs through a highly mobile trade network with constantly shifting trade routes as he also identified an average of 27 new unique routes emerging every year globally. It could also be presumed in our study area that though trade might seem to be declining, it might still be rising via shifted route especially through other routes rather than previous check posts.

CONCLUSION

The results suggest that majority of youths (especially unemployed) and children were involved in illegal hunting and trading of pangolin. Unemployed youth and children were lured to these activities by NTFP

Figure 6. Trade route from Bhojpur, Dhankuta, and Tehrathum districts leading to and within Sankhuwasava District.

traders from local areas for small sums of money. The results also suggest that hunting was done mainly for monetary benefits. We found that illegal hunting is the major reason for the decline of pangolin population in the area. Though the trend of seizure appears to be declining, we do not have any knowledge if it is due to decline in pangolin population. But, the result suggested that the poachers might have been discouraged to use specific routes after deployment of Nepal Army, as there are few seizures. Thus we recommend the continuation of strong border security mainly in the trade route (Khandbari to Kimathanka through Num, Hatiya, and Chepwa) to China. Our findings suggest the significant involvement of youth and children in illegal hunting; to reduce this we recommend strong and sustained awareness programs in the area as most of arrestees do not know about the consequence of the illegal trade. Development of alternative livelihood opportunity may also be useful for poorer people to avoid taking the risk. Furthermore, formation of community-based anti-poaching units in the potential pangolin habitat could be a major intervention to halt the trade. For this, sustained motivation, anti-poaching trainings, security assurance, and mostly incentives for worthy conservation outcomes are mandatory. Middlemen are being arrested rather than the actual traders. This calls for capacity building of enforcement agencies for detailed investigation of seizure data to reach to the bottom of this illegal trade. Finally, we suggest for a national-level study on looking into illegal hunting and trade of pangolin, as its conservation is in peril.

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COMMUNICATION

Diversity and synanthropy of flies (Diptera: Calyptratae) from Ecuador, with new records for the country

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Abstract: The Calyptratae are one of the most diverse groups of Diptera. Some species have immature states involved in the decomposition of organic matter of animal origin (i.e., they are sarcosaprophagous). In this study, we examined the diversity and synanthropy of sarcosaprophagous calyptrates in several environmental zones of the Ecuadorian Andes. Captures were performed in an urban zone located in the Tocachi community with monocultures (MC) and polycultures (PC), a rural zone with an agroecological farming system (AFS), and a forest zone with a montane forest located in the Parque Arqueológico Cochasquí (PAC) and the Cochasquí montane forest (CMF). A total of 2,925 specimens of Calyptratae were collected, representing 38 morphotypes and 17 species. Four are new reports for Ecuador: *Dolichophaonia trigona* (Shannon & Del Ponte), *Phaonia trispila* (Bigot), *Compsomyiops melloi* Dear, and *Calliphora lopesi* Mello. CMF and PAC presented high abundance and richness, followed by AFS, MC, and PC; PAC showed the highest diversity, in contrast to lowest in MC; the evenness decreased from forest to urban zones. Species that exhibited a preference for human settlements (positive synanthropic index) included *Limnophora marginata* Stein, *Phaonia trispila*, *Lucilia cuprina* (Wiedemann), *Calliphora lopesi*, *Compsomyiops melloi*, and *Calliphora nigribasis* Macquart. Those with a preference for uninhabited areas (negative index) included *Tricharaea* sp1, *Sarconesiopsis magellanica* (Le Guillou), and *Sarconesia chlorogaster* (Wiedemann).

Keywords: Blow flies, Calliphoridae, flesh flies, Muscidae, Sarcophagidae.

Resumen: Calyptratae es uno de los grupos más diverso de Diptera. Algunas larvas están implicados en la descomposición de la materia orgánica de origen animal (es decir, son sarcosaprófagas). En este estudio, examinamos la diversidad y la sinantropía de los caliptratos sarcosaprófagos en varios ambientes de los Andes ecuatorianos. Las capturas se realizaron en una zona urbana ubicada en la comunidad de Tocachi, en áreas de monocultivos (MC) y policultivos (PC), una zona rural con un sistema de agricultura agroecológica (AFS) y una zona forestal con un bosque montano ubicado en el Parque Arqueológico Cochasquí (PA) y el bosque montano de Cochasquí (CMF). Se recolectaron un total de 2.925 especímenes de Calyptratae, que representan 38 morfotipos y 17 especies. Cuatro son nuevos reportes para Ecuador: Dolichophaonia trigona (Shannon y Del Ponte), Phaonia trispila (Bigot), Compsomyiops melloi Dear y Calliphora lopesi Mello. CMF y PAC presentaron alta abundancia y riqueza, seguidos de AFS, MC y PC; PAC mostró la mayor diversidad, en contraste con la más baja en MC; la equidad disminuyó de bosque a zonas urbanas. Las especies que mostraron preferencia por los asentamientos humanos (índice sinantrópico positivo) fueron Limnophora marginata Stein, Phaonia trispila, Lucilia cuprina (Wiedemann), Calliphora lopesi, Compsomyiops melloi y Calliphora nigribasis Macquart. Aquellas con preferencia por áreas deshabitadas (índice negativo) incluyeron Tricharaea sp1, Sarconesiopsis magellanica (Le Guillou) y Sarconesia chlorogaster (Wiedemann).

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Author contribution: KB and ASV conducted the Diptera identification and wrote the first manuscript draft. KB and ASV conducted the specimens collections. ASV and JL wrote the final manuscript. ASV prepared the specimen photographs. All authors elaborated the data analysis.

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INTRODUCTION

The highly diverse Dipteran infraorder Calyptratae has members that widely distributed through most biogeographic regions (Wiegmann et al. 2011; Lambkin et al. 2013). These insects are characterized by a high capacity for decomposing organic matter, where their larvae play an important role in nutrient recycling (Byrd & Castner 2001; Kimberly et al. 2005). Some species are important as disease vectors and feature in medico-legal investigations (Catts & Mullen 2002; Benecke et al. 2004; Magaña et al. 2006). Several Calyptratae are well adapted to human-perturbed habitats, forming an anthropo-biocenosis (Polvoný 1971). This taxon is highly specialized in some feeding habits: Saprophagous, coprophagous, necrophagous, hematophagous and pollen feeders (Hernández & Dzul 2008).

In Ecuador, calyptrate species have been recorded in Muscidae (77 species), Calliphoridae (23 species), Sarcophagidae (18 species), and Fanniidae (4 species) (Löwenberg-Neto & Carvalho 2013; Whitworth 2014; Salazar & Donoso 2015). Ecological investigations in sarcosaprophagous dipterans are scarce. Torres (2016) studied blowfly diversity in different types of human-modified and wild environments, and noted that diversity decreased and species dominance increased in human environments (urban and rural), in contrast to wild habitats.

This study aimed to describe the diversity and synanthropy in Calyptratae from a protected forest in the Archaeological Cochasquí Park, and in human environments in the Tocachi parish, Pedro Moncayo canton. This investigation was authorized with permission Nº 007-2018-RIC-FLO-FAU-DPAP-MA and collection Nº 007-2019-DPAP-MA.

MATERIAL AND METHODS

Study area

The study was undertaken in the Pedro Moncayo canton, north-west of Pichincha province, on the southern slope of Nudo de Mojanda. The total area comprises 339.10km^2 with four life zones in the High Andino zoogeographic level (1,730–2,952 m): lower montane dry forest, montane moist forest, lower montane moist forest, and montane wet forest (Albuja et al. 1980; PDOT 2015). In this area, three types of environment (urban, rural, and forest) were identified: (i) urban zone located in the Tocachi community (-0.0352S & 78.282W), characterized by basic services, with paved streets, a school area, a housing yard consisting of monocultures (MC) and polycultures (PC); (ii) rural zone located 1km away from the community (-0.048S & 78.290W), characterized by a small human population (< 30 permanent inhabitants) without basic services in an agro-ecological farming system (AFS); (iii) forest zone corresponding to low human disturbance, with a lower montane forest located in the Parque Arqueológico Cochasquí (PAC) (-0.059S & 78.304W) and the Cochasquí montane forest (CMF) (-0.058S & 78.304W).

Sampling

Flies were captured with Morón & Terrón (1984) modified necrotraps made of two transparent plastic soup containers, with an internal funnel formed from a foam container. Traps were baited with fish viscera and beef, placed 1m above the ground (Uribe-M et al. 2010; Moreno et al. 2016); 100 traps separated by 30m each following transects in each site (MC, PC, AFS, PAC and CMF) for a period of 48 hours each month from May to November 2017. Trapped specimens were separated into morphotypes, mounted and identified using taxonomic keys (Mc Alpine et al. 1981; Carvalho 2002; Toro 2007; Amat et al. 2008; Carvalho & Mello 2008; Buenaventura et al. 2009; Marshall et al. 2011; Vairo et al. 2011; Patitucci et al. 2013a).

Data analysis

We evaluated the local diversity using Hill numbers (Hill 1973; Moreno 2001) for site diversity estimation ($N_0 = S$, $N_1 = e^{H'}$ and $N_2 = 1 / \lambda$; where S corresponds to species richness, H' Shannon-Wiener index and λ Simpson index); for evenness the $E_{2,1}$ Alatalo index (Heip et al. 1998) was calculated using the formula: $N_1 - 1 / N_2 - 1$. The diversity between sites was evaluated using the Jaccard (quantitative) similarity index. All analyses were made using PAST (Hammer et al. 2001) and EstimateS (Colwell 2019) software.

The synanthropic index (SI) was calculated according to Nuorteva (1963): SI = (2a+b-2c)/2, where "a" corresponds to the percentage of individuals of each species collected in the urban zone, "b" the percentage of the same species collected in the rural zone, and "c" the percentage of the same species collected in the forest zone. The SI fluctuates between +100 to -100, where a value of +100 indicates a strong species preference for densely populated urban areas, -100 indicates a complete avoidance of human settlements and intermediate values indicate differential degrees of synanthropy. For this analysis, only those species with 10 or more individuals were considered.

RESULTS

A total of 2,925 specimens of Calyptratae were collected, representing 38 morphotypes and 17 species; four of these are new reports for Ecuador (Table 1). Muscidae and Sarcophagidae representing 39.6% and 24.7% abundance, respectively. In Muscidae, the most common taxa were *Limnophora marginata* Stein, 1904, followed by *Phaonia trispila* (Bigot, 1885), *Dolichophaonia trigona* (Shannon & Del Ponte, 1926), *Phaonia* sp1, and *Dolichophaonia* sp1. Sarcophagidae was commonly represented by *Tricharea* sp1 and *Peckia* (*Sarcodexia*) sp1. In Calliphoridae, the most abundant species were: *Sarconesiopsis magellanica* (Le Guillou, 1842), *Calliphora nigribasis* Macquart, 1851, and *Lucilia cuprina* (Wiedemann, 1830). Finally, Tachinidae comprises a high number of morphotypes (25) and two species: *Eulasiopalpus* nr. *niveus* Townsend, 1914 and *Eulasiopalpus* nr. *vittatus* Curran, 1947.

Concerning the abundance and species composition between sites, CMF and PAC presented high abundance and richness, followed by AFS, MC, and PC. The PAC presented the highest N_1 and N_2 Hill diversity index, in contrast to MC which showed the lowest; PC presented intermediate diversity values. On the other hand, evenness $F_{2,1}$ index decreased from forest to urban sites: PAC-CMF > AFS > PC > MC. Figure 1 shows the dendrogram based on Jaccard index similarity; PAC is separated from the other sites, and CMF and AFS form a cluster separated from the crops group (MC and PC).

The synanthropic index was calculated for the most common species (10 individuals or more). In this study, the species and morphotypes that exhibited positive synanthropic index values were (Table 2): *Limnophora marginata* Stein, 1904 (+86.62) showing strong preference for human settlements, *Peckia* (*Sarcodexia*) sp1 (+8.60), *Phaonia trispila* (+6.24), *Lucilia cuprina* (Wiedemann, 1830) (+5.48), *Calliphora lopesi* Mello, 1962 and *Compsomyiops melloi* Dear, 1985 with (+2.98), and *Calliphora nigribasis* (+2.57), all with a preference for human settlements. The values for the other species and morphotypes were negative (showing preference for uninhabited areas): Fannidae sp1 (-40.89), *Tricharaea* sp1 (-14.94), *Sarconesiopsis magellanica* (-5.55), Scatophagidae sp1 (-3.12), *Sarconesia chlorogaster* (Wiedemann, 1831) (-1.75), Sarcophagidae sp1 (-1.36), and *Boettcheria* sp1 (-0.11).

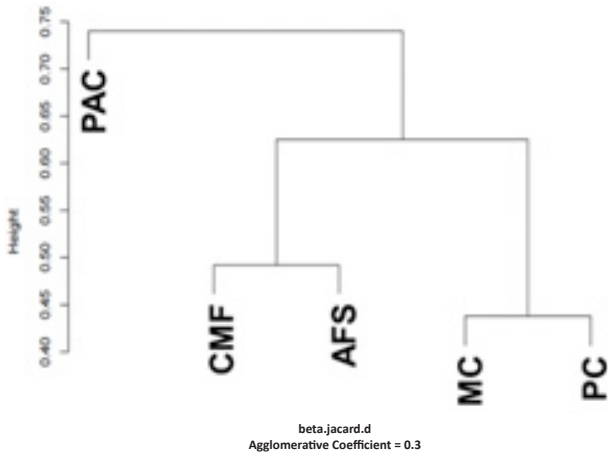

Figure 1. Dendrogram based on the Jaccard coefficient index showing the similarity in the composition of Calyptratae species in the sites sampled. Parque Arqueológico Cochasquí (PAC), Cochasquí montane forest (CMF), agroecologycal farming system (AFS), polyculture (PC), and monoculture (MC).

The list of new records with diagnostic characters and distribution is given below:

Family Calliphoridae

Subfamily Calliphorinae

***Calliphora lopesi* Mello, 1962 (Image 1A)**

This species of *Calliphora* can be distinguished by its bare stem vein, lower calypter setose above, bare suprasquamal ridge, thorax dull grey with whitish microtomentum, and abdomen subshining metallic blue with more or less whitish microtomentum. Other characters include a robust orange palpus with stout black setae; parafacial black to brown, lower half sometimes reddish to orange; parafacial with one or two changeable spots in both sexes, females also with a changeable spot midway on fronto-orbital plate when viewed from above; gena usually brown or black, genal groove black in *C. nigribasis*. Thorax with typical chaetotaxy; normally two postsutural intra-alars. Base of wing infuscated along costa to apex of costal cell, angling back to anterior edge of basal medial and posterior cubital cells, intensity and extent of area with color somewhat variable; and fringe of lower calypter normally brown *C. nigribasis*, rim and fringe are usually white or pale in the remaining four in C. *lopesi*.

Diagnostic characters: Differ from *C. nigribasis* by the reddish genal groove (black in *C. nigribasis*); rim and fringe of lower calypter white (dark reddish-brown in *C. nigribasis*); male frons narrower (related to head width), averaging 0.066 (0.06–0.07/5) (whereas averaging 0.102 (0.09–0.12/5) in *C. nigribasis*); male surstylus and cercus slender (whereas shorter and more stout in *C. nigribasis*); ST5 normal (exceptionally broad in *C. nigribasis*); female T5 without incision (T5 with incision in *C. nigribasis*) (Whitworth & Rognes, 2012).

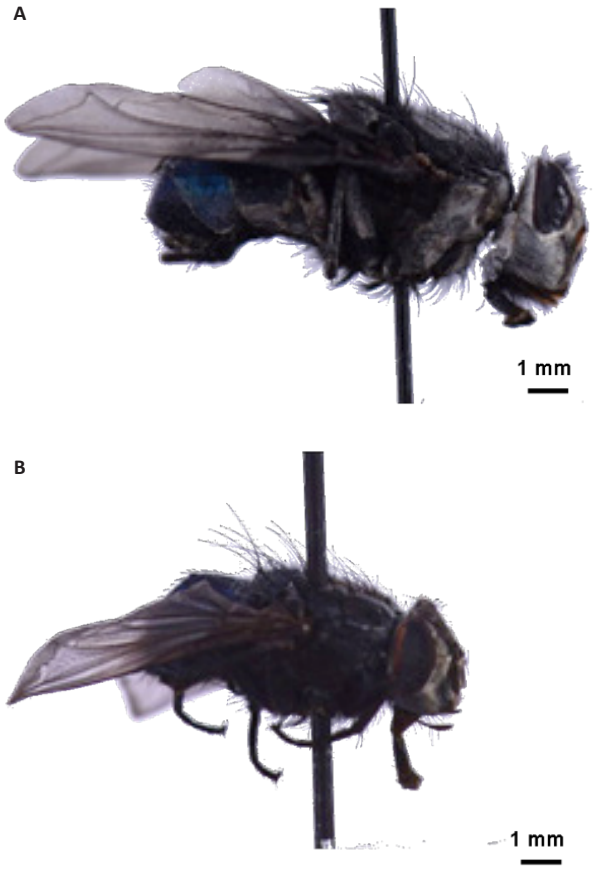

Image 1. Lateral views of Calliphoridae new records species collected at Pedro Moncayo canton in the Pichincha province: A—*Calliphora lopesi* | B—*Compsomyiops melloi*. © Yesenia Tovar & Ana Soto-Vivas

Material examined: MECN-EN-DIP-4862, 17.xi.2017, 1 female, polyculture in urban zone located in the Tocachi community, Pichincha, -0.035S & 78.282W, 2,816m, coll. Blacio & Soto-Vivas.

Distribution (Whitworth & Rognes 2012; Kosmann et al. 2013): Brazil, Uruguay.

Subfamily Chrysomyinae

***Compsomyiops melloi* Dear, 1985 (Image 1B)**

Compsomyiops species can be distinguished by the haired parafacials, pubescent greater ampulla and normal sized palpi (Dear 1985).

Diagnostic characters: Differs from *C. fulvicrura* (Robineau-Desvoidy, 1830) frons 0.40 of the head width; frontal vitta broader than a fronto-orbital plate measured at lunula; parafacial hairs dark and proclinate; genae silvery-yellow dusted anteriorly; frontal vitta orange-brown dusted; calypters pale brown (Dear 1985).

Material examined: MECN-EN-DIP-4861, MECN-EN-DIP-4865, MECN-EN-DIP-4866, MECN-EN-DIP-4867, MECN-EN-DIP-4868, 22.x.2017, 5 females, polyculture in urban zone located in the Tocachi community, Pichincha, -0.035S & 78.282W, 2,816m, coll. Blacio & Soto-Vivas.

Distribution (Dear 1985; Amat 2009; Kosmann et al. 2013): Colombia, Mexico.

Family Muscidae

Subfamily Phaoniinae

***Dolichophaonia trigona* (Shannon & Del Ponte, 1926) (Image 2A)**

Dolichophaonia species are characterized by eye with short cilia, arista plumose, presutural acrostichals often differentiated, dorsocentral setae 2:3-4, prealar present, except in *D. vockerothi* (Carvalho, 1983), shorter than notopleural anterior seta, katepisternals 1:2, meron haired or not; wing veins bare, vein M parallel or very slightly forward-curved apically, calcar present, about twice as long as the basal width of hind tibia; female: clypeus, in lateral view, with a strong, hook-shaped anterior tip, posteriorly with a prominent sclerotization, ovipositor with large tergites and sternites (Carvalho & Couri 2002).

Diagnostic characters: One prepimeral setae development; mid tibia often with 2 median posterior setae; female palpus more dilated than in male; sternite 1 bare; pre-alar present, shorter than noto-pleural anterior seta; two intra-alars post-sutural setae; wing with two conspicuous clouds on cross-veins dm-cu; upper calypter yellowish with dark brown margins; wing with costal margin yellowish; dorso-central setae 2:3-4 (Carvalho & Couri 2002).

Material examined: MECN-EN-DIP-4859, MECN-EN-DIP-4869, MECN-EN-DIP-4870, 22.ix.2017, 3 females, Cochasquí

montane forest, Pichincha, -0.058969S & 78.304351W, 3052m, coll. Blacio & Soto-Vivas. MECN-EN-DIP-4871, MECN-EN-DIP-4872, 22.ix.2017, 2 females, monoculture in urban zone located in the Tocachi community, Pichincha, -0.035S & 78.282W, 2,816m, coll. Blacio & Soto-Vivas.

Distribution (Löwenberg-Neto & Carvalho 2013): Argentina, Brazil, Uruguay.

***Phaonia trispila* (Bigot, 1885) (Image 2B)**

Phaonia species are characterized by: eyes ciliated, arista plumose, dorsocentral setae 1–2:3–4, notopleuron with covering setulae and with two setae, the posterior one weaker; pre-alar seta present (absent in *P. lentiginosa* Snyder), lower calypter glossiform, *Phaonia* type, Rs node bare or ciliated, vein M usually curved forward apically, hind tibia on postero-dorsal surface with the calcar about as long as the width of the tibia at calcar

Image 2. Lateral views of Muscidae new records species collected at Pedro Moncayo canton in the Pichincha province: A—*Dolichophaonia trigona* | B—*Phaonia trispila*. © Yesenia Tovar & Ana Soto-Vivas

insertion; female: ovipositor elongated, tubular, tergites narrow; stemite 8 reduced to two sclerites, microtrichia usually well-developed only on the membrane, cerci free (Carvalho & Couri 2002).

Diagnostic characters: General coloration black; scutellum with a yellowish-brown apex; wing with dark brown macules in the anterior and posterior transverse veins and a slight spot at the end of the Sc vein; posterior spiracle on the PV margin without setae. Male: Paramere without concavity on the ventral surface; gonopod with the anterior region not exceeding the paramere width; ventral face curved. Female: proboscis in lateral view, with the clypeus, in the anterior region, with a strong tip; dorsal and basal haustellum sclerites with many setae (Coelho 2000).

Material examined: MECN-EN-DIP-4864, MECN-EN-DIP-4860, 22.ix.2017, 2 females, Cochasquí montane forest, Pichincha, -0.058S & 78.304W, 3,052m, coll. Blacio & Soto-Vivas. MECN-EN-DIP-4857, 22.ix.2017, 1 female, monoculture in urban zone located in the Tocachi community, Pichincha, -0.035S & 78.282W, 2,816m, coll. Blacio & Soto-Vivas. MECN-EN-DIP-4858, 17.xi.2017, 1 female, polyculture in urban zone located in the Tocachi community, Pichincha, -0.035S & 78.282W, 2,816m, coll. Blacio & Soto-Vivas. MECN-EN-DIP-4863, 22.x.2017, 1 female, agroecological farming system 1km away from the Tocachi community, Pichincha, -0.048S & 78.290W, 3,000m, coll. Blacio & Soto-Vivas.

Distribution (Löwenberg-Neto & Carvalho 2013): Argentina, Brazil, Venezuela, Uruguay.

DISCUSSION

The most abundant and diverse Calyptratae community was observed in the wild environment (Cochasquí Archaeological Park). This suggests that the species share the available resources, from pollen to organic matter in animal and plant decay (Baumgartner & Greenberg 1985; Carson & Schnitzer 2008). In contrast to the urban area (mono- and polycultures) where the richness was lower, possibly due to anthropogenic modifications such as garbage and drains which support flies adapted to these environments (Carvalho et al. 1984; Souza et al. 2014). On the other hand, the dipteran community similarity found between urban areas and the montane forest and agro-ecological farming system could be associated with the fact that Tocachi rural and urban environments are partially preserved, due to the agricultural practices that are carried out in some areas.

Muscidae were the most abundant taxa in this study; adults can be predatory, hematophagous, saprophagous or necrophagous, living in varied habitats, such as dung, decomposing organic vegetable or animal matter, wood, fungi, nests, and dens, among others (Couri & Carvalho 2005). These flies are relatively common at high altitude regions, where they are important as pollinators and

Table 1. Absolute frequency of Calyptratae in five sites in Pedro Moncayo canton, Ecuador from May to November 2017. * New report from Ecuador.

Family	Species / morphotype	PAC	CMF	AFS	PC	MC	Total
Calliphoridae	*Calliphora lopesi* Mello, 1962*	0	0	0	10	0	10
	Calliphora nigribasis Macquart, 1851	9	1	10	10	2	32
	Chlorobrachycoma splendida Townsend, 1918	2	0	0	2	0	4
	Chrysomya albiceps (Wiedemann, 1819)	1	0	0	0	1	2
	Cochliomyia hominivorax (Coquerel, 1858)	7	0	0	0	0	7
	Cochliomyia macellaria (Fabricius, 1775)	1	0	0	0	0	1
	Compsomyiops melloi Dear, 1985*	0	0	0	10	0	10
	Lucilia cuprina (Wiedemann, 1830)	1	0	0	19	0	20
	Lucilia eximia (Wiedemann, 1819)	0	0	0	3	0	3
	Lucilia sericata (Meigen, 1826)	0	0	0	0	5	5
	Sarconesia chlorogaster (Wiedemann, 1831)	10	0	0	0	0	10
	Sarconesiopsis magellanica (Le Guillou, 1842)	87	67	28	17	35	234
	Roraimomusca roraima Townsend, 1935	2	0	0	0	0	2
	Rhiniinae sp1	0	0	0	2	0	2
Sarcophagidae	*Blaesoxipha* sp1	0	0	1	0	0	1
	Boettcheria sp1	11	7	8	2	5	33
	Peckia sp1	0	0	0	1	0	1
	Peckia (Sarcodexia) sp1	61	59	97	25	40	282
	Tricharaea sp1	189	44	82	38	20	373
	Sarcophagidae sp1	16	1	10	0	3	30
	Sarcophagidae sp2	0	0	0	0	1	1
Muscidae	*Dolichophaonia* sp1	0	1	0	0	3	4
	Dolichophaonia trigona (Shannon & Del Ponte, 1926)*	0	4	0	0	4	8
	Phaonia trispila (Bigot, 1885)*	1	13	15	16	7	52
	Phaonia sp1	0	0	7	0	1	8
	Limnophora marginata Stein, 1904	43	333	336	158	210	1080
Fanniidae	Fanniidae sp1	64	413	60	14	17	568
Scatophagidae	Scatophagidae sp1	51	10	24	8	10	103
Tachinidae	*Eulasiopalpus* nr. *niveus* Townsend, 1914	0	1	0	0	0	1
	Eulasiopalpus nr. *vittatus* Curran, 1947	0	0	1	0	0	1
	Adejeania sp1	0	0	4	0	0	4
	Tachinidae sp1	1	0	0	0	0	1
	Tachinidae sp2	1	0	0	0	0	1
	Tachinidae sp3	1	0	0	0	0	1
	Tachinidae sp4	1	0	0	0	0	1
	Tachinidae sp5	1	0	0	0	0	1
	Tachinidae sp6	1	0	0	0	0	1
	Tachinidae sp7	4	0	0	0	0	4
	Tachinidae sp8	5	0	0	0	0	5
	Tachinidae sp9	0	1	0	0	0	1
	Tachinidae sp10	0	1	0	0	0	1
	Tachinidae sp11	0	1	0	0	0	1
	Tachinidae sp13	0	1	0	0	0	1

Family	Species / morphotype	PAC	CMF	AFS	PC	MC	Total
	Tachinidae sp14	0	1	0	0	0	1
	Tachinidae sp15	0	1	0	0	0	1
	Tachinidae sp16	0	1	0	0	0	1
	Tachinidae sp17	0	1	0	0	0	1
	Tachinidae sp18	0	1	0	0	0	1
	Tachinidae sp19	0	1	0	0	0	1
	Tachinidae sp20	0	0	0	0	1	1
	Tachinidae sp21	0	0	0	0	1	1
	Tachinidae sp22	0	0	0	0	1	1
	Tachinidae sp23	0	0	3	0	0	3
	Tachinidae sp26	0	0	1	0	0	1
	Tachinidae sp27	0	0	0	1	0	1
	Hill N_0 (=S)	**25**	**23**	**16**	**17**	**19**	
	N_1 ($e^{H'}$)	**8.51**	**4.44**	**5.63**	**7.07**	**5.10**	
	N_2 (1/λ)	**5.80**	**3.19**	**3.51**	**3.96**	**2.81**	
	Alatalo $E_{2,1}$ (N_1-1/N_2-1)	**0.64**	**0.64**	**0.54**	**0.49**	**0.44**	

PAC—Parque Arqueológico Cochasquí | CMF—Cochasquí montane forest | AFS—Agroecologycal farming system | PC—Polyculture | MC—Monoculture.

floral visitors and account for a high proportion of fauna (Proctor et al. 1996; Carvalho et al. 2005; Pérez & Wolff 2011). The most common species were *L. marginata*, *D. trigona* and *P. trispila*, the last two species have not been collected previously in Ecuador; *D. trigona* is reported in Argentina, Brazil, and Uruguay, and *P. trispila* has been registered in Argentina, Brazil, Venezuela and Uruguay (Löwenberg-Neto & Carvalho 2013). In this study, *L. marginata* showed a highly positive synanthropic index, suggesting strong preference for human settlements, in contrast to *P. trispila* that showed a low positive synanthropic index, indicating a mild preference for human settlements. Patitucci et al. (2013b) studied the ecological assemblages of saprophagous muscids in three sites with different urbanization levels. Particularly, *P. trispila* showed high abundance in rural areas, and a negative synanthropic index associated with complete avoidance of human settlements. Sarcophagidae was mainly represented by *Tricharaea* sp1, *Peckia* (*Sarcodexia*) sp1 and *Boettcheria* sp1; this family have a wide variety of habits, some species being scavengers, coprophages, hosts of ant and termite nests, some cause myiasis to amphibians and mammals, others are predators on arachnid eggs, butterfly larvae and bee pupae (Pape et al. 2004). Yepes-Guarisas et al. (2013) investigated the ecology and synanthropy of Sarcophagidae from Antioquia-Colombia. These authors found that *Tricharaea* spp. and *Pekia* (*Sarcodexia*) *lambens* (Wiedemann, 1830), showed a positive synanthropic index. Pinilla et al. (2012) studied the synanthropy of Calliphoridae and Sarcophagidae in three zones in Bogotá-Colombia. They reported a *Boettcheria* morphotype associated mainly in the forest but also represented in rural areas.

With Calliphoridae, most species are sarcosaprophagous, but there are also predators and parasitoids. Souza et al. (2014) point out that this family is associated with regenerating forest, due to certain species colonizing at some stages. Also, studies with different degrees of urbanization showed that calliphorids prefer baits of animal origin (D'Almeida & Almeida 1998). This taxon is one of the most important families representative of synanthropic species (Souza & Zuben 2012). In the present study, the Calliphoridae species had a greater relationship in wild and rural environments, however, they are also present in the urban environment; this could be due to small vegetation patches and the association with domestic or farm animals. *S. magellanica* was the most abundant species and demonstrated a preference for uninhabited areas; Figueroa & Linhares (2002) and Pinilla et al. (2012) stated that this species was abundant in rural and wild areas. In concordance with our results, *S. chlorogaster* was reported by Schnack et al. (1989) in Argentina and Vianna et al. (1998) in Brazil, as a species with independence from human settlements. *L. cuprina* was found to be widely distributed in rural and urban areas on Pedro Moncayo canton, in particular, densely

Table 2. Synanthropic index of Calyptratae in five sites in Pedro Moncayo canton, Ecuador from May to November 2017 from those species with a number equal or higher to 10 individuals.

Species / morphotype	PAC	%	CMF	%	AFS	%	PC	%	MC	%	Total	SI
Sarconesiopsis magellanica (Le Guillou, 1842)	87	15.24	67	6.95	28	4.08	17	5.06	35	9.54	234	-5,55
Sarconesia chlorogaster (Wiedemann, 1831)	10	1.75	0		0		0		0		10	-1,75
Calliphora nigribasis Macquart, 1851	9	1.58	1	0.10	10	1.46	10	2.98	2	0.54	32	2,57
Calliphora lopesi Mello, 1962	0		0		0		10	2.98	0		10	2,98
Compsomyops melloi (Wiedemann, 1819)	0		0		0		10	2.98	0		10	2,98
Lucilia cuprina (Wiedemann, 1830)	1	0.18	0		0		19	5.65	0		20	5,48
Tricharaea sp1	189	33.10	44	4.56	82	11.94	38	11.31	20	5.45	373	-14,94
Peckia (Sarcodexia) sp1	61	10.68	59	6.12	97	14.12	25	7.44	40	10.90	282	8,60
Boettcheria sp1	11	1.93	7	0.73	8	1.16	2	0.60	5	1.36	33	-0,11
Sarcophagidae sp1	16	2.80	1	0.10	10	1.46	0		3	0.82	30	-1,36
Phaonia trispila (Bigot, 1885)	1	0.18	13	1.35	15	2.18	16	4.76	7	1.91	52	6,24
Limnophora marginata Stein, 1904	43	7.53	333	34.54	336	48.91	158	47.02	210	57.22	1080	86,62
Fannidae sp1	64	11.21	413	42.84	60	8.73	14	4.17	17	4.63	568	-40,89
Scatophagidae sp1	51	8.93	10	1.04	24	3.49	8	2.38	10	2.72	103	-3,12

PAC—Parque Arqueológico Cochasquí | CMF—Cochasquí montane forest | AFS—Agroecologycal farming system | PC—Polyculture | MC—Monoculture | SI—Synanthropic Index.

inhabited areas. Several authors associate *L. cuprina* with densely populated areas and due to this, this species is considered to be a medical-veterinary important species because it is associated with the transmission of pathogenic micro-organisms and primary myiasis in sheep and humans (Vianna et al. 1998; Souza & Zuben 2012). *C. melloi* and *C. lopesi* were collected for the first time in Ecuador in this study. Dear (1985), Amat (2009) and Kosmann et al. (2013) recorded *C. melloi* in Mexico and Colombia, and Whitworth & Rognes (2012), and Kosmann et al. (2013) reported *C. lopesi* in Brazil and Uruguay. Finally, *C. lopesi* and *C. nigribasis* showed independence from human settlements; similar findings to those reported by Vianna et al. (1998) and Pinilla et al. (2012), in Brazil and Colombia, respectively.

Finally, Tachinidae presented a high number of morphotypes and two species *Eulasiopalpus* nr. *niveus* and *Eulasiopalpus* nr. *vittatus*. This family is extremely diverse in the Neotropics, a common taxon at middle elevations (1,000–2,000 m) along the mountain chains of tropical Central and South America (Stireman et al. 2006; Stireman 2007). Only a fraction of Neotropical Tachinidae have been described, and for most of those that have been described, the life history host associations, or behavior are poorly known (Guimarães 1977; Toma 2012). The tachinid species provide various ecosystem services in the Andean forests, their value as pest controllers and pollinators, favors the variability of the forest flora as well as maintaining the balance of the ecosystem by regulating populations (Ssymank et al. 2008; Quintero et al. 2017).

Urbanization processes cause an ecosystem negative impact by decreasing the proportion of native species, while introduced species usually occupy urbanized environments due to pre-adaptation processes (McKinney 2002; 2008). Several authors affirm that the introduced species proportion increases as it approaches large heavily urbanized sectors; in contrast to those native species that are more abundant in less modified sectors. In sarco-saprophagous dipterans, the environmental colonization success depends on their morphology, flexibility in the use of different resources, as well as on life history (Vianna et al. 1998; Uribe-M et al. 2010; Mulieri et al. 2011; Pinilla et al. 2012).

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COMMUNICATION

Butterfly diversity in Gidakom Forest Management Unit, Thimphu, Bhutan

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Abstract: This study was carried out to establish the diversity and distribution of butterflies in Gidakom Forest Management Unit (GFMU), Thimphu, Bhutan. A survey was conducted from June 2016 to July 2017 in three locations within GFMU: Jamdo, Chimithanka, and Jedekha. A total of 90 species belonging to 52 genera and five families of butterflies were recorded. Nymphalidae was dominant with 38 species, followed by Lycaenidae with 19, Pieridae with 15, Papilionidae with 11, and Hesperiidae with seven species. Diversity of butterfly species was highest in farmland associated with pockets of forest cover in the lower valley, and a decreasing trend was observed towards higher elevations. The maximum species richness (83 species) was recorded from Chimithanka between 2500m & 2900m, where agriculture is associated with patches of forest, streams, forest edges, and open scrub land. Butterfly diversity was lowest at Jedekha above 2,900m (37 species), an area dominated by mixed conifer forest with little agriculture.

Keywords: Butterflies, Hesperiidae, Lepidoptera, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, sweep net.

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Author contribution: TPK—field surveys, and data collection, and manuscript writing; BKK— data analysis & editing; JK—data collection.

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INTRODUCTION

Butterflies are quite sensitive to environmental factors such as temperature, humidity, rainfall, solar radiation, wind, and availability of larval host plants (Hill et al. 2002; Ribeiro & Freitas 2012). This sensitivity makes butterflies ideal indicators of habitat disturbance (Kocher & Williams 2000; Bonebrake et al. 2010; Castro & Espinosa 2015).

The first study of butterflies in Bhutan was reported in 1905 by (Binghan 1905). Since then estimates of total species in the country have ranged from 800–900 (ven der Poel & Wangchuk 2007), to 670 (Singh & Chib 2015). It should be noted, however, that butterfly data is lacking from many parts of Bhutan. Of the several checklists available (Harada 1987 a,b; van der Poel & Wangchuck 2007**;** Wangdi & Sherub 2012 a,b; Singh & Chib 2015; Sbordoni et al. 2015; Wangdi & Sherub 2015; Singh 2016), none cover Gidakom Forest Management Unit (GFMU), situated in Thimphu District, western Bhutan. This study aims to address that gap.

MATERIAL AND METHODS

Study area

The overall study area under Gidakom Forest Management Unit is situated in northwestern Bhutan between (27.571–27.382 ^{0}N and 89.481–89.592 ^{0}E). The overall study area consists of farmland between 2,100m & 2,900m with pockets of forest cover, and a mountain ridge with complete forest cover above 2,900m. Traditional wood extraction has long been practiced by the local community, and scientific commercial timber logging in the area began in 1990. Annually, more than 5000m^3 of wood are removed as per the management plan (Phuntsho 2012).

The study area is divided into three sites based on altitude, forest type and land use.

Site-I: Jamdo, 2100–2500 m; this forest is quite degraded due to past overexploitation and forest fires. The dominant forest type in the area is young blue pine stands, followed by oak forest and *Populus* sp. along the stream adjacent to the settlement. Agriculture is dominated by paddy cultivation, apple orchards and vegetable gardens. The annual average maximum temperature ranges from 26.7–9.6 ^{0}C. The highest temperatures are recorded in July, and the lowest during January and December. The highest precipitation occurs in August (130mm) and the lowest in December (12mm) only.

Site-II: Chimithanka 2500–2900 m. More than 60% of the total study area is under good forest cover of young Blue pine forest as a dominant species in the lower valley up to 2800m followed by mixed conifer species like Spruce *Picea spinulosa* and Hemlock *Tsuga dumosa* and broad-leaved species like Oak *Quercus semecarpifolia*. The lower region is characterized by scrub land, streams, and farmlands. Agricultural farming is confined to vegetable cultivation, orchards and livestock rearing. The annual average maximum temperature of the area recorded is 24.7°C and minimum is 7.6°C.

Site-III: Jedekha, 2900–3400 m. The vegetation here is characterized by mixed conifer forest, largely dominated by Fir *Abies densa*; different species of Rhododendron also occur above 3000m. Agriculture farming is very limited in this area, but timber logging is done for rural and commercial purposes. Precipitation is 90mm annually and the temperature often falls below freezing point during winter months.

Methods

A sweep net butterfly survey was conducted in the study areas described above from June 2016 to July 2017. The three altitude zones: 2100–2500 m, 2500–2900 m, and 2900–3400 m were further divided into eight habitat types. A 500m transect was established at each site, and attempts were made to catch every butterfly seen following Pollard's transect walking technique (Pollard et al.1975; Pollard & Yates 1993). Each study site was visited three times a month, and four man hours were spent in each survey event for a total of 432.

Most observations were recorded in the morning (08.00–12.00 h), with surveys also conducted 16.30–17.00 h for shade-loving butterflies. Considering the geographical location of the study sites, morning hours were preferred as this specific time is usually characterized by warm sunny weather providing favorable conditions for surveying butterflies. Preferred butterfly habitats such as closed canopy, forest openings, forest edges, roads, trails, shrub land, crop fields, farmland, and river/stream beds were scanned at 2,100–3,300 m. Whenever possible, photographs of specimens were taken using a digital camera (Canon EOS 70D with Canon-EF 100mm f/2.8L Macro IS USM Lens). The elevation and geospatial location of each species was recorded using GPS. Specimens were identified following ven der Poel & Wangchuck (2007). In addition, Nymphalidae and Papilionidae were identified with the help of field guides (Wangdi & Sherab 2012a,b). Identifications of Pieridae and Lycaenidae were guided by the recent study of Wangdi & Sherab (2015). Other

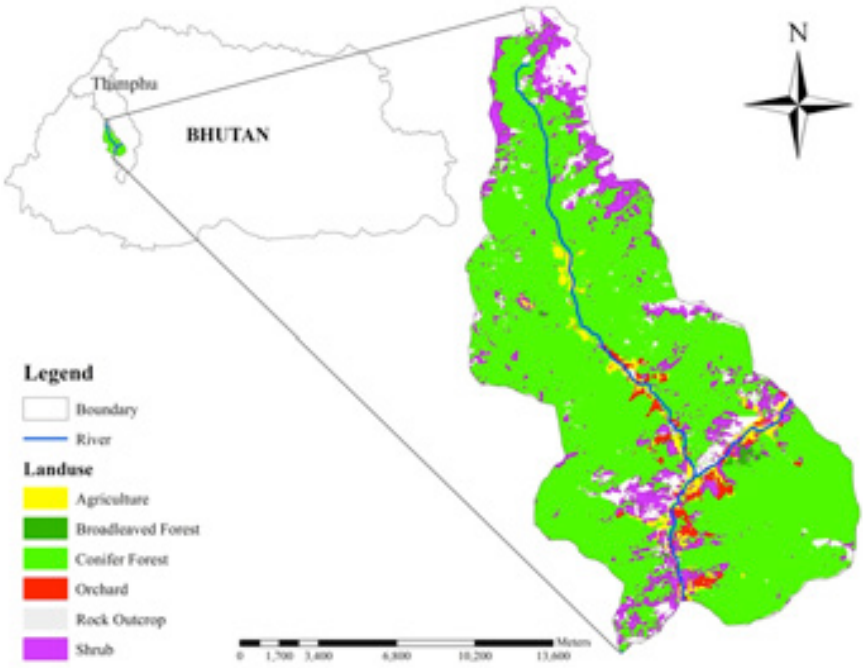

Figure 1. Study area, Gidakom Forest Magagement Unit, Bhutan.

sources for identification of butterflies included Singh & Chib (2014); Singh (2016); and Sondhi & Kunte (2016). Data were analyzed using Microsoft Excel 2010 and SPSS (Statistical Package for the Social Sciences). The Shannon diversity index (H') was used to calculate diversity in different study sites.

RESULTS

Diversity

A total of 90 species belonging to 52 genera, distributed among five families were recorded in this study (Table 1). Family Nymphalidae was dominant among the five families with 38 (42%) species belonging to 25 (48.07%) genera, followed by Lycaenidae comprising of 19 (21%) species from 12 (23.07%) genera, Pieridae with composition of 15 species (16%) belonging to seven genera (13.46%), Papilionidae with 11 species (12%) from three genera (5.76%) and Hesperiidae with seven species (8%) from five genera (9.61%). A maximum of 83 species of butterflies were recorded from Chimithanka (2,500–2,900 m), this was followed by Jamdo (2,100–2,500 m) with 72 species, and minimum of 37 species were recorded from Jedekha.

Species composition based on habitat types

Of the 90 species recorded, the maximum species richness was observed in agricultural fields with 24 species (22.64%), followed by scrublands with 17 species (16.03%), forest edge and river bank 16 species (15.09%) each, forest opening 13 species (12.26%), barren ground with eight species (7.54%), forest road with (5.66%) and minimum number of species were recorded in forest canopy accounting for only five species (4.71%) of the total species recorded (Figure 3).

Large Tawny Wall *Rhaphicera satricus*, Doherty's Satyr *Aulocera loha*, Larger Silver Stripe *Argynnis childreni*, Common Wood Brown *Lethe sidonis*, Small Wood Brown *L. nicetella*, Treble Silverstripe *L. baladeva*, Veined Labyrinth *Neope pulaha*, Scarce Labyrinth *Neope pulahina*, Chocolate *Junionia iphita*, Nepal Comma *Polygonia agnicula*, Common Yellow Swallowtail *Papilio machaon*, Common Peacock *Papilio bianor*, Chumbi Wall *Chonala masoni*, Common Baron *Euthalia aconthea*, Mountain Tortoiseshell *Aglais rizana*, Blue Admiral *Kaniska canace*, and Indian Fritillary *Argynnis hyperbius* were primarily recorded from forest opening and forest edge only. It was observed that distribution of Lycaenidae and Peiridae species primarily occupied farmland, apple orchards, scrubland and open grassy fields. Nymphalidae species were common in forested areas as well as farmland. Papilionidae were commonly recorded in forest openings and edges, and along the stream bank and from moist or wet ground. Hesperiidae were sighted in areas close to wet ground and in open grassy fields.

Table 1. Checklist of butterflies recorded in Gidakom Forest Management Unit (June 2016–July 2017).

	Family	Scientific name	Common name
1	Hesperiidae	*Borbo bevani* (Moore, 1878)	Bevan's Swift
2	Hesperiidae	*Caltoris tulsi* de Nicéville, 1883	Purple Swift
3	Hesperiidae	*Parnara bada* (Moore, 1878)	Grey Swift
4	Hesperiidae	*Parnara guttata* (Bremer & Gray, 1852)	Straight Swift
5	Hesperiidae	*Pelopidas conjuncta* (Herrich-Schaffer, 1869)	Conjoined Swift
6	Hesperiidae	*Taractrocera danna* (Moore, 1865)	Himalayan Grass Dart
7	Hesperiidae	*Taractrocera meavius* (Fabricius, 1793)	Common Grass Dart
8	Lycaenidae	*Acytolepis puspa* (Horsfield, 1828)	Common Hedge Blue
9	Lycaenidae	*Celastrina argiolus* (Linnaeus, 1758)	Hill Hedge Blue
10	Lycaenidae	*Celastrina huegelii* (Moore, 1882)	Large Hedge Blue
11	Lycaenidae	*Celastrina lavendularis* (Moore, 1877)	Plain Hedge Blue
12	Lycaenidae	*Celatoxia marginata* (de Niceville, [1894])	Margined Hedge Blue
13	Lycaenidae	*Cupido argiades* (Pallas, 1771)	Tailed Blue
14	Lycaenidae	*Everes lacturnus* (Godaet, [1824])	Oriental Cupid
15	Lycaenidae	*Heliophorus brahma* (Moore, 1857)	Golden Sapphire
16	Lycaenidae	*Heliophorus epicles* (Godart, [1824])	Purple Sapphire
17	Lycaenidae	*Heliophorus moorei* (Hewitson, 1865)	Azure Sapphire
18	Lycaenidae	*Heliophorus tamu* (Kollar, [1848])	Powdery Green Sapphire
19	Lycaenidae	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue
20	Lycaenidae	*Lycaena panava* (Kollar, 1848)	White-Bordered Copper
21	Lycaenidae	*Lycaena phlaeas* (Linnaeus, 1761)	Small Copper
22	Lycaenidae	*Phengaris atroguttata* (Oberthür, 1876)	Great Spotted Blue
23	Lycaenidae	*Pseudozizeeria maha* (Kollar, [1844])	Pale Grass Blue
24	Lycaenidae	*Rapala nissa* (Kollar, [1844])	Common Flash
25	Lycaenidae	*Udara dilecta* (Moore, 1879)	Pale Hedge Blue
26	Lycaenidae	*Zizeeria karsandra* (Moore, 1865)	Dark Grass Blue
27	Nymphalidae	*Aglais caschmirensis* (Kollar, [1848])	Indian Tortoiseshell
28	Nymphalidae	*Aglais rizana* (Moore, 1872)	Mountain Tortoiseshell
29	Nymphalidae	*Argynnis altissima (*Elwes, 1882)	Mountain Silverspot
30	Nymphalidae	*Argynnis childreni* Gray, 1831	Large Silverstripe
31	Nymphalidae	*Argynnis hyperbius* (Linnaeus, 1763)	Indian Fritillary
32	Nymphalidae	*Athyma opalina* (Kolar, [1844])	Hill Sergeant
33	Nymphalidae	*Aulocera loha* Doherty, 1886	Doherty's Satyr
34	Nymphalidae	*Aulocera padma* (Kollar, [1844])	Great Satyr
35	Nymphalidae	*Aulocera saraswati* (Kollar, [1844])	Striated Satyr
36	Nymphalidae	*Aulocera swaha* (Kollar, [1844])	Common Satyr
37	Nymphalidae	*Chonala masoni* (Elwes, 1883)	Chumbi Wall
38	Nymphalidae	*Euthalia aconthea* (Cramer, [1777])	Common Baron
39	Nymphalidae	*Euthalia telchinia* (Ménétriés, 1857)	Blue Baron
40	Nymphalidae	*Issoria issaea* (Moore, 1946)	Himalayan Queen of Spain Fritillary
41	Nymphalidae	*Junonia iphita* (Cramer, [1779])	Chocolate Pansy
42	Nymphalidae	*Junonia orithya* (Linnaeus, 1758)	Blue Pansy
43	Nymphalidae	*Kaniska canace* (Linnaeus, 1763)	Blue Admiral
44	Nymphalidae	*Lethe baladeva* (Moore, 1865)	Treble Silverstripe
45	Nymphalidae	*Lethe maitrya* de Nicéville, 1880	Barred Wood Brown

	Family	Scientific name	Common name
46	Nymphalidae	*Lethe mekara* (Moore, 1858)	Common Red Forester
47	Nymphalidae	*Lethe nicetas* (Hewitson, 1863)	Yellow Wood Brown
48	Nymphalidae	*Lethe nicetella* de Nicéville, 1887	Small Wood Brown
49	Nymphalidae	*Lethe sidonis* (Hewitson, 1863)	Common Wood Brown
50	Nymphalidae	*Libythea myrrha* Godart, 1819	Club Beak
51	Nymphalidae	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown
52	Nymphalidae	*Mimathyma ambica* (Kollar, [1844])	Indian Purple Emperor
53	Nymphalidae	*Neope pulaha* (Moore, 1858)	Veined Labyrinth,
54	Nymphalidae	*Neope pulahina* (Evans, 1923)	Scarce Labyrinth
55	Nymphalidae	*Nymphalis antiopa* (Linnaeus, 1758)	Camberwell Beauty
56	Nymphalidae	*Parantica sita* (Kollar, [1884])	Chestnut Tiger
57	Nymphalidae	*Polygonia agnicula* (Moore, 1872)	Nepal Comma
58	Nymphalidae	*Rhaphicera moorei* (Butler, 1867)	Small Tawny Wall
59	Nymphalidae	*Sephisa chandra* (Moore, 1858)	Eastern Courtier
60	Nymphalidae	*Tirumala septentrionis* (Butler, 1874)	Dark Blue Tiger
61	Nymphalidae	*Vanessa cardui* (Linnaeus, 1758)	Painted Lady
62	Nymphalidae	*Vagrans egista* (Cramer, 1780)	Vagrant
63	Nymphalidae	*Vanessa indica* (Herbst, 1794)	Indian Red Admiral
64	Nymphalidae	*Ypthima parasakra* Eliot, 1987	Dubious Five-Ring
65	Papilionidae	*Byasa dasarada* (Moore, 1857)	Great Windmill
66	Papilionidae	*Byasa latreillei* (Donovan, 1826)	Rose Windmill
67	Papilionidae	*Byasa polyeuctes* (Doubleday, 1842)	Common Windmill
68	Papilionidae	*Graphium cloanthus* (Westwood, 1841)	Glassy Bluebottle
69	Papilionidae	*Graphium paphus* (de Nicéville, 1886)	Spectacle Swordtail
70	Papilionidae	*Graphium sarpedon* (Linnaeus, 1758)	Common Bluebottle
71	Papilionidae	*Papilio arcturus* (Westwood, 1842)	Blue Peacock
72	Papilionidae	*Papilio bianor* (Cramer, [1777])	Chinese Peacock
73	Papilionidae	*Papilio demoleus* (Linnaeus, 1758)	Lime Butterfly
74	Papilionidae	*Papilio helenus* (Linnaeus, 1758)	Red Helen
75	Papilionidae	*Papilio machaon* (Linnaeus, 1758)	Common Yellow Swallowtail
76	Pieridae	*Aporia agathon* Gray, 1831	Great Blackvein
77	Pieridae	*Aporia harrietae* (de Niceville, [1892])	Bhutan Blackvein
78	Pieridae	*Aporia peloria* (Hewitson, 1852)	Tibetan Blackvein
79	Pieridae	*Colias fieldii* (Menetries, 1855)	Dark Clouded Yellow
80	Pieridae	*Delias sanaca* (Moore, 1857)	Pale Jezebel
81	Pieridae	*Eurema andersonii* (Moore, 1886)	One Spot Grass Yellow
82	Pieridae	*Eurema blanda* (Boisduval, 1836)	Three- Spot Grass Yellow
83	Pieridae	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow
84	Pieridae	*Eurema laeta* (Boisduval, 1836)	Spotless Grass Yellow
85	Pieridae	*Gonepteryx mahaguru* Gistel, 1857	Lesser Brimstone
86	Pieridae	*Gonepteryx rhamni* (Linnaeus, 1758)	Common Brimstone
87	Pieridae	*Ixias pyrene* (Linnaeus, 1764)	Yellow Orange Tip
88	Pieridae	*Pieris brassicae* (Linnaeus, 1758)	Large Cabbage White
89	Pieridae	*Pieris canidia* (Linnaeus, 1768)	Indian Cabbage White
90	Pieridae	*Pieris extensa bhutya* Poujade, 1888	Bhutan Extended White

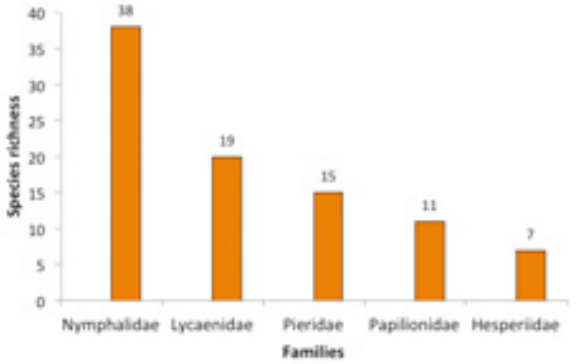

Figure 2. Family-wise distribution of butterfly species in Gidakom Forest.

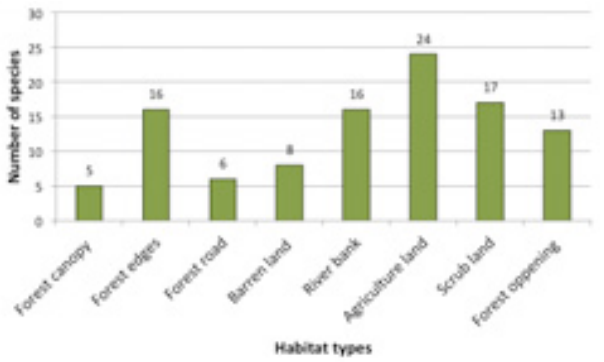

Figure 3. Distribution of butterfly species based on habitat types in Gidakom Forest

Figure 4. Temporal distribution of butterfly species in Gidakom Forest

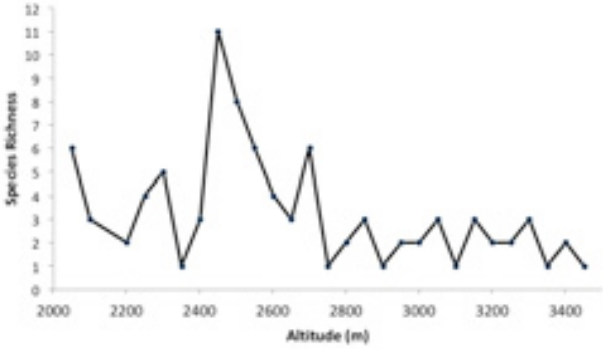

Figure 5. Distribution of butterfly species along the altitudinal gradients in Gidakom Forest.

Temporal distribution of butterflies

Most species were found in the monsoon season, particularly between May and August. Minimum species richness was observed during January (n=16, 17.77%) and a monotonic increasing trend of species occurrence was observed over succeeding months reaching a maximum (n=86, 95.55%) in August. From September a monotonic declining trend of species richness was observed until winter. The high numbers of butterflies during the monsoon season corresponded with the flowering of local plant species in the study locations.

Dark Clouded Yellow *Colias fieldii*, Large Cabbage White *Pieris brassicae*, Indian Cabbage White *Pieris canidia*, Green Veined White *Pieris napi*, Pale Clouded Yellow *Colias fieldii*, Lesser Brimstone *Gonepteryx mahaguru*, and Common Brimstone *Gonepteryx rhamni nepalensis* belonging to Peiridae family and species such as; Blue Pansy *Junonia orithiya*, Indian Red Admiral *Vanessa indica*, Indian Tortoiseshell *Aglais cashmiriensis*, Queen of Spain Fritillary *Issoria issaea*, Painted Lady *Vanessa cardui*, and Mountain Tortoiseshell *Aglais rizana* belonging to Nymphalidae family were recorded throughout the year. Of the 90 recorded species, about 14% of them were seen throughout the year in the study area.

Spatial distribution

The spatial distribution of butterflies (species richness) of Gidakom varied from 84 to 37 among study locations. Maximum species richness (S=83), diversity (H'=4.17) and relative abundance (42.75%) were observed in Chimithanka. This was followed by Jamdo, and minimum species richness (S= 42), diversity (H'=3.47), relative abundance (23.41%) was observed in Jedekha, however, there was marginal variation in species evenness among these three study locations (Table 2). Species richness pecked at an altitudinal range between 2400–2600 m with (32, 35.16%) of the total observed species and declining trend was observed in subsequent zones towards higher elevational (Figure 5). A total number of individuals recorded varied from 127 to four individuals. The calculated median value for each site is shown in (Figure 6).

The Blue Pansy *Junonia orithiya* was found to be most common and widely distributed species, followed by Straited Satyr *Aulocera saraswati*, Dark Clouded Yellow

Table 2. Species composition in different study locations within Gidakom Forest.

	Study locations		
Parameters	**Jamdo**	**Chimithanka**	**Jedekha**
Altitude (m)	2100–2500	2500–2900	2900–3400
Species richness	72	83	37
Diversity(H)	3.90	4.15	3.34
Evenness (E)	0.91	0.93	0.92
Relative abundance (%)	33.82	42.75	23.41

Colias fieldii, Large Cabbage White *Pieris brassicae*, and Indian Cabbage White *Pieris canidia*. These species were found in all the three study sites.

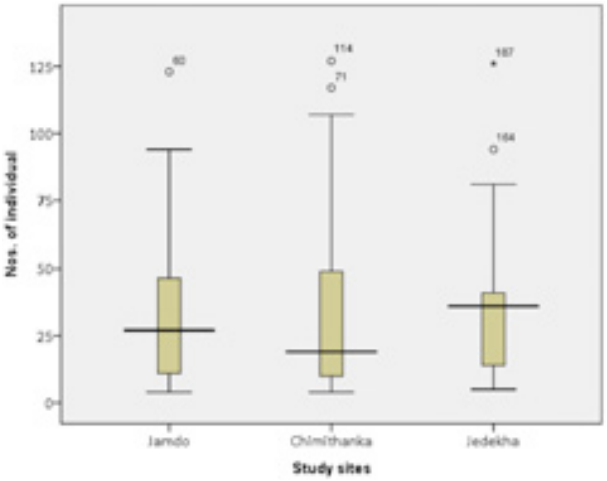

Figure 6. The box plots showing the median of species abundance in three different study sites.

DISCUSSION

More than 12% of 732 butterfly species were recorded in Gidakom Forest. Observed species previously reported as rare in Bhutan (Singh 2016) included: White Banded Copper *Lycaena panava* (Lycaenidae), Pale Clouded Yellow *Colias fieldii* (Pieridae), Camberwell Beauty *Nymphalis antiopa*, Mountain Tortoiseshell *Aglais rizana*, and Scarce Labyrinth *Neope pulahina* (Nymphalidae), and Blue Peacock *Papilio arcturus* (Papilionidae).

Nymphalidae were found to be the dominant family, occupying a majority of habitat types and occurring throughout the year in Gidakom Forest. This is consistent with Nymphalidae being the largest butterfly family, accounting for one third of known species worldwide (Kumar & Sharma 2013). The dominance of Nymphalidae species may be attributed to their ability to feed on various kinds of food, and many species of this family are active fliers, thus having ecological advantages to forage larger areas.

Majority of the species were found in heterogeneous habitats: farmland, scrubland, forest edges and river banks. Many studies have reported a positive relationship between habitat heterogeneity and species diversity (Bazzaz 1975; Brooks 1997; Atauri & Lucio 2001; Tews et al. 2004). Possible reasons include increased availability and variety of host plants. The distribution and diversity of butterflies varies with the seasons. They are abundant in some months and rare or absent during others (Kunte 2000). In this study, we observed that species richness and relative abundance peaked during the monsoon (June–August). This has been reported in other studies (e.g. Qureshi et al. 2013), but it has also been reported that butterfly numbers and diversity peaked post-monsoon (e.g. Tiple et al. 2007; Tiple 2012). This dissimilarity in seasonal distribution of butterflies may be due to variation in geographical region with corresponding environmental factors. In mountain ecosystem, distribution of butterfly species is determined by its habitat and climatic stability (Stroch et al. 2003).

Species richness, abundance and diversity followed a declining trend along the elevation gradient, with only 37 species occurring above 2900m. Studies in Sikkim showed a similar distribution pattern (Acharya & Vijayan 2015). A strong link between altitude and changes in climate and vegetation was observed by Körner (2007), thus species assemblages can shift rapidly over relatively short distances (Bullock et al. 1995; van Ingen et al. 2008). The climate above 2900m is characterized by a prolonged winter with freezing temperatures and a relatively short growing season. According to McCain (2010), decreasing species diversity is mainly because of decreasing temperature, productivity, precipitation and plant species diversity along the elevation gradient. We observed a majority of butterfly species in areas below 2900m. The higher species richness, diversity, and abundance in lower altitudinal areas could be due to relatively high temperature, habitat heterogeneity and increased diversity of host and food plants. According to Sengupta et al. (2014) butterfly community is mostly determined by the larval host plants.

Image 1. Bhutan Blackvein

Image 2. Blue Admiral

Image 3. Blue Pansy

Image 4. Chestnut Tiger

Image 5. Lesser Brimstone

Image 6. Common Grassdart

Image 7. Hill Hedge Blue

Image 8. Common Flash

Image 9. Common Evening Brown

Image 10. Dubious Five-Ring

Image 11. Eastern Courtier

Image 12. Painted Lady

Image 13. Indian Purple Emperor

Image 14. Large Cabbage White

Image 15. Large Silverstripe

Image 16. Common Yellow Shallowtail

Image 17. Nepal Comma

Image 18. Pale Clouded Yellow

Image 19. Queen of Spain Fritillary

Image 20. Spectacle Swallowtail

Image 21. Straited Satyr

Image 22. Tailed Cupid

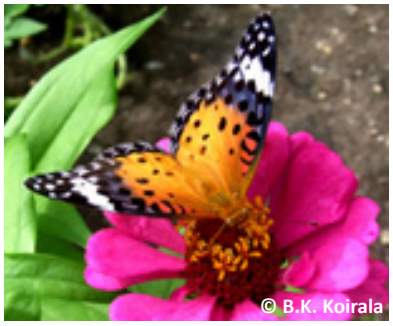

Image 23. Indian Fritillary

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COMMUNICATION

Butterfly diversity in heterogeneous habitat of Bankura, West Bengal, India

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Abstract: Butterfly diversity was observed in different habitats of Bankura District, West Bengal, India. This district is located at the junction of Chotanagpur plateau and Gangetic plain; it contains a variety of transitional habitats. We found 117 butterfly species from our covered survey area. The highest species recorded in the present study belonged to family Lycaenidae (30.76%) and Nymphalidae (29.91%) followed by Hesperiidae (16.23%), Pieridae (13.67%), Papilionidae (8.54%), and Riodinidae (0.85%), respectively. Based on sighting we found that 12.82% of all the butterflies recorded were abundant in nature while 21.36% were very common, 41.88% were frequent, and 23.93% were rare. Cluster analysis and other diversity indices gives us an overall idea about environmental health. The pattern of diversity change from plain to plateau gradient gives important insight about ecological edge effect. High species number in relation with low individual numbers were found in forest habitat. This preliminary study showed that heterogeneous habitats could harbour many butterflies and need proper conservation efforts to sustain it.

Keywords: Chotanagpur plateau, diversity, heterogenous habitat, Lepidoptera, transitional habitats.

সারাংশ : পশ্চিমবঙ্গের বাঁকুড়া জেলায় প্রজাপতির বৈচিত্র পর্যবেক্ষণ করা হয়েছে। এই জেলাটি গাঙ্গেয় সমভূমি ও ছোটনাগপুর মালভূমির সংযোগস্থলে অবস্থিত, সুতরাং এটা বিভিন্ন পরিবর্তকালীন স্বাভাবিক আবাসস্থল ধারণ করে। আমরা মোট ১১৭ রকমের প্রজাপতি প্রজাতি পেয়েছি এই এলাকা থেকে। সবচেয়ে বেশি প্রজাতি পাওয়া গেছে লাইসিনাইডি (৩০.৭৬%) ও নিমফালাইডি (২৯.৯১%) পরিবারে, তার পরে যথাক্রমে হেস্পেরিডি (১৬.২৩%), পিয়েরাইডি (১৩.৬৭%), পাপিলোনিডি (৮.৫৪%) এবং রিওডিনিডি (০.৮৫%) পরিবারে। পর্যবেক্ষণ অনুসারে আমরা প্রচুর পরিমানে পেয়েছি ১২.৮২%, যথেষ্ট পরিমানে পেয়েছি ২১.৩৬%, মোটামুটি পরিমানে পেয়েছি ৪১.৮৮%, ও কম পরিমানে পেয়েছি ২৩.৯৩% প্রজাপতি। প্রজাতির বৈচিত্র সূচক ও গুচ্ছবদ্ধকরণ আমাদের স্থানীয় পরিবেশের স্বাস্থ্য সম্পর্কে ধারণা দেয়। সমভূমি থেকে মালভূমিতে প্রজাপতি বৈচিত্রের ক্রমপরিবর্তন বাস্তুতন্ত্রের প্রান্তিক প্রভাব সম্পর্কে গুরুত্বপূর্ণ তথ্য সরবরাহ করে। বেশি প্রজাতি পাওয়া গেছে জঙ্গলযুক্ত আবাসস্থলে। প্রাথমিক ভাবে এই গবেষণা মনে করছে নানাধর্মী আবাসস্থল অনেক বেশি পরিমানে প্রজাপতি প্রজাতি ধারণে সক্ষম ও তাদের যথাযত সংরক্ষণের প্রয়োজন।

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Author contribuion: KM collected all the field data and photographs. He also wrote primary draft of the manuscript. AM analysed the data and helped in manuscript improvement.

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INTRODUCTION

Butterflies are one of most important pollinators and herbivores in nature (Kunte 2000; Tiple et al. 2006) and they also have coevolved with plants (Ehrlich & Raven 1964). Mostly they live on nectar and in larval condition leaves of host plant. Larva of the member of Family Lycaenidae sometimes may associated with ants (Nimbalkar et al. 2011). They are also considered as good indicators of ecosystem health due to their sensitivity to environmental parameters (New 1991; Pollard et al. 1994; Kunte 2000; Thomas 2005; Bonebrake et al. 2010). Anthropogenic effects on habitat quality are well reflected by these organisms (Kocher & Williams 2000; Kunte 2000; Summerville & Crist 2001; Koh 2007). In general, species diversity and richness indices with special references to bioindicator group helps in better ecosystem management (Wilson et al. 2004).

In the present investigation we studied butterfly diversity of Bankura District of West Bengal, India, that contains some completely different types of habitat having unique geomorphological variations. Being a part of Chotanagpur plateau the present study sites contained undulating landscape, some hills as well alluvial plain, and the probability of harbouring many new species too (Mirza & Mondal 2018). So, this less explored area might shed light upon how butterfly diversity could have changed across the geomorphological gradient in relation to ecosystem health. Major outcome of this study might help in conservation of this least explored area of West Bengal, India.

MATERIALS AND METHODS

Study site

Bankura District is situated in the western part of southern West Bengal (Figure 1). It contains both plains of Bengal and plateau of Chotanagpur. Eastern to north-eastern site of this land are low-lying alluvial plains while on other side western zone gradually rises altitude, and fringed region of plateau starts; characterized by rocky undulating landscape. Numerous small monadnocks are interspersed in this area which are locally known as 'Tila' along with two major hills, namely: Susunia (448m) and Biharinath (451m). They are mainly made up of igneous rocks of the Archaean era as well as coal-bearing mudstone and quartzite rocks of Carboniferous period. The district also contains several rivers like Damodar, Dwarakeswar, Shilabati, Kangsabati, Sali, Gandheswari, Kukhra, Birai, Jaypanda and Bhairabbanki. Climatic condition of the characterized by an overbearingly hot summer, high humidity nearly all the year around and well distributed rainfall (1,303.7mm) during the monsoon months. The cold weather starts from about middle of November and lasts till the end of February. Summer months extends from March to May. We had chosen six area (Image 1) to conduct our survey along the geomorphological and altitudinal gradient to cover almost every type landscape and habitat of this district (Table 1).

Site A Deciduous Sal forest and red, laterite soil covers a major portion of this district. Taldangra, Simlapal, Onda, Joypur, Bishnupur, Beliator represents this region. Average altitudinal variation ranges 75–150 m. Moisture content of soil is relatively low compared to Vindhya alluvial soil and also vegetation type majorly differs from it.

Site B Raipur, Sarenga, Pali are situated beside Kangasabati River. Numerous 'tila' can be found dispersed throughout the region which are locally called "Masaker Pahar". Poor ferruginous soil and hard bed laterite are the characteristic soil types. Vegetation is mainly characterized by scrub jungles. Actually, this is located at the fringed region of Chotanagpur plateau.

Site C The rarh region in this district is represented by the region between Damodar and Dwarakeswar rivers, especially areas like Raibaghini, Kotulpur, Indas, and Patrasayer. Average altitudinal variation is 5–100 m and soil profile is characterized by Vindhya alluvial soil type. Actualy, almost 37% of this district contain this type of soil.

Site D This study site was mostly associated with dry agricultural land. Kadamdeuli and its surroundings constituted an excellent wetland as well as riparian ecosystem that harboured a rich butterfly diversity. Kadamdeuli reservoir is situated on Silabati River near Hatirampur.

Site E Susunia one of two hill situated in this district. This arid region contains a special type of island like habitat in the midst of agricultural land. Tropical dry deciduous type forest dominated by Sal tree (*Shorea robusta* Roth.). The hill is very rich in its plant resources including medicinal plants. Highest peak of this region is 442m.

Site F Jhilimili, Ranibandh, Sutan represents a dense dry deciduous forest mainly dominated by sal, nim, kendu tree. Average altitudinal variation is around 200m. Humus rich, friable gravelly soil with undulating perfect plateau landscape.

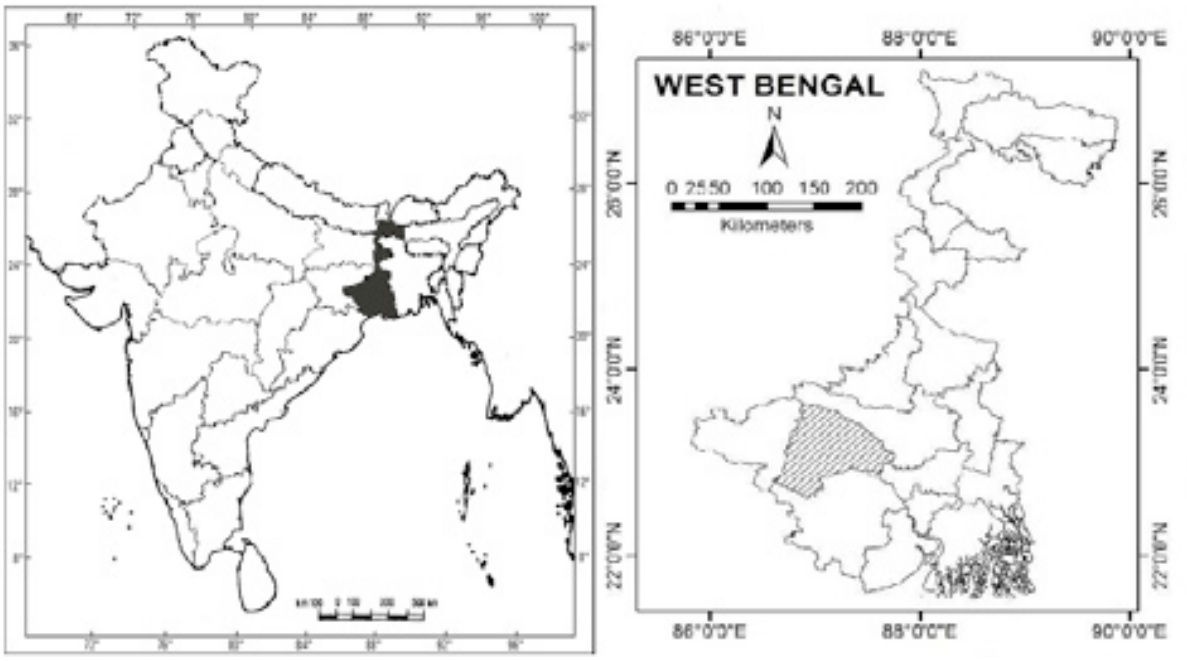

Figure 1. Location of Bankura District in West Bengal, India

Data Collection

The selected sites were surveyed from December 2012 to January 2019 to assess the diversity of butterflies. Yearly survey was categorized into three different seasons, viz., the Summer (March, April, May, and June), Winter (October, November, December, January, and February), Monsoon (July, August, and September). Pollard Walk Method (Pollard 1977) was followed for recording the butterflies while walking along surveyed paths along the areas. The observation width was limited to about 3m and at a stretch 150m on an average path covered. Flight periods, seasonality and abundance of butterfly species in different habitats were also recorded. Butterfly species were identified directly in the field or, in difficult cases, following capture or photography. As conservation policy, over collection was avoided and in fact specimens were collected only if doubts persisted in their specific identity. Rainfall and calm wind data were taken from India Meteorological Department and temperature, humidity data were taken by using a portable digital KTJ thermometer with humidity sensor.

Identification of the butterflies were primarily made directly in the field. In critical condition, specimens were collected only with handheld aerial sweep nets. Each specimen was placed in plastic bottles and was carried to the laboratory for further identification with the help field guide (Wynther-Blyth 1957; Kunte 2000) and butterfly taxonomist. The observed butterflies were grouped in five categories based on number of sighting in the field. The butterflies were categorized as Abundant (A>30%), Very Common (VC=10–30%), Frequent (F=5–10%), and Rare (R=1–5%) (Rajasekhar 1995).

Data Interpretation

Single factor ANOVA were done separately among sites and different season. Dominance_D, Simpson_1-D, Shannon_H, Evenness_e^H/S, Brillouin, Menhinick, Margalef, Equitability_J, indices were calculated. Individual rarefaction analysis was done among sites. Hierarchical classical clustering was performed using single linkage algorithm with Bray-Curtis similarity index and 10,000 bootstraps among sites. All the analysis was done in statistical software PAST Version 3.26 developed by Øyvind Hammer, Natural History Museum, University of Oslo.

RESULTS

During the course of study 117 species of butterflies, belonging to six families (Figure 2) were recorded. The highest number of butterflies was recorded belonging to the families Lycaenidae (36 species; Image 3), and Nymphalidae (35 species; Image 2), followed by Hesperiidae (19 species; Image 4), Pieridae (16 species; Image 5), Papilionidae (10 species; Image 6), and Riodinidae (1 Species; Image 7). Among them 15 were

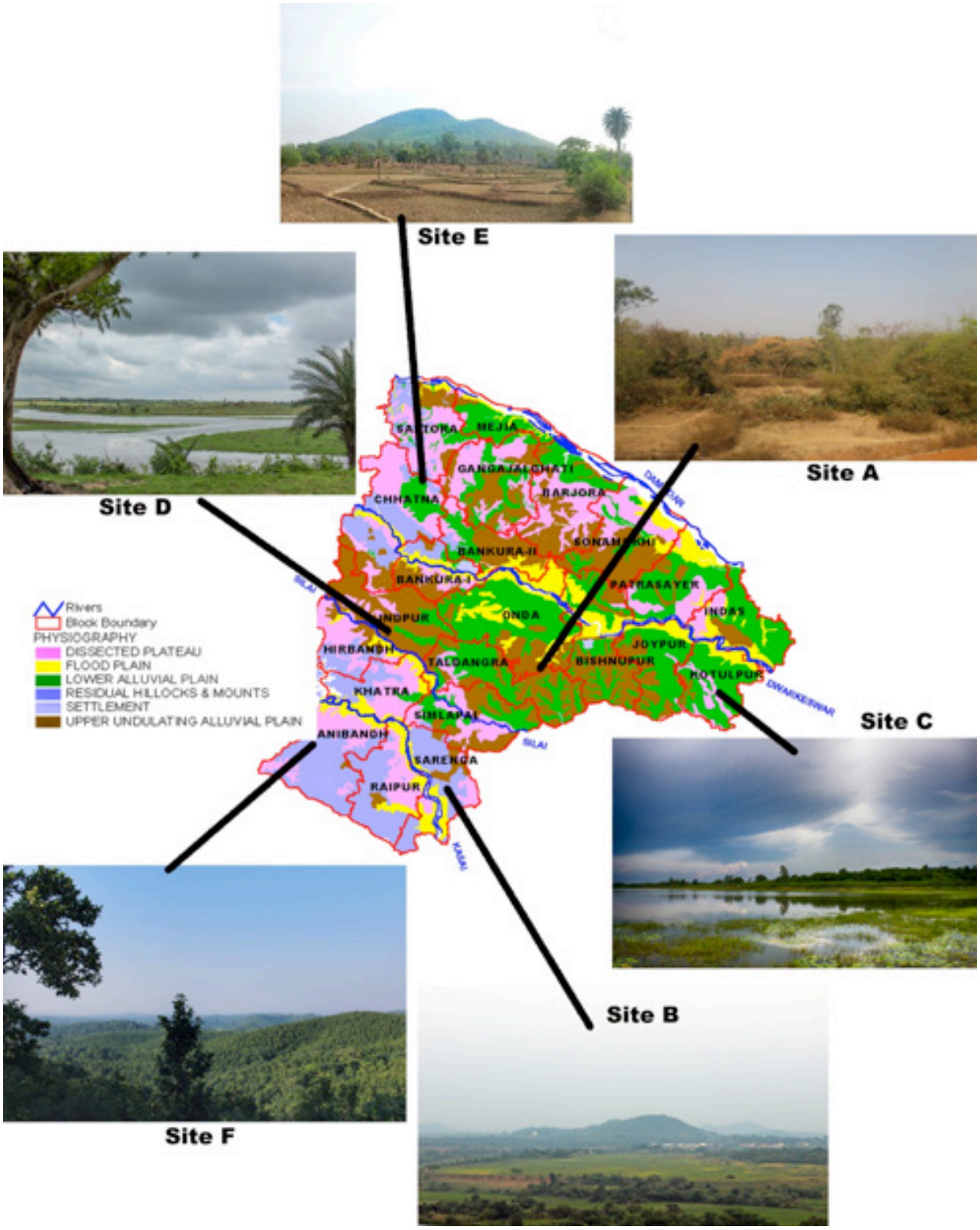

Image 1. Study sites and corresponding habitats.

Table 1. A brief description of the selected sites with habitat types (as per Champion & Seth 1968).

Site name	Habitat and forest type	Dominant larval host plants	Region (Latitude, Longitude), altitude
Site A	Tropical dry deciduous forest; Agricultural lands	*Soria robusta*, *Citrus limon*, *Citrus grandis*, *Citrus medica*, *Murraya koenigii*, *Sida rhombifolia*, *Portulaca oleracea*, *Cleome viscosa*, *Aristlochia indica*, *Aegle marme*, *Psidium guava*, *Glycosmis pentaphylla*, *Hygrophilia auriculata*, *Mangifera indica*, *Butea monosperma*, *Costus speciosus*	Taldangra (23.036°N, 87.126°E) 107m; Simlapal (22.946°N, 87.069°E) 96m; Onda (23.139°N, 87.208°E) 77m; Joypur (23.058°N, 87.429°E) 75m; Beliatore (23.314° N, 87.195°E) 106m; Bishnupur (23.039°N, 87.319°E) 94m
Site B	Tropical throny/scrub forests; Open grassland	*Aristlochia indica*, *Citrus grandis*, *Sida rhombifolia*, *Soria robusta*, *Tragia involucrate*, *Barleria cristata*, *Hygrophilia auriculata*, *Mangifera indica*, *Butea monosperma*, *Phoenix acaulis*	Raipur (22.805°N, 86.923°E) 104m; Sarenga (22.779°N, 87.041°E) 112m; Pali (22.780°N, 86.827°E) 131m
Site C	Agricultural lands and remnant of dry deciduous forest	*Citrus limon*, *Aristlochia indica*, *Mangifera indica*, *Phoenix acaulis*, *Ixora coccinea*, *Zingiber officinale*, *Laportea interrupta*, *Abrus precatorius*, *Polyalthia longifolia*, *Tamarindus indica*, *Bombax* sp., *Bauhinia acuminate*, *Flacourtia indica*, *Passiflora indica*, *Neolamarckia cadamba*, *Turnera ulmifolia*, *Ziziphus jujube*, *Glycosmis pentaphylla*	Raibaghini (23.029°N, 87.557°E) 37m; Indas (23.141°N, 87.614°E) 36m; Patrasayer (23.184°N, 87.540°E) 48m
Site D	Wetland and open grasslands	*Aristlochia indica*, *Mangifera indica*, *Phoenix acaulis*, *Tamarindus indica*, *Abrus precatorius*, *Hybanthus enneaspermus*, *Flacourtia indica*, *Cocos nucifera*, *Soria robusta*, *Butea monosperma*	Kadamdeuli (23.108°N, 86.867°E) 128m
Site E	Tropical dry deciduous forest	*Phoenix acaulis*, *Tamarindus indica*, *Soria robusta*, *Butea monosperma*, *Ziziphus jujuba*, *Ziziphus rugosa*, *Hygrophilia auriculata*, *Aristlochia indica*	Susunia (23.396°N, 86.988°E) 410m
Site F	Tropical Moist deciduous forest	*Aristlochia indica*, *Mangifera indica*, *Butea monosperma*, *Flacourtia indica*, *Terminalia elliptica*, *Ficus benghalensis*, *Terminalia bellirica*, *Abrus precatorius*, *Psidium guava*, *Glycosmis pentaphylla*, *Soria robusta*	Jhilimili (22.818°N, 86.633°E) 194m; Sutan (22.405°N, 86.739°E) 214m; Ranibandh (22.854°N, 86.779°E) 204m

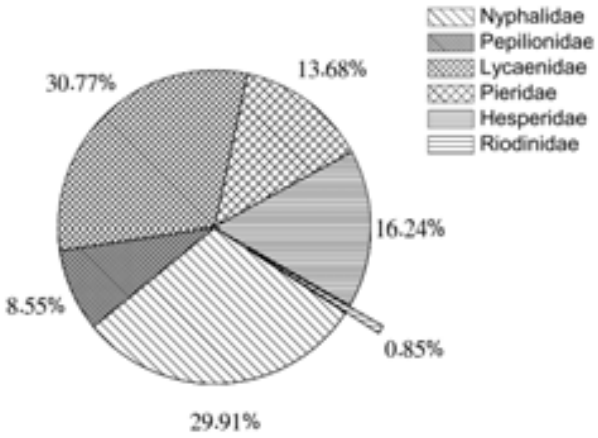

Figure 2. Relative number of species abundances among different family.

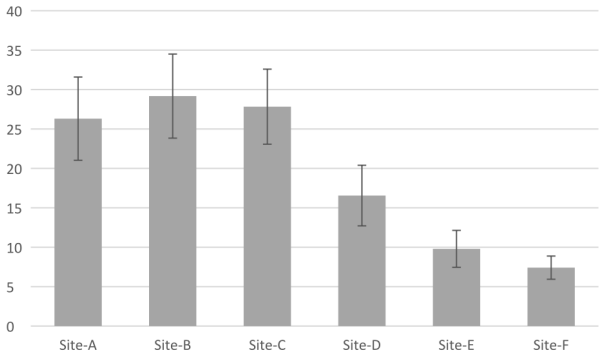

Figure 3. Site-wise average individual number per species.

abundant, 25 were very common, 49 were frequent, and 28 were rare (Table 2).

Ascending order of altitudinal heights of our sites are C < A < B < D < F < E (Table 1). Average individual number per species were highest in Site-B followed by C, A, D, E, and F (Figure 3). Single factor ANOVA among sites on the basis of individual number of different species showed significant difference ($p<0.001$). Number of butterfly species was highest in Site-C (91) followed by F (78), A (76), B (73), D (67), and E (65). Dominance index of all six sites ranges from 0.037 to 0.065 also Simpson 1-D index of all sites remains very close to 1. Berger-Parker index indicating single taxa dominance is relatively high in Site-D and E followed by F than A, B, C. But overall evenness and equitability show very little difference among sites. Shannon, Brillouin, Menhinick and Margalef index are also calculated (Table 3). There are significant differences ($p<0.05$) of butterfly diversity among different seasons. Individual rarefaction analysis of data when plotted in respect to 95 percent confidence of taxa in a conditional way showed probability of finding highest specimen in Site-B, followed by C, A, D, E, and F (Figure 4). Site-B and C are closely associated in terms

Table 2. List of butterflies with their local occurrence status: A—abundant (A>30%) | VC—very common (VC— 10–30%) | F—frequent (F—5–10%) | R—rare (R—1–5%) (Rajasekhar 1995)). Observed flight period (January—1 | February—2, March—3 | April—4 | May—5 | June—6 | July—7 | August—8 | September—9 | October—10 | November—11 | December—12).

Common name	Scientific name	Index of abundance	Flying period
Lycaenidae			
Common Pierrot	*Castalius rosimon*	A	1–12
Striped/Rounded Pierrot	*Tarucus nara*	VC	1–12
Lime Blue	*Chilades lajus*	VC	1–12
Tiny Grass Blue	*Zizula hylax*	F	3–7
Pale Grass Blue	*Pseudozizeeria maha*	VC	2–9
Dark Grass Blue	*Zizeeria karsandra*	A	1–12
Lesser Grass Blue	*Zizina otis sangra*	VC	1–12
Zebra Blue	*Leptotes plinius*	F	2–10
Gram Blue	*Euchrysops cnejus*	F	3–11
Common Line Blue	*Prosotas nora*	F	3–7
Large Oak Blue	*Arhopala amantes*	F	1–5,7–10
Indian Oak Blue	*Arhopala atrax*	F	2–7
Common Guava Blue	*Virachola Isocrates*	F	1–12
Pea Blue	*Lampides boeticus*	F	1–6
Leaf Blue	*Amblypodia anita*	F	4–7
Forget Me not	*Catochrysops strabo strabo*	VC	1–12
Common Cerulean	*Jamides celeno aelianus*	F	4–10
Dark Cerulean	*Jamides bochus*	F	10–7
Plains Blue Royal	*Pratapa deva deva*	R	4
The Quaker	*Neopithecops zalmora*	A	1–12
Common Red Flash	*Rapala airbus*	F	11–4
Indigo Flash	*Rapala varuna*	F	2–9
Slate Falsh	*Rapala manea*	F	12–7
Apefly	*Spalgis epeus*	F	11–3
Grass Jewel	*Freyeria trochylus*	F	10–4
Silver Streak Blue	*Iraota timoleon*	F	12–6
Monkey Puzzle	*Rathinda amor*	F	1–12
Yamfly	*Loxura atymnus*	F	3–11
Common Silverline	*Spindasis vulcanus*	F	1–12
Scarce Shot Silverline	*Spindasis elima*	R	6
Common Shot Silverline	*Spindasis ictis*	R	3–6
Tailless Lineblue	*Prosotas dubiosa*	R	3–8
Pointed Ciliate Blue	*Anthene lycaenina*	F	1–12
Indian Sunbeam	*Curetis thetis*	VC	8–1
Angled Sunbeam	*Curetis acuta*	R	12
Bright Babul Blue	*Azanus ubaldus*	R	6–7
Riodinidae			
Double Banded Judy	*Abisara bifasciata*	F	10–3

Common name	Scientific name	Index of abundance	Flying period
Nymphalidae			
Tawny Coster	*Acraea violae*	A	1–12
Angled Castor	*Ariadne ariadne*	A	1–12
Common Castor	*Ariadne merione*	VC	1–12
Great Eggfly	*Hypolimnas bolina*	VC	1–12
Danied Eggfly	*Hypolimnas misippus*	F	8–3
Common Leopard	*Phalanta phalantha*	A	1–12
Chocolate Pansy	*Junonia iphita*	F	1–12
Yellow Pansy	*Junonia hierta*	VC	5–9
Grey Pansy	*Junonia atlites*	VC	1–12
Blue Pansy	*Junonia orithiya*	VC	12–6
Lemon Pansy	*Junonia lemonias*	VC	1–12
Peacock Pansy	*Junonia almana*	VC	1–12
Baronet	*Euthalia nais*	VC	6–1
Gaudy Baron	*Euthalia lubentina indica*	R	4–6
Common Baron	*Euthalia aconthea*	A	1–12
Chestnut Streaked Sailer	*Neptis jumbah jumbah*	F	12–4
Common Sailer	*Neptis hylas*	F	12–4
Common Bushbrown	*Mycalesis perseus*	VC	1–12
Common Evening Brown	*Melanitis leda*	VC	1–12
Common Palmfly	*Elymnias hypermenstra*	VC	1–12
Plain Tiger	*Danaus chrysippus*	A	1–12
Striped/Common Tiger	*Danaus genutia*	F	9–2
Blue Tiger	*Tirumala limniace*	F	2–11
Common Crow	*Euploea core core*	A	1–12
Bamboo Tree Brown	*Lethe europa*	F	4–11
Commander	*Moduza procris*	F	2–11
Painted Lady	*Vanessa cardui*	R	3–6
Common Four Ring	*Ypthima huebneri*	F	1–12
Double Branded Crow	*Euploea sylvester*	R	1–12
Common Five Ring	*Ypthima baldus*	R	1–12
Black Rajah	*Charaxes solon*	R	3–9
Brown King Crow	*Euploea klugii*	F	1–12
Dark Branded Bushbrown	*Mycalesis mineus*	R	8–12
Common Nawab	*Charaxes athamas*	R	10–1
Tawny Rajah	*Charaxes bernardus*	R	4–10
Papilionidae			
Common Mormon	*Papilio polytes*	A	1–12
Blue Mormon	*Papilio polymnestor*	F	1–12

Common name	Scientific name	Index of abundance	Flying period
Common Rose	*Pachliopta aristolochiae*	VC	1–12
Tailed Jay	*Graphium agamemnon*	F	1–12
Common Jay	*Graphium doson*	F	1–12
The Lime	*Papilio demoleus*	A	1–12
Common Mime	*Papilio clytia*	F	1–12
Red Helen	*Papilio helenus*	R	8
Spot Swordtail	*Graphium nomius*	F	4–6
Common Banded Peacock	*Papilio crino*	R	2–11
Pieridae			
Common Jezebel	*Delias eucharis*	F	1–12
Psyche	*Leptosia nina nina*	A	1–12
Pioneer or Cape White	*Belenois aurota aurota*	F	1–12
Striped Albatross	*Appias olferna*	VC	1–12
Yellow Orange Tip	*Ixias pyrene*	VC	9–2
White Orange Tip	*Ixais marianne*	VC	9–2
Common Gull	*Cepora nerissa*	A	1–12
Common Emigrant	*Catopsilia pomona*	A	1–12
Mottled Emigrant	*Catopsilia pyranthe*	A	1–12
Common Grass Yellow	*Eurema hecabe*	VC	1–12
Three Spot Grass Yellow	*Eurema blanda*	F	1–12
Spotless Grass Yellow	*Eurema laeta*	R	1–12
Common Albatross	*Appias alpina*	R	2–6
One Spot Grass Yellow	*Eurema brigitta*	F	1–12

Common name	Scientific name	Index of abundance	Flying period
Indian Cabbage White	*Pieris canidia*	R	1
Chocolate Albatross	*Appias lyncida*	R	6–7
Hesperiidae			
Indian Skipper	*Spialia galba*	VC	1–12
Chestnut Bob	*Iambrix salsala*	F	3–11
Indian Palm Bob	*Suastus gremius*	F	1–12
Common Redeye	*Gangara thyrsis*	VC	1–12
Dark Palm Dart	*Telicota bambusae*	F	2–8
Rice Swift	*Borbo cinnara*	F	1–12
Brown Awl	*Badamia exclamationis*	F	2–11
Grass Demon	*Udaspes folus*	VC	5–10
Common Small Flat	*Sarangesa dasahara*	R	8–10
Common Grass Dart	*Taractrocera maevius*	R	6
Complete Paint-brush Swift	*Baoris farri*	F	3–8
Common Banded Awl	*Hasora chromus*	R	12–4
Tree Flitter	*Hyarotis adrastus*	R	10
Golden Angle	*Caprona ransonnettii*	R	10
Small-banded Swift	*Pelopidas mathias*	F	8–10
Obscure Branded Swift	*Pelopidas agna*	F	7–11
Water Snow Flat	*Tagiades litigiosa*	R	6
Tricolor Pied Flat	*Coladenia indrani*	R	7–8
Bush Hopper	*Ampittia dioscorides*	R	3–10

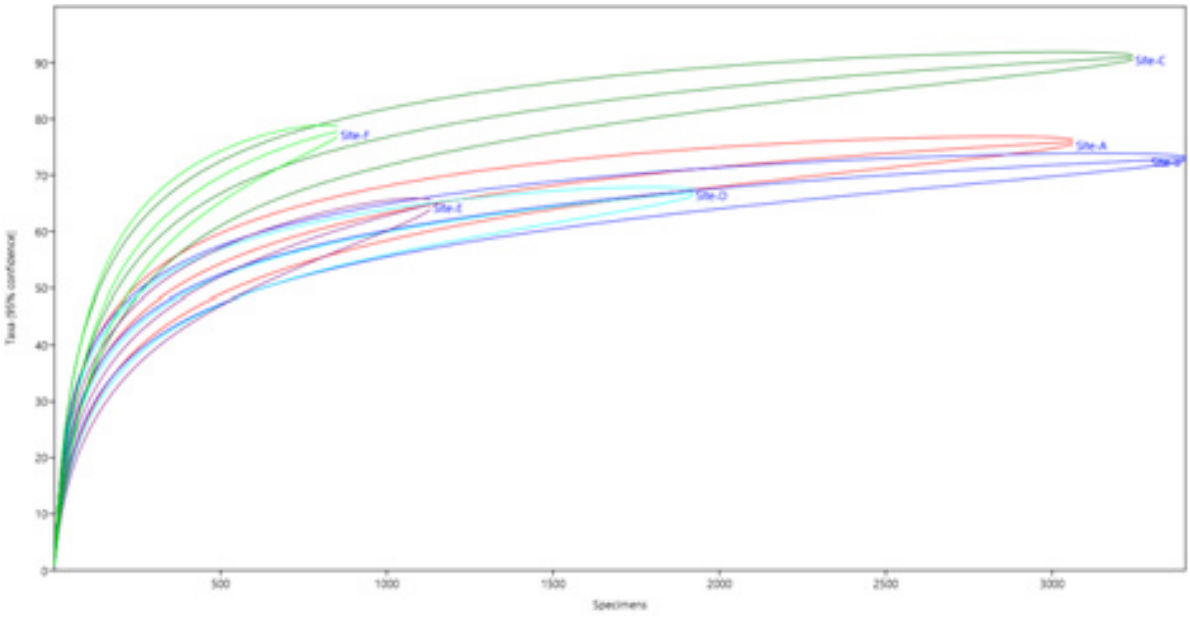

Figure 4. Individual rarefaction analysis plot.

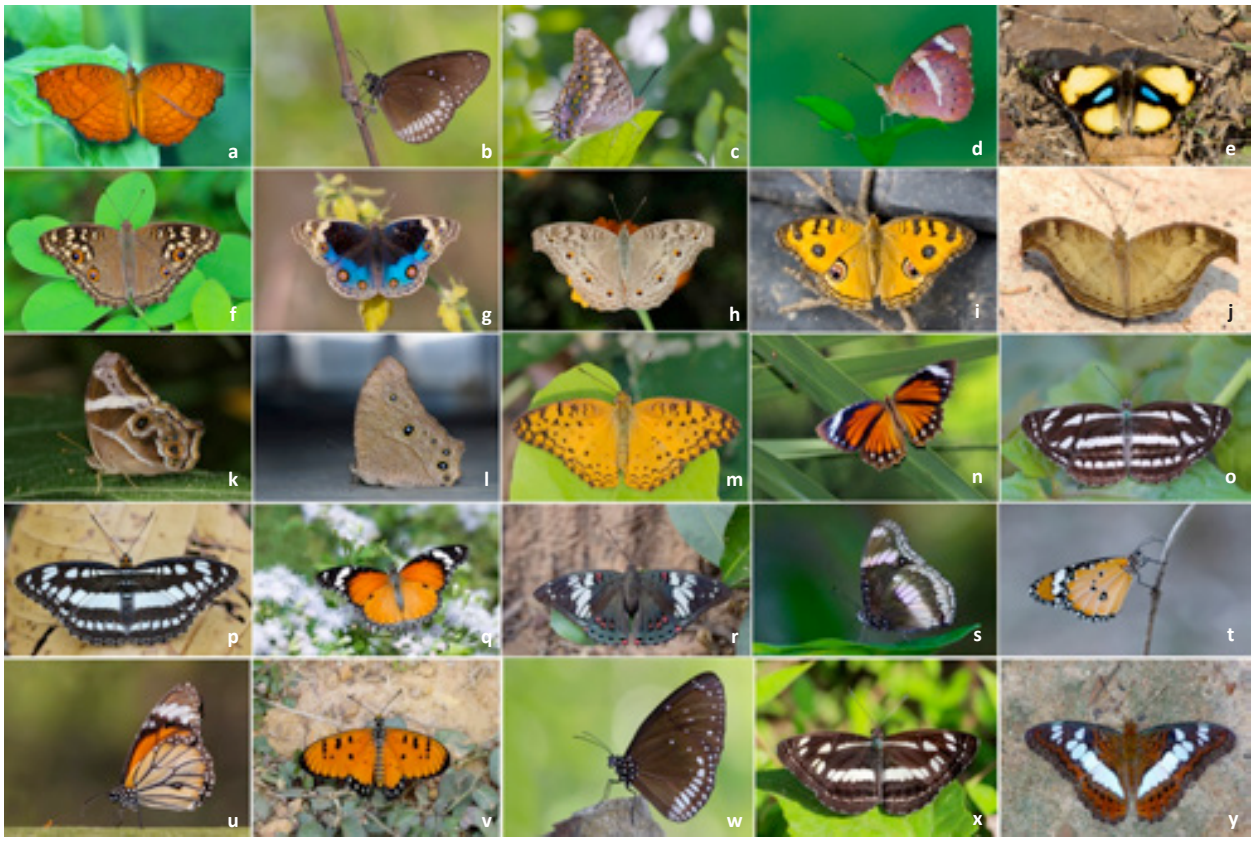

Image 2. Nymphalidae butterflies: a—Angled Castor | b—Common Crow | c—Black Rajah | d—Baronet | e—Yellow Pansy | f—Lemon Pansy | g—Blue Pansy | h—Grey Pansy | i—Peacock Pansy | j—Chocolate Pansy | k—Bamboo Tree Brown | l—Common Evening Brown | m—Common Leopard | n—Common Palmfly | o—Common Sailer | p—Common Sergeant | q—Danaid Eggfly | r—Gaudy Baron | s—Great Eggfly | t—Plain Tiger | u—Common Tiger | v—Tawny Coster | w—Brown King Crow | x—Chestnut Streaked Sailer | y—Commander. © Kalyan Mukherjee.

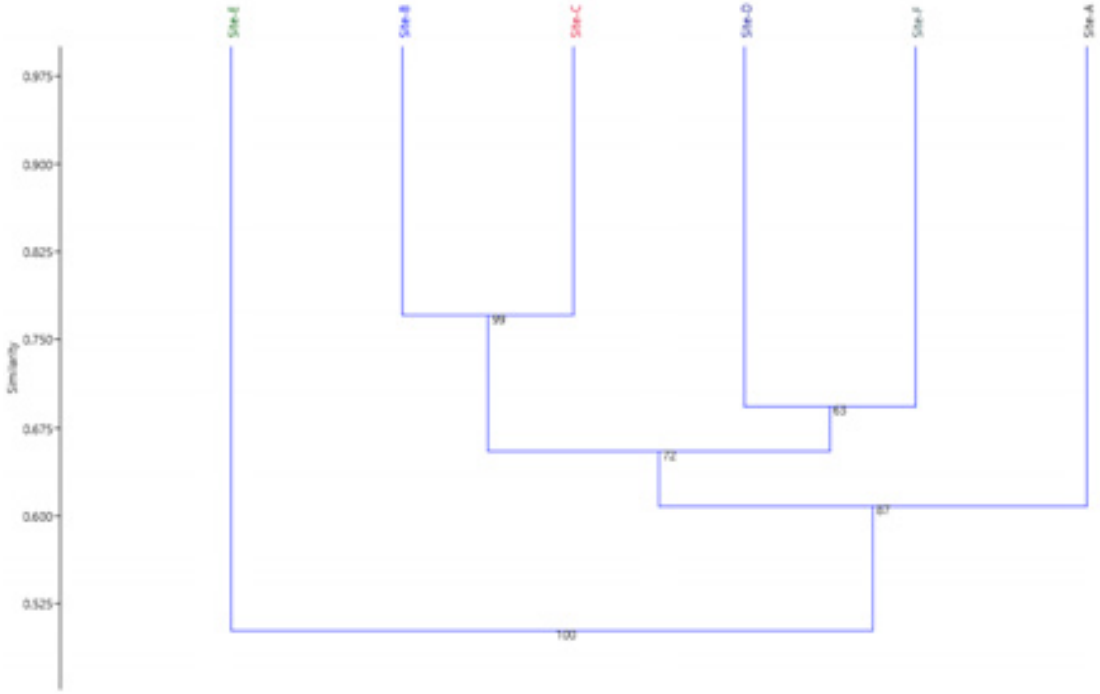

Figure 5. Hierarchical clustering using Bray-Curtis similarity index of studied sites.

Image 3. Lycaenidae butterflies: a—Plains Cupid | b—Red Flash | c—Silverstreak Blue | d—Slate Flash | e—Quaker | f—Zebra Blue | g—Tiny Grass Blue | h—Pale Grass Blue | i—Pea Blue | j—Pointed Ciliate Blue | k—Dark Grass Blue | l—Forget Me Not | m—Indian Sunbeam | n—Grass Jewel | o—Gram Blue | p—Bright Babul Blue | q—Guava Blue | r—Common Lineblue | s—Common Pierrot | t—Dark Cerulean | u—Apefly | v—Tailless Lineblue | w—Yamfly | x—Common Cerulean | y—Common Silverline. © Kalyan Mukherjee.

Table 3. Site-wise diversity and evenness indices.

	Site A	Site B	Site C	Site D	Site E	Site F
Taxa_S	91	76	73	65	78	67
Individuals	3256	3078	3413	1146	867	1937
Dominance_D	0.03756	0.0485	0.04168	0.06532	0.04768	0.06198
Simpson_1-D	0.9624	0.9515	0.9583	0.9347	0.9523	0.938
Shannon_H	3.698	3.419	3.479	3.217	3.595	3.303
Evenness_e^H/S	0.4435	0.4018	0.4442	0.384	0.4671	0.4059
Brillouin	3.638	3.367	3.432	3.118	3.441	3.234
Menhinick	1.595	1.37	1.25	1.92	2.649	1.522
Margalef	11.13	9.338	8.85	9.086	11.38	8.72
Equitability_J	0.8198	0.7894	0.8109	0.7707	0.8253	0.7856
Berger-Parker	0.09214	0.09942	0.07559	0.1745	0.1153	0.1719

of associated species composition after then D and F, these two-cluster associated with each other 73 percent similarity. Conjugated cluster of Site-B, C, D, and F are linked with A and E shows low level of similarity with rest of the cluster (Figure 5).

DISCUSSION

Butterfly diversity in different sites of this district helps to visualize the habitat heterogeneity; that indicates spatial distribution of host plant and nectaring plant along the landscape (Harrington & Stork 1995; Öckinger

Image 4. Hesperiidae butterflies: a—Brown Awl | b—Chestnut Bob | c—Tree Flitter | d—Indian Skipper | e—Complete Paint Brush swift | f—Common Red Eye | g—Common Grass Dart | h—Common Small Flat | i—Dark Palm Dart | j—Pale Palm Dart | k—Golden Angle | l—Grass Demon. © Kalyan Mukherjee.

Table 4. Correlation matrix among butterfly families and environmental factors.

	Nyphalidae	Papilionidae	Lycaenidae	Pieridae	Hesperiidae	Temp.	Humidity	Clam Wind	Rainfall
Nyphalidae	1.00								
Papilionidae	0.85	1.00							
Lycaenidae	0.88	0.83	1.00						
Pieridae	0.62	0.61	0.79	1.00					
Hesperiidae	0.69	0.59	0.83	0.80	1.00				
Temparature	0.01	-0.03	0.13	-0.02	0.08	1.00			
Humidity	-0.84	-0.72	-0.66	-0.35	-0.43	0.05	1.00		
Clam Wind	-0.23	-0.01	-0.15	0.11	-0.08	-0.65	0.24	1.00	
Rainfall	-0.55	-0.54	-0.49	-0.32	-0.38	0.43	0.68	-0.32	1.00

& Smith 2006; Öckinger et al. 2006, 2009; Mukherjee & Ghosh 2018). Being a good indicator of the health of an ecosystem (Stefanescu et al. 2004), richness of data of some distinct species found in different geographical area will help us to get an overview about the habitat of concerned locality. Generally, we can say among six studied sites, equitability index shows a similar pattern while Simpson 1-D and dominance index state that very few dominant species were present. Besides that, Shannon, Brillouin, and Menhinnick indices show little variability in those sites. High diversity of nymphalids and lycaenids in our data is consistent with other study on butterfly diversity (Dronamraju 1960; Roy et al 2012; Harsh 2014; Mukherjee et al 2015). Number of species and average individual number shows most ambiguous result in case of Site F. But this could be easily explained by the habitat characteristics of that site. This site mostly covered by dense forest. Probably we found lowest number of individuals per species here due to visual barrier in dense forest; but comparatively species number were higher due to presence of various types of host plant in forested area. Among 28 rare species Red

Image 5. Pieridae butterflies: a—Chocolate Albatross | b—White Orange Tip | c—Yellow Orange Tip | d—Pioneer | e—Striped Albatross (Male) | f—Striped Albatross (Female) | g—Common Gull | h—Common Grass yellow | i—Indian Jezebal | j—Common Wanderer (Male) | k—Common Wanderer Female | l—Mottled Emigrant (Male) | m—Psyche | n—Spotless Grass Yellow | o—Common Emigrant | p—Mottled Emigrant (Female). © Kalyan Mukherjee.

Image 6. Papilionidae butterflies: a—Blue Mormon | b—Common Banded Peacock | c—Common Jay | d—Common Mime | e—Common Mormon | f—Tailed Jay | g—Lime | h—Common Rose | i—Red Helen. © Kalyan Mukherjee.

Image 7. Riodinidae butterfly: Double Banded Judy.

Helen *Papilio helenus* and Chocolate Albatross *Appias lyncida* were just seen for couple of times.

Result of individual rarefaction analysis indicates that highest number of taxa could be found in Site C that contains a mixed habitat and landscape (Table 1). In contrast site B required more specimen than other sites to cover all the found taxa. Significant seasonal and site wise variation in species assemblage number were seen during the study period. Cluster analysis result shows hill region Site E is much distinct than other sites. Site-D and F were in plateau region, also clustered with 63% similarity; this is due to differences in habitat quality and type. It is indicating that altitude and landscape are not only determines species assemblage similarity, but habitat type and quality also effect on it. Site-B and C are representative of fringe region of plateau and makes a cluster with highest level of similarity. These two-cluster linked with each other with 72% similarity and the joined cluster linked with Site A, that is plains with totally different types of habitat. Family Nymphalidae, Papilionidae, and Lycaenidae negatively correlated with humidity. No noteworthy correlation found with temperature and clam wind; families Nymphalidae and Papilionidae shows moderately correlated with rainfall.

CONCLUSION

Butterfly diversity significantly changes throughout habitat and landscape type change. The rich diversity of butterflies, especially the nymphalids and lycaenids in the study area indicates a varied assemblage of floral species. Many rare species also indicating that some preferred habitat is in peril. Probability of getting high individual in fringe region of plateau as well as junction of two different landscape plain and plateau ecologically that can be stated as ecotone clearly shows the edge effect that is consistent with robust ecological theoretical concept. Plain, fringe region, plateau and hill region showing sharp differences among species richness and habitat quality through cluster analysis. Forested habitat shows high species with low number of individual, so it may harbour much more unexplored species. Being potential pollinating agents of their nectar plants as well as indicators of the health and quality of their host plants and the ecosystem as a whole, exploration of butterfly fauna thus becomes important in identifying and preserving various habitats under threat.

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COMMUNICATION

A second report on butterflies (Lepidoptera) from Ladakh Union Territory and Lahaul, Himachal Pradesh, India

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Abstract: Additional butterfly records and natural history observations are reported from a two-week survey of butterflies in Ladakh and Lahaul in the inner Himalaya in Ladakh Union Territory, and Himachal Pradesh in August 2018. These records follow an earlier report from a two-week survey in June–July 2016, and reports 10 species not sighted during the previous survey. Observations on early stages of *Pieris deota*, *Aglais ladakensis*, and *Papilio machaon ladakensis* are reported, as well as a mass emergence of *Parnassius epaphus*.

Keywords: Himalayas, Lepidoptera, mass emergence, palearctic.

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Author contribution: All the three authors participated in the field survey in Ladakh. Sanjay Sondhi drafted the manuscript and prepared some of the plates and the tables. Balakrishnan Valappil prepared some of the plates, provided inputs to and edited the manuscript. Vidya Venkatesh provided inputs to and edited the manuscript.

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INTRODUCTION

Sondhi et al. (2017) reported on butterflies sighted during a 12-day survey in Ladakh in June and July 2016, during which 42 species were recorded. In August 2018, the authors undertook another two week survey in Ladakh Union Territory (LUT). Species not sighted in 2016 are reported here, and a checklist of all butterflies recorded is provided with details of locations, altitudes and number of individuals sighted. Other interesting natural history observations are mentioned.

MATERIALS AND METHODS

A survey was conducted 3–15 August 2018 with the aim of covering as many habitats and altitudes as possible in Ladakh, making it necessary to use a vehicle throughout the survey period. The route (Table 1) extended through most parts of Leh District, covering its central, northern, eastern, and southern parts, as well as the exit through the Lahaul region in Lahaul and Spiti District of Himachal Pradesh (HP).

The methodology consisted primarily of visual encounter surveys in suitable habitats for butterflies, such as alpine meadows, grasslands, crop fields, and edges of stream and lakes. As we did not have permission to collect specimens, we relied primarily on photographs for identification. In addition to the date and location of sightings, we also noted the times at which individuals were encountered. Altitudinal elevations were recorded using a Garmin Etrex 10.

Existing literature was consulted for species identification and distributions (Marshall & de Nicéville 1882–1890, Bingham 1905–07; Swinhoe 1912–13; Evans 1927, 1932; Talbot 1939, 1947; Wynter-Blyth 1957; Cantlie 1963; Mani 1986; Smith 1994, 2006; Kinyon 2004; Tshikolovets 2005**;** Kehimkar 2008; Varshney & Smetacek, 2015; van Gasse 2017). Online sources were also consulted as aids to taxonomy and identification (Kunte et al. 2019; Savela 2019).

RESULTS

The 12-day survey resulted in the record of 42 species of butterflies from five families in 11 subfamilies (Table 2). Many of these species are rare and found in Palearctic habitats in the inner Himalaya. Seven species are protected under Schedule II of the Indian Wildlife (Protection) Act, 1972. A checklist of the species recorded along with their locations, altitudinal range, and estimated number of individuals is listed in Table 3. The summary of photographic records of the species not recorded in Sondhi et al. (2017) is provided in Image 1–7.

Table 1. Route taken during butterfly surveys

	Date	Route taken
1	03.viii.2018	Leh City outskirts (Spituk, Choklamsar) Leh District, LUT
2	04.viii.2018	Leh City outskirts (Sabu village & Chushut) in Leh District, LUT
3	05.viii.2018	Leh-Ganglas-South Pullu-Khardung La-North Pullu-Khardung village in Leh District, LUT
4	06.viii.2018	Khardung village-Khalsar-Hundar-Skuru-Turtuk in Leh District, LUT
5	07.viii.2018	Turtuk and surrounds in Leh District, LUT
6	08.viii.2018	Turtuk-Skuru-Hundar-Khema-Kinru in Leh District, LUT
7	09.viii.2018	Kinru-Khema-Warila Pass in Leh District, LUT
8	10.viii.2018	Warila Pass-Serthi-Sakti in Leh District, LUT
9	11.viii.2018	Sakti-Karu-Upshi-Miru-Latu-Rumste in Leh District, LUT
10	12.viii.2018	Rumste-Tanglang La-Debring-Pang in Leh District, LUT
11	13.viii.2018	Pang-Lachung La-Whiskey nala-Serchu in Leh District, LUT
12	14.viii.2018	Serchu-Baralacha Pass-Zing Zing Bar-Darcha-Jispa-Keylong in Lahaul Spiti District, HP
13	15.viii.2018	Keylong-Tandi-Sissu-Teling-Khoksar-Rohtang La-Kothi-Manali in Lahaul Spiti District, HP

Table 2. Species break up by family and subfamily

	Family	No of subfamilies	No of species
1	Hesperiidae	1	1
2	Lycaenidae	3	11
3	Nymphalidae	3	18
4	Pieridae	2	11
5	Papilionidae	1	1

DISCUSSION

The following section provides detailed information about the additional species recorded during the survey in August 2018 including dates/times at which they were recorded, locations, altitudes as well as relevant natural history observations and taxonomic notes, wherever necessary. The common names as well as alternative common names (ACN) in use are also mentioned (Evans 1932; Kunte et al. 2019). The legal protection accorded to these species, under the Indian Wildlife (Protection) Act, 1972, if any, is mentioned. Photographs of these

Image 1–7. Butterflies of Ladakh and Lahaul: 1—*Pieris rapae rapae* | 2—*Colias stolickzana stolickzana* | 3—*Lasiommata manava* (3a ♀ UP), (3b ♀ UN), (3c ♂ UP) | 4—*Paroeneis pumilus* | 5—*Karanasa* sp. | 6—*Lycaena aditya* (6a ♂ UN), (6b ♂ UP) | 7—*Parnassius epaphus* (7a UN), (7b UP), (7c crevice crawling). © © Sanjay Sondhi.

butterfly species are included in Image 1–7. In these images, the upperside of species is only provided if this is essential for species identity. In addition, gender of the butterfly in image as male (♂) or female (♀), if known, is mentioned.

Notes on species recorded in Ladakh and Lahaul in August 2018.

Family Pieridae, Subfamily Pierinae, Tribe Pierini

***Pieris rapae rapae* (Linnaeus, 1758) (Small Cabbage White)**

During the previous survey, we searched extensively for *P. rapae rapae* (Linnaeus, 1758), but did not record any individuals. During this visit we recorded this species

(Image 1) in multiple locations. On 03 August 2018, 15.30h, Choklamsar near Leh, altitude 3,211m, at least half a dozen individuals recorded. Most individuals were worn. Distinctly smaller in size than Indian Cabbage White *Pieris canidia indica*; very much whiter above, with a much narrower border on FW apex, along with a small, sometimes indistinct spot on UPF disc. On 04 Aug 2018, 14.44h, Chushut, Leh outskirts, altitude 3,500m, about half a dozen individuals were recorded. On 06 Aug 2018, 12.00h, farm fields beyond Hundar, altitude 3,123m, a few individuals were recorded. On 06 August 2018, 17.34h onwards, Turtuk, altitude 2,857m at least 15 individuals were spotted in the farm fields above Turtuk and photographed roosting in the evening after 18.00h. On 07 August 2018, 07.39h, Turtuk., 08.15–12.00 h fields above Turtuk, altitude 2,918m, 120 individuals counted. 10 August 2018, 16.53h, Sakti Village, altitude 3,740m, one individual.

Pieris rapae rapae (Linnaeus, 1758) is a range-restricted pierid, which is known only from Kashmir and Ladakh Union Territory in India (Wynter-Blyth 1957; Tshikolovets 2005; Varshney & Smetacek 2015). While we recorded the butterfly at multiple locations in reasonable numbers, there are a few published records of this species from Kashmir. The Butterflies of India website (Kunte et al. 2019) has only a single record of this species from Pakistan, and no records from India. A report by Bhardwaj et al. (2012) reported this species from Har-ki-dun in Gangotri Pashu Vihar National Park but presented no evidence in the form of photographs or specimens; hence this record from Uttarakhand remains unverified (Sondhi & Kunte 2018). Going by the numbers we encountered during our visit, *P. rapae* is locally abundant, especially in flowering fields.

***Pieris deota* de Nicéville, 1884 (Kashmir White)**

09 August 2018, 10.06h. Spotted an individual near Khema. 09 August 2018, 10.50–12.45 h, Khema, altitude 3,628m. Numerous individuals spotted before, at and beyond Khema Village. We spotted an egg-laying female (Image 8a–c). The host plant, yet to be identified, had dozens of caterpillars of *Pieris deota*. 11 August 2018, 10.07h, Sakti-Rumste road, altitude 3,632m. A few individuals spotted in fields along the road. Numerous caterpillars of *Pieris deota* recorded on the host plant, which is yet to be identified. We reported this species during the survey undertaken in 2016 (Sondhi et al. 2017), and as during the earlier survey in 2016, the species was not common anywhere.

Family Pieridae, Subfamily Coliadinae

***Colias stolickzana stolickzana* Moore, 1882 (Orange Clouded Yellow)**

10 August 2018, 10.18–10.53 h, below Warila Pass, altitude 5,205m. About 3km beyond the Warila Pass, the meadows were teeming with activity of Clouded Yellows, but the butterflies were not sitting at all. At one point, we ended up chasing butterflies across the meadows for 30 minutes without getting a photograph. In flight, the butterflies were bright orange above. A few distant photographs revealed the UNH veins were not pale yellow, and dark discal spots usually present, thereby identifying them as *Colias stolickzana stolickzana* Moore, 1882 (Image 2) and separating them from the similar *Colias eogene* (Evans 1932; Talbot 1947; Tshikolovets 2005).

Family Nymphalidae, Subfamily Nymphalinae, Tribe Nymphalini

***Aglais ladakensis* Moore, 1878 (Ladakh Tortoiseshell)**

05 August 2018, 10.33h, South Pullu, altitude 4,663m. A solitary individual recorded at the edge of the stream before South Pullu. The individual flew swiftly over the grassy patch, settled and took to wing again. The butterfly did not return to the area, despite SS spending 30 minutes searching the area. 10 August 2018, just below Warila Pass, altitude 4,927m. Photographed by LV at the stream below Warila Pass. 12 August 2018, 07.00–08.00 h, Rumste, altitude 4,558m. A kilometer after Rumste, enroute to Tanglang Pass, lots of caterpillars and pupae found on nettle plants along side road. The plant was identified as the Himalayan or Northern Nettle *Urtica hyperborea* Jacquem. ex Wedd (Urticaceae), whose local name is 'Dzatsutt' or 'Zozot' (Chaurasia et al. 2008). The caterpillar and its pupae were successfully reared, and its early stages documented (Images 9–17). Interestingly, though the caterpillars and pupae were abundant on most *Urtica hyperborea* plants that we examined, we spotted only two adults during our two-week visit, leading us to believe that the emergence of this species had yet to occur in large numbers. We did not record *A. ladakensis* during our Ladakh survey in June and July 2016 (Sondhi et al. 2017).

***Nymphalis xanthomelas fervescens* Esper, 1781 (Large Tortoiseshell)**

09 August 2018, 10.33h, just beyond Khema, altitude 3,628m. A single individual spotted alongside the road just after village Khema. 11 August 2018, 09.20h, Sakti-Rumste road, altitude 3,604m. A single individual

Image 8. ***Pieris deota*** **life cycle: a—♀ egg laying, b & c** ***Pieris deota*** **caterpillars. © Balakrishnan Valappil.**

was recorded in rocky habitat with some shrubs, alongside the road, near a stream. We did not record *N. xanthomelas* during our Ladakh survey in June and July 2016 (Sondhi et al. 2017).

Family Nymphalidae, Subfamily Satyrinae, Tribe Satyrini

***Lasiommata menava* Moore, 1865 (Dark Wall)**

04 Aug 2018, 08.34h, Sabu Village, Leh outskirts, altitude 3,900m. Solitary sighting of the female. 07 August 2018, 09.24h, fields above Turtuk, altitude 2,918m. Spotted a male and a worn female amongst the rocks bordering the fields above Turtuk. While the male (Image 3c) is entirely dark brown above, the female has a bright tawny sub-apical patch on the upperside of the forewing (Image 3a, 3b). We did not record *L. menava* during our Ladakh survey in June and July 2016 (Sondhi et al. 2017). *Lasiommata menava's* known range is from Baluchistan and Chitral in Pakistan east to Kashmir (Evans 1932; Talbot 1947; Tshikolovets 2005; Varshney & Smetacek 2015), however, a recent record by Abhay Soman and team from Himachal Pradesh extends its known range eastwards (Anonymous 2019).

***Paroeneis pumilus* (Felder & Felder, [1867]) (Ladakh Mountain Satyr)**

09 August 2018, 14.00h onwards, enroute to Warila Pass, altitude 4,139m. Spotted in a meadow, approximately 12km before Warila Pass. We counted at least 40–50 individuals. The butterfly (Image 4) had a very weak flight; never flying for long. The butterflies would settle amongst the grass blades, often hidden from view. 10 August 2018, 11.00h, ~ 4km below Warila Pass. Two individuals spotted alongside the road. 11 August 2018, 15.52–16.30 h, Rumste, altitude 4,379m. Spotted at least 40–50 individuals in the meadow alongside a stream, approximately 3km beyond Rumste. 12 August 2018, 07.30h, Rumste. Some individuals were active at 07.30h the next morning in the same meadow. We did not record *P. pumilus* during our Ladakh survey in June and July 2016 (Sondhi et al. 2017). This little-known species, whose distribution extends from Kashmir eastwards to Nepal (Smith 2006; Sondhi & Kunte 2018), was surprisingly common locally. Tshikolovets (2005) recorded it from Rupshu in 1998 and this remains the only recent published record of this species from India.

***Karanasa* sp.**

05 August 2018, 15.07h, North Pullu, altitude 4,658m. A solitary individual (Image 5) was recorded at the stream edge; only its underside was photographed. It was not possible to identify this to the species level without collecting specimens and molecular phylogeny and/or genitalia dissection.

Family Lycaenidae, Subfamily Theclinae

***Satyrium (Superflua) deria* (Moore, 1865) (Indian White-line Hairstreak)**

15 August 2018, 10.13–10.37 h, Tandi, altitude 2,992m. On a dry hill slope, 4km from Tandi Village, we spotted a large number of *Satyrium deria*. On a particular flower species, a small shrub with pinkish-purple flowers, there were always hairstreaks to be found; sometimes up to five individuals on a single bush.

Image 9–17. *Aglais ladakensis* life cycle: 9 & 10—Imago | 11,12(a,b)—Early instar caterpillar | 13—Final instar caterpillar | 14—Pupation | 15—Hostplant *Urtica hyperborea* | 16(a–c)—Pupa| 17—Pupal leaf cell. 9–16 © Balakrishnan Valappil, 17 © Sanjay Sondhi.

Table 3. Checklist of butterflies recorded during the August 2018 survey along with locality, altitude range, and abundance.

	Common name	Scientific name	Locations seen at	Altitude range in m	Estimated number of adults
Hesperiidae, Hesperiinae, Hesperiini					
1	Chequered Darter	*Hesperia comma dimila*	Below Warila Pass, below Tanglang Pass, below Baralacha Pass	4,900	3
Lycaenidae, Lycaeninae					
2	Ladakh Copper	*Lycaena aditya*	South Pullu	4,348	1
3	Common Copper	*Lycaena phlaeas*	Below Baralacha Pass, Patsio, Keylong, Tandi, Kokhsar	2,900–4,900	15–20
Lycaenidae, Polyommatinae					
4	Common Mountain Blue	*Albulina lehanus*	Khardung, Khema, Kinru, Sakti	3,700–4,130	10
5	Bright Green Underwing	*Pamiria chrysopis*	Keylong	3,000	6–8
6	Dusky Green Underwing	*Pamiria omphisa omphisa*	Sabu (near Leh), South Pullu, North Pullu, Warila Pass	3,900–4,800	20
7	Lahaul Meadow Blue	*Polyommatus ariana*	South Pullu, Ganglas, Hundar, Turtuk, Zing Zing Bar, Keylong, Kokhsar	3,000–4,600	85–90
8	Ladakh Meadow Blue	*Polyommatus stolickzana*	Spituk, Choklamsar, Sabu (all near Leh), Turtuk, Keylong, Sisoo, Kokhsar	2,800–3,200	10–12
9	Sea Jewel Blue	*Plebejus samudra samudra*	Spituk (near Leh), Turtuk	3,000	5–7
10	Eastern Baton Blue	*Pseudophilotes vicrama vicrama*	Ganglas, Turtuk	2,900–3,200	2
11	Hill Hedge Blue	*Celastrina argiolus kollari*	Choklamsar, Chushut (near Leh), Hundar, Turtuk	2,900–-3,200	15
Lycaenidae, Theclinae, Theclini					
12	Indian Whiteline Hairstreak	*Satyrium deria*	Tandi	3,000	15–20
Nymphalidae, Nymphalinae, Nymphalini					
13	Indian Tortoiseshell	*Aglais caschmirensis caschmirensis*	Below Baralacha Pass	4,900	1
14	Ladakh Tortoiseshell	*Aglais ladakensis*	Before South Pullu, below Warila Pass. Larvae near Rumste.	3,600–4,300	2
15	Large Tortoiseshell	*Nymphalis xanthomelas fervescens*	Khema, between Sakti & Rumste	3,600 m	2
16	Painted Lady	*Vanessa cardui*	Between Khardung & Khalsar, Turtuk, between Sakti & Rumste, Miru, below Baralacha Pass	3,500–4,290	4–5
Nymphalidae, Nymphalinae, Melitaeini					
17	Blackvein Fritillary	*Melitaea amoenula*	Near Khema & Kinru	3,600–4,100	10–12
Nymphalidae, Heliconiinae, Argynnini					
18	Highbrown Silverspot	*Argynnis jainadeva persephone* IWPA, SCH II	South Pullu, beyond Khardung, Khema, Kinru, enroute to Warila Pass	3,800–4,400	17–20
Nymphalidae, Satyrinae, Satyrini					
19	Common Satyr	*Aulocera swaha garuna*	Patsio, Keylong, Tandi,	3,000–3700	35–40
20	Narrow-banded Satyr	*Aulocera brahminus brahminus* IWPA, SCH II	near Khoksar, below Rohtang La	3,000–3,600	4–5
21	Scarce Mountain Argus	*Callerebia kalinda kalinda* IWPA, SCH II	Tandi	3,200	1
22	Short-branded Meadowbrown	*Hyponephele brevistigma brevistigma*	Khema, between Sakti & Rumste, Miru	3,600–3,800	5
23	Dusky Meadowbrown	*Hyponephele pulchra*	Keylong, Tandi, Kokhsar	3,000–3,200	15–20
24	Tawny Meadowbrown	*Hyponephele pulchella pulchella*	Ganglas, South Pullu	4,200	2
25	Tawny Satyr	*Karanasa cf. huebneri*	25 km before Serchu, after Serchu	4,400	8–10
26	Satyr sp.	*Karanasa sp.*	North Pullu	4658	1
27	Yellow Argus	*Paralasa mani mani* IWPA, SCH II	Ganglas, near South Pullu,	4,200–4,500	4
28	Tawny Rockbrown	*Pseudochazara lehana*	Sabu (near Leh), beyond Khardung village, Khema, near Serchu	3,600–4,400	12–15
29	Dark Wall	*Lasiommata menava*	Sabu (near Leh), Turtuk	2,900–3,900	3

	Common name	Scientific name	Locations seen at	Altitude range in m	Estimated number of adults
30	Ladakh Mountain Satyr	*Paroeneis pumilus*	Enroute to Warila Pass, below Warila Pass, near Rumste	4,100–4,340	>100
Pieridae, Pierinae, Pierini					
31	Large Cabbage White	*Pieris brassicae nepalensis*	Spituk, Choklamsar, Sabu, Chushut (all near Leh), Hundar, Khalsar, Turtuk, Khema, Sakti, Rumste, Miru, Keylong, Tandi	2,900–3,800	>200
32	Indian Cabbage White	*Pieris canidia indica*	Choklamsar (near Leh), Hundar, Turtuk, Kokhsar	2,900–3,200	15–20
33	Small Cabbage White	*Pieris rapae rapae*	Choklamsar & Chushut (near Leh), Hundar, Turtuk, Sakti	2,800–3,800	>150
34	Kashmir White	*Pieris deota* IWPA, SCH II	Khema, Sakti	3,600	8–10
35	Lofty Bath White	*Pontia callidice kalora*	Below Tanglang Pass. Below Baralacha Pass	4,900	3
36	Lesser Bath White	*Pontia chloridice* IWPA, SCH II	Khema, Miru	3,600–3,800	3
37	Bath White	*Pontia daplidice moorei*	Miru	3,800	6–7
Pieridae, Coliadinae					
38	Pale Clouded Yellow	*Colias erate erate*	Spituk, Choklamsar, Sabu, Chushut (all near Leh), Hundar, Turtuk, Sakti	2,900–3740	~20
39	Dark Clouded Yellow	*Colias fieldi fieldi*	Turtuk, below Baralacha Pass, Serchu Keylong, Tandi, Kokhsar	2,800–4,900	10–15
40	Ladak Clouded Yellow	*Colias ladakensis ladakensis* IWPA, SCH II	Kinru, below Tanglang Pass	4,100–4,900	10–12
41	Orange Clouded Yellow	*Colias stolickzana stolickzana*	Below Warila Pass	5,205	5–7
Papilionidae, Parnassiinae, Parnassiini					
42	Common Red Apollo	*Parnassius epaphus epaphus*	Before South Pullu, between Ganglass and Khardung La, near North Pullu, before Warila Pass, before Tanglang Pass	4,600–5,400	>300

Many individuals were worn. We estimated between 15–20 individuals on that particular hill slope alone, leading us to believe that the species is locally common in appropriate nectaring habitat. We had sighted just two individuals of this species in June and July 2016 (Sondhi et al. 2017). SS had also spotted a few individuals of this species in Gangotri National Park, Uttarakhand (Sondhi 2019) on 25 June 2018. These previous sightings in Ladakh and Uttarakhand always consisted of one or two individuals; hence the large numbers of *S. deria* spotted at a single location near Tandi was unusual. This species was reported as *Superflua deria* Moore, 1865 during the last survey, and now stands revised to *Satyrium deria* (Moore, 1865) (Krupitsky et al. 2018).

Family Lycaenidae, Subfamily Lycaeninae

***Lycaena aditya* (Moore, [1875]) (Ladakh Copper)**

05 August 2018, 09.35h, near Ganglas, altitude 4,348m. A solitary male of *Lycaena aditya* (Image 6a, 6b) was sighted amidst short shrubs before South Pullu. The butterfly was observed basking. When it took to wing, it flew rapidly and did not re-appear. There are few recent published records of this species from India. We did not record *L. aditya* during our Ladakh survey in June and July 2016 (Sondhi et al. 2017). Tshikolovets (2005) reported only three records of this species from Stok, Dras Valley and Namika La from northwestern Ladakh confirming that it is an extremely rare species. *L. aditya* has a narrow distribution from Chitral District (Pakistan) to Kashmir (India) (Evans 1927, 1932; Tshikolovets 2005; Varshney & Smetacek 2015).

Family Lycaenidae, Subfamily Polyommatinae, Tribe Polyommatini

***Pamiria chrysopis* (Grum-Grshimaïlo, 1888) (Bright Green Underwing)**

15 August 2018, 08.30–09.03 h, Keylong, altitude 2,993m. 4–5 individuals recorded. 15 August 2018, 12.38h, Kokhsar, altitude ~3,200m. 2–3 individuals recorded. Two species of Underwings *Albulina metallica* and *Albulina omphisa* were recorded during our previous survey (Sondhi et al. 2017). These species are now listed under the genera *Pamiria* based on revised classification using molecular data (Talavera et al. 2012). In addition,

Image 18–24. *Papilio machaon* life cycle: 18—Imago | 19(a,b)—Hostplant *Heracleum candicans*, plant and flowers | 20(a,b) & 21—Early instar caterpillar | 22, 23(a–c)—Final instar caterpillar | 24(a–c)—Pupa. © Balakrishnan Valappil.

the individuals spotted at Keylong and Kokhsar were incorrectly identified as *omphisa* in the 2016 survey, whereas they are actually *Pamiria chrysopis*. These corrections are now made in the updated checklist (Table 3).

Family Papilionononidae, Subfamily Papilioninae, Tribe Papilionini

***Papilio machaon ladakensis* Moore, 1884 (Common Yellow Swallowtail)**

05 Aug 2019, 09.51h, near Ganglas, altitude 4,348m. Numerous caterpillars of *P. machaon* in early and late instars were spotted on its larval host plant *Heracleum candicans* Wall (Apiaceae). An incomplete life cycle of the butterfly was recorded, as the adult did not emerge (Images 18–24).

Family Papilionidae, Subfamily Parnassiinae, Tribe Parnassiini

***Parnassius epaphus* Oberthür, 1879 (Common Red Apollo)**

05 August 2018, 10.33h, before South Pullu, altitude 4,600m. Two individuals at the edge of the stream. 05 August 2018, 12.00–13.00 h, between Ganglas and Khardung La. At altitude between 4,700–5,174 m on the stretch of road leading up to Khardung La, till up to about a kilometer from the pass, we witnessed a mass emergence of *P. epaphus*. We estimated between 100–200 individuals flying on the road and in the meadows surrounding the road. Everywhere we looked, we could see *Parnassius* species on the wing. Some *Parnassius* individuals were victims of road kills on account of passing vehicles. 05 August 2018, 13.20–14.45 h, between Khardung La and North Pullu, altitude 4,824m. On passing Khardung La, we observed very few individuals of *Parnassius*. 05 August 2018, 14.46h, 5km beyond N. Pullu, after Khardung La, altitude 4,824m, one individual. 10 August 2018, 09.47–10.20 h, before Warila Pass, altitude 5,200m, 30–40 individuals. After Warila Pass, 2–3 individuals. 12 August 2018, 09.32h, before Tanglang Pass, altitude 5,343m, 15–20 individuals. After Tanglang Pass, no sightings. Our observations of the swarms of *P. epaphus* at numerous locations had some patterns. All the swarms at Khardung La, Warila Pass and Tanglang Pass were in meadows around the road, about a kilometer below the pass, on the south-facing slopes. In each of the passes, we recorded a very small number of *Parnassius* individuals (0–5), on the north-facing hills slopes. In contrast, the south facing hill slopes of Khardung La, Warila Pass and Tanglang Pass, we observed large numbers of *Parnassius* (20–200 individuals) (Image 7a,b). Some of the individuals we observed we worn, while others were very fresh, and we also spotted quite a few mating pairs. Older literature does mentions swarming *Parnassius* (Wynter-Blyth 1957), but there are few recent published records of this phenomenon from India. On occasion, the butterflies would sit on the ground and attempt to crawl into a crevice formed by rocks on the ground (Image 7c), making it difficult to photograph.

These new records reveal that much needs to be studied across seasons in high altitude cold deserts of India. The impact of unbridled tourism, climate change and other anthropogenic factors are yet to be quantified and urgent assessments of Lepidoptera in these regions are needed across the country.

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COMMUNICATION

Collecting parasitic Aculeata (Hymenoptera) from rice ecosystems of Tamil Nadu, India

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Abstract: Surveys were conducted to explore the parasitic aculeate fauna in rice ecosystems of Tamil Nadu in 2015–2016 in three different rice growing zones, viz., the western zone, the Cauvery delta zone and the high rainfall zone. The study recorded a total of 32 aculeates that represent 12 species under seven families belonging to three super families, viz., Apoidea (Apidae), Chrysidoidea (Bethylidae, Chrysididae, & Dryinidae), and Vespoidea (Mutillidae, Scoliidae, & Thiphiidae). Alpha and beta diversity were computed for the three zones and the diversity indices (Simpson's index, Shannon-Wiener index, Pielou's index) revealed the high rainfall zone as the most diverse zone, with the Cauvery delta zone being the least diverse. On comparing the species similarities using the Jaccard's index in between the three zones taken in pairs, it was found that 42 per cent similarity existed between the western and Cauvery delta zone and 11 per cent similarity between high rainfall and Cauvery delta zones and 16 per cent similarity between the high rainfall and western zones.

Keywords: Apidae, Bethylidae, Chrysididae, diversity, Dryinidae, indices, Mutillidae, Scoliidae, Tiphiidae.

ஆய்வுச்சுருக்கம்: தமிழ் நாட்டில் 2015 ஆம் ஆண்டு ஆகஸ்ட் மாதம் முதல் 2016 ஆம் ஆண்டு ஜனவரி மாதம் வரை ஒட்டுண்ணி அக்கியுலேட்டாக்களுக்கான கணக்கெடுப்பு மூன்று மண்டலங்களில் நடத்தப்பட்டது, அவையாவன மேற்கு மண்டலம், காவேரி டெல்டா மண்டலம் மற்றும் மழைமிகு மண்டலம். இந்த கணக்கெடுப்பின் மூலம் மொத்தம் 32 அக்கியுலேட்டா ஒட்டுண்ணிகள் அகப்பட்டன. இவற்றுள் 12 இனங்கள் அடங்கும். இந்த 12 இனங்கள் மூன்று பெருங்குடும்பங்களின் (ஏப்பாய்டியா, கிரைஸிடாய்டியா மற்றும் வெஸ்பாய்டியா) கீழ் உள்ள 7 குடும்பங்களின் கீழ் வகைப்படுத்தப்பட்டுள்ளது அவையாவன ஏப்பிடே, பெத்திலிடே, கிரைஸிடிடே, டிரைனிடே, மியூட்டிலிடே, ஸ்கோலிடே மற்றும் திப்பிடே. ஜெக்கர்டு குறியிடைக் கொண்டு மண்டலங்களுக் கிடையிலான ஒப்புமைத் தன்மையை கணக்கிட்டபோது 42 சதவீத ஒப்புமை மேற்கு மற்றும் காவேரி டெல்டா மண்டலங்களுக்கிடையில் இருப்பது கண்டறியப்பட்டது. மழைமிகு மண்டலம் மற்றும் காவேரி டெல்டா மண்டலங்களுக்கிடையில்11 சதவீத ஒப்புமையும் 16 சதவீத ஒப்புமை மழைமிகு மற்றும் மேற்கு மண்டலங்களுக் கிடையிலும் இருப்பது கண்டறியப்பட்டது. பன்முகத்தன்மை குறியீடுகளான சிம்ப்ஸன்ஸ், ஷெணான் மற்றும் மார்கலெப் குறியீடுகள் கணக்கிடப்பட்டு மழைமிகு மண்டலத்திலேயே அதிக பல்லுயிர் பெருக்கம் இருப்பதாக கண்டறியப்பட்டது. மிக குறைந்த பல்லுயிர் பெருக்கம் காவேரி டெல்டா மண்டலத்தில் இருப்பதாக தெரியப்பட்டது.

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Author contribution: JAD involved in the collection of insects, segregation of collected insects up to family level, performed statistical analysis, and wrote the manuscript. KR involved in correction of the manuscript and he is the advisor of the whole study.

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INTRODUCTION

Rice fields have unique characteristics that make them ideal grounds for diverse biological organisms. In addition, the different growth stages of the rice plant from seedling to harvest create micro-climatic conditions, offering a variety of habitats and niches conducive to a variety of life forms (Edirisinghe & Bambaradeniya 2010). Thus, it is an ecosystem which sustains not only the people whose staple diet is rice but also a diverse assemblage of plants and animals that have made rice fields their niche. But indiscriminate use of insecticides in rice fields has resulted in the loss of biodiversity of beneficial organisms like hymenopteran insects (Dudley et al. 2005).

Reducing the mortality of hymenopterans caused by insecticides is essential for greater sustainability in rice pest management (Heong & Hardy 2009; Gurr et al. 2011). They show greater stability to the ecosystem than any group of natural enemies of insect pests because they are capable of living and interacting at a lower host population level. A typical phytophagous insect is host to about five species of Hymenoptera (Hawkins 1993). Destroying one parasitoid species, therefore, may have unpredictable and immeasurable effects on the abundance of a number of phytophagous insects (LaSalle 2003). These studies suggest how important hymenopterans are in their natural habitats.

Although the species composition of terrestrial insects in rice fields throughout the world is relatively well documented, only a few studies have examined the biodiversity of hymenopterans in rice fields (Heckman 1974, 1979). The studies regarding the ability of aculeate Hymenoptera to utilize wetlands is far from satisfying (Stapenkova et al. 2017). Aculeata is one of the largest groups of insects and a few of them are parasitoids attacking a wide range of insects in their various stages of development, thereby playing a pivotal role in ecological balance. The diversity of parasitic aculeates associated with rice ecosystem is poorly studied in Tamil Nadu, hence the present study was undertaken.

MATERIALS AND METHODS

Sites of collection

The survey was carried out in the rice fields in 2015–2016 in three different agroclimatic zones of Tamil Nadu State, viz.: western zone (District representation: Coimbatore at Paddy Breeding Station, Coimbatore, 427m, 11.007N, 76.937E), Cauvery delta zone (District representation: Thiruvarur at Krishi Vigyan Kendra, Needamangalam, 26m, 10.774N, 79.412E), and high rainfall zone (District representation: Kanyakumari at Agricultural Research Station, Thirupathisaram, 17m, 8.207N, 77.445E). Collections were made for 20 consecutive days in each zone to give equal weightage and to minimize chances of variations in the collection. The time of sampling in each zone was decided based on the rice growing season of the zone and the stage of the crop, i.e., 20 days from August–September 2015 in the western zone, October– November 2015 in the high rainfall zone, and December 2015–January 2016, in the Cauvery delta zone.

Methods of collection

A total of three different gadgets, viz., sweep net, yellow pan trap kept at ground level, and yellow pan trap erected at canopy levels were employed. All the three gadgets were employed continuously for 20 days.

Preservation and identification of the specimens

The parasitoids, thus, collected were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under a Stemi (Zeiss) 2000-C and photographed under Leica M205A stereozoom microscopes and identified through conventional taxonomic techniques by following standard keys. For future references all the identified specimens were submitted at Insect Biosystematics Laboratory, Tamil Nadu Agricultural University, Coimbatore. Species identity was made by following standard keys and also by confirming them with concerned experts from various institutes like, Lynn S. Kimsey, professor of entomology, UC Davis Department of Entomology and Nematology for Chrysididae and Tiphiidae, Arkady S. Lelej, entomology professor, Russian Entomological Society for Mutillidae, and Manickavasagam of Annamalai University for Dryinidae.

Measurement of diversity

Relative density (calculated by the formula, Relative Density (%) = (Number of individuals of one species / Number of individuals of all species) X 100, alpha diversity, viz., Simpson's index (Simpson 1949), (SDI is calculated using the formula $D = \Sigma n\ (n-1)/\ N(N-1)$ where n=total number of organisms of a particular species and N=total number of organisms of all species. Subtracting the value of Simpson's index from 1, gives Simpson's Index of Diversity (SID). The value of the index ranges from 0 to 1, the greater the value the greater the sample diversity). Shannon-index (Shannon, 1948), Margalef

richness index (Margalef 1958), Pielou's evenness index (Pielou 1966; Magurran 1988), and beta diversity using Jaccard index (Jaccard 1912) were calculated using the online software Biodiversity Calculator (https://www.alyoung.com/labs/biodiversity_calculator.html).

Statistical analysis

The statistical test ANOVA was also used to check whether there was any significant difference in the collections from three zones. The data on population number were transformed into X+0.5 square root before statistical analysis. The mean individuals caught from three different zones were analyzed by adopting randomized block design (RBD) to find least significant difference (LSD). Critical difference (CD) values were calculated at five per cent probability level. All these statistical analyses were done using Microsoft Excel 2016 version and Agres software version 3.01.

RESULTS AND DISCUSSION

Parasitic Aculeata

In the present study, a total of 32 aculeates were collected from rice ecosystems that represent 12 species under seven families (Images 1–12), viz., Apidae, Bethylidae, Chrysididae, Dryinidae, Mutillidae, Scoliidae, and Tiphiidae.

Parasitic aculeate faunal surveys of rice ecosystems in western Cauvery delta and high rainfall zones of Tamil Nadu revealed that the species richness was maximum (7) in both western and high rainfall zones. Abundance wise, the high rainfall zone stood first with a total collection of 14 individuals. The western zone ranks second with a total collection of nine individuals and Cauvery delta region represented the least abundant with a total collection of seven individuals.

The Simpson's index of diversity is highest for high rainfall zone (0.91) and lowest for western zone (0.87) (Table 2), revealing more diversity in high rainfall zone than the western zone. A similar trend was observed for the Shannon index also. From the values of Margalef richness index for the three zones, it was found that the high rainfall zone was very rich in species with a richness value of 3.03 followed by western zone (2.08), while for Cauvery delta zone the value is 2.05. The Pielou's evenness value for the sites clearly indicated that the evenness patterns of all the three zones were almost the same with evenness index value 0.41 for Cauvery delta zone, followed by western zone (0.40) and high rainfall zone (0.40) (Table 2). The species composition among elevational zones can indicate how community structure changes with biotic and abiotic environmental pressures (Shmida & Wilson 1985; Condit et al. 2002). Studies on the effect of elevation on species diversity of taxa such as spiders (Sebastian et al. 2005), moths (Axmacher & Fiedler 2008), paper wasps (Kumar et al. 2008), and ants (Smith et al. 2014) reported that species diversity decreased with an increase in altitude, however, according to Janzen (1976), diversity of parasitic Hymenoptera is not as proportionately reduced by elevation as in other insect groups, a fact that is in support of our results.

A similar study conducted by Shweta & Rajmohana (2016) to assess the diversity of members belonging to the subfamily Scelioninae also declared that the elevation did not have any major effect on the overall diversity patterns. Daniel et al. (2017) obtained similar results by conducting experiments to assess the diversity of pteromalids of rice ecosystems in Tamil Nadu. The elevation dealt with in that work ranged from 17–427 m which was not very high. So taking into account the scale and extent of elevational gradients, it can be said that species diversity and richness have not showed any correlation, i.e., species diversity and richness were not proportional with that of elevation.

On comparing the species similarities using the Jaccard's index in between the three sites taken in pairs, it is found that 42 percent similarity between western zone and Cauvery delta zone and 11 per cent similarity between high rainfall zone and Cauvery delta zone. The similarity between western zone and high rainfall zone is 16 per cent. All the parasitic aculeates that were collected along with their host details were presented in Table 3.

Apidae

Under the family Apidae, only one species, *Thyreus ceylonicus* (Friese) was collected only from the western zone. Since, only one species was caught, diversity indices cannot be calculated.

The bee genus *Thyreus* Panzer is cleptoparasitic on species of *Amegilla* Friese possibly on *Anthophora* Latreille and *Eucera* Scopoli (Stoeckhert 1954). Matsumura et al. (2004) have collected a few kleptoparasitic cuckoo bees from the rice fields of Japan.

Bethylidae

Two species of bethylids, viz., *Goniozus indicus* (Ashmead) and *Holepyris hawaiiensis* were collected in the present study. Though *G. indicus* was found to be common to all the three zones, *H. hawaiiensis* was

Images 1–12. Twelve species of parasitic Aculeata collected from three rice growing zones of Tamil Nadu. 1—*Thyreus ceylonicus* (Friese) | 2—*Goniozus indicus* (Ashmead) | 3—*Holepyris hawaiiensis* (Ashmead) | 4—*Stilbum cyanarum* (Forster) | 6—*Dryinus* sp. | 6—*Gonatopus* sp. | 7—*Haplogonatopus* sp. | 8—*Storozhenkotilla* sp. | 9—*Zavatilla* sp. | 10—*Campsomeriella collaris* Betrem | 11—*Scolia affinis* Guerin | 12 — *Mesa* sp. © Alfred Daniel, J.

Table 1. Comparison of parasitic Aculeata collected from three rice growing zones of Tamil Nadu.

Species	Zones						Total			
	Western		Cauvery Delta		High Rainfall					
	No.	%	No.	%	No.	%	No.	%	F	P
Apidae *Thyreus ceylonicus*	1	100	0	0.0	0	0.00	1	100	1.00	0.37
Bethylidae *Goniozus indicus*	3	75	2	100	7	100	12	92.3	1.33	0.27
Holepyris hawaiiensis	1	25	0	0	0	0	01	7.7	1.00	0.37
Chrysididae *Stilbum cyanarum*	0	0.0	0	0.0	1	100	1	100	1.00	0.37
Dryinidae *Dryinus* sp.	1	50	2	40.0	0	0	3	37.5	1.03	0.36
Gonatopus sp.	1	50	3	60.0	0	0	4	50.0	1.20	0.30
Haplogonatopus sp.	0	0	0	0	1	100	1	12.5	1.00	0.37
Mutillidae *Storozhenkotilla* sp.	0	0.0	0	0.0	1	33.3	1	33.3	1.00	0.37
Zavatilla sp.	0	0	0	0	2	66.7	2	66.7	1.00	0.37
Scoliidae *Campsomeriella collaris*	1	100	0	0	1	50	2	66.7	0.5	0.60
Scolia affinis	0	0	0	0	1	50	1	33.3	1.00	0.37
Tiphiidae *Mesa* sp.	3	100	0	0.0	0	100	3	100	1.00	0.37
Total collected	**11**	-	**07**	-	**14**	-	**32**	-	-	
Number of species	**07**	-	**03**	-	**07**	-	**12**	-		

%- Relative Density, No.- Total number of individuals collected, F-Value, P-Value

found only in the western zone. Among the three zones, high rainfall zone (7) was found to have more number of bethylids followed by western zone (4) and Cauvery delta zone (2) (Table 1). A total of 13 numbers of bethylid individuals were collected from all the three zones.

A mean of 0.20 ± 0.12 bethylids were collected per day from western zone. Cauvery delta zone and high rainfall zone yielded 0.10 ± 0.07 and 0.35 ± 0.15 bethylids per day, respectively.

Chrysididae

Under the family Chrysididae, only one species, *Stilbum cyanarum* (Forster) was collected in the present study. *Stilbum cyanarum* was collected from high rainfall zone alone. Since only one species was caught, diversity indices could not be calculated.

Dryinidae

In the present study, a total of eight dryinid individuals comprising three different species, viz., *Dryinus* sp., *Gonatopus* sp. and *Haplogonatopus* sp. were collected. *Dryinus* sp. and *Gonatopus* sp. were common to both western zone and Cauvery delta zone, but *Haplogonatopus* sp. was obtained only from the high rainfall zone. It was found that the Cauvery delta zone was the most dryinid abundant zone with a total collection of five numbers followed by western zone (2) and high rainfall zone represented by only one individual

Mutillidae

Two species, *Storozhenkotilla* sp. and *Zavatilla* sp., were collected under the family Mutillidae. Both the species were collected from the high rainfall zone alone. A total of three mutillid individuals were collected in the present study (Table 1).

High rainfall zone recorded a mean of 0.15 ± 0.11 individuals per day. Since, mutillids were collected only from high rainfall zone no comparison between zones were made. Heong et al. (1991), Bambaradeniya et al. (2004), and Samin et al. (2011) have recorded mutillids from the rice fields of Philippines, Sri Lanka, and Iran, respectively.

Scoliidae

Two species, *Campsomeriella collaris* Betrem and *Scolia affinis* Guerin, were collected in the current study. Though *C. collaris* was obtained both from the western and high rainfall zones, *S. affinis* was obtained only from high rainfall zone. No scoliids was caught from Cauvery delta zone.

Table 2. Diversity indices of parasitic Aculeata from three rice growing zones of Tamil Nadu.

Zones	Mean number of all aculeates collected/day	SE	SID	*H'*	a	*E1*	b %
Western	0.55 (0.94)	± 0.22	0.87	0.72	2.08	0.40	W and C – 42
Cauvery Delta	0.35 (0.87)	± 0.15	0.90	0.67	2.05	0.41	C and H - 11
High Rainfall	0.70 (1.02)	± 0.23	0.91	0.88	3.03	0.40	H and W - 16
S.ED	0.10	-	-	-	-	-	
CD (p=0.05)	0.20	-	-	-	-	-	

Figures in parentheses are square root transformed values; In a column, means followed by a common letter(s) are not significantly different by LSD (p=0.05) | SID—Simpson's Index of Diversity | *H'*—Shannon Index | a—Margalef index | *E1*—Pielou's index | b—Beta diversity (Jaccard Index) | W—Western Zone | C—Cauvery Delta Zone | H—High Rainfall Zone | S.ED—Standard Deviation | CD—Critical Difference | SE—Standard Error (same table third column).

Table 3. Parasitic aculeates collected in the study along with their host.

Parasitoid	Host	Reference
Thyreus ceylonicus	*Amegilla* sp. & *Anthophora* sp.	Lieftinck, 1962
Goniozus indicus	*Cnaphalocrocis medinalis* *Scirpophaga* sp.	Gifford, 1965
Holepyris hawaiiensis	*Corcyra cephalonica*, & *Plodia interpunctella*	Amante et al. 2018
Stilbum cyanarum	Eumenidae, Sphecidae, & Megachilidae	Tormos et al. 2006
Dryinus sp.	Plant hoppers	Guglielmino et al. 2013
Gonatopus sp.	Plant hoppers	Guglielmino et al. 2013
Haplogonatopus sp.	Plant hoppers	Guglielmino et al. 2013
Storozhenkotilla sp.	Coleoptera, Diptera, & Hymenoptera	Lelej et al. 2007
Zavatilla sp.	Coleoptera, Diptera, & Hymenoptera	Lelej et al. 2007
Campsomeriella collaris	Scarabaeoidea	Vidyasagar & Bhat 1991
Scolia affinis	Scarabaeoidea	Vidyasagar & Bhat 1991
Mesa sp.	Scarabaeoidea	Vidyasagar & Bhat 1991

A mean of 0.05 ± 0.05 and 0.10 ± 0.10 scoliids were collected per day from western zone and high rainfall zone, respectively. Since only one species was recorded from western zone and no species were recorded from Cauvery delta zone, diversity indices could not be calculated for these two zones

Tiphiidae

Under the family Tiphiidae, three individuals of *Mesa* sp. were collected from western zone. The other two zones have not accounted for Tiphiidae. These are parasitoids of subterranean beetle larvae, especially of Scarabaeoidea and Tenebrionidae occurring in soil or rotten wood; some are found to parasitize mole crickets (Allen 1996). Heong et al. (1991), Bambaradeniya et al. (2004), and Fritz et al. (2011) have collected Tiphiidae from rice ecosystem of Philippines and Sri Lanka.

CONCLUSION

This study reveals the diversity of parasitic Aculeata of three different rice ecosystems of Tamil Nadu, where the high rainfall zone is the most diverse and the Cauvery delta zone being the least. The reasons for the significant changes in diversity of aculeates and their host insects are to be further studied.

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COMMUNICATION

An annotated checklist of sea slug fauna of Gujarat coast, India

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Abstract: An annotated checklist of sea slugs from Gujarat coastal waters was prepared, based on published literature and field observations from 2014–2019. Ninety-five species from 62 genera belonging to 29 families were recorded. Species are listed with synonyms and distribution status.

Keywords: Distribution, Gastropoda, Opisthobranch.

વર્ષ ૨૦૧૪ થી ૨૦૧૯ દરમિયાન દરીયાકિનારે કરાયેલ ક્ષેત્રીય અવલોકનો તેમજ પુર્વ પ્રકાશિત સાહિત્યને આધારે ગુજરાતના દરીયાકાંઠાના વિસ્તારમાંથી સમુદ્રી ગોકળગાયની સુચિત યાદી તૈયાર કરવામાં આવેલ. ૨૯ કુળમાની ૬૨ જાતિની ૯૫ પ્રજાતિ નોંધવામા આવેલ છે. પ્રજાતિની વિસ્તરણ સ્થિતી અને સમાનાર્થી નામોની યાદી સામેલ છે.

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Author contribution: PV—survey, photography and identification of sea slugs and preparation of the draft of paper. HK—survey, photography and identification of sea slugs and preparation of the draft of paper; IB—survey, preparation of the manuscript.

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INTRODUCTION

Sea slugs are one of the largest groups of marine gastropods. They show a wide range of colors, designs, and patterns, including varieties of body decorations such as flaps, sensory organs, tubercles, and tentacles (Wagele & Klussmann-Kolb 2005). They are found from the polar regions to the tropics in habitats ranging from intertidal (coral reefs, mudflats, rocky shores, and tide pools) to deep sea, and in association with bryozoans, hydroids, sponges, seagrasses, and seaweeds (Wollscheid-Lengeling et al. 2001; Apte & Desai 2017). Sea slugs possess a variety of predator defense mechanisms that include autotomizing organs, chemical & ink secretion, crypticism, camouflage, and deimatic displays (Wollscheid-Lengeling et al. 2001; Apte & Desai, 2017).

There are approximately 6,000 species of sea slugs (Wagele et al. 2008), of which about half have been described from the Indo-Pacific region (Gosliner et al. 2015). Recently, Apte & Desai (2017) documented 361 species from India, with the Andaman & Nicobar Islands possessing the greatest diversity (273 species), followed by the western coast of India (121 species), Lakshadweep Islands (106 species), and the eastern coast of India (75 species).

In Gujarat, Hornell was the first to collect sea slugs from the Kathiawar coast, which were identified by Eliot (Eliot 1909; Hornell 1909). Subsequent reports were made by Gideon et al. (1957), Menon et al. (1961), Narayanan (1969, 1970, 1971), Burn (1970), Burn & Narayanan (1970), Rudman (1973, 1980, 1983), Rao & Rao (1980), Rao (2003), Raghunathan et al. (2004, 2016), Rao et al. (2004), Rao & Sastry (2005), Apte et. al. (2010, 2015), Matwal & Joshi (2011), Parasharya (2012), Apte (2013), GEER (2013, 2014a,b), Prasade et al. (2013, 2015), Carmona et al. (2014), Poriya et al. (2015), Venkataraman et al. (2015), GSBTM (2015), Bhave et al. (2015), Kumari et al. (2015), Apte & Desai (2017), and Bharate et al. (2020).

Using information from these sources and field observations, we present here an annotated checklist of the sea slugs of the Gujarat coastal waters, which provides basic details of diversity and present distributions.

MATERIALS AND METHODS

Gujarat State is situated on the western coast of India, with a coastline extending for 1,600km. The Gujarat coast supports a variety of habitats, including mangroves, coral reefs, rocky shores, mudflats, sandy shores, seagrasses, and seaweeds, contributing to a high degree of marine faunal and floral diversity. The coast is divided into three areas: the Gulf of Kachchh, Saurashtra coast, and the Gulf of Khambhat (Beleem et al. 2019). The Gulf of Kachchh is a large inlet of the Arabian sea that tapers towards the north-east and contains a Marine National Park and Sanctuary with 42 islands where coral reef and mangrove ecosystems support a high level of faunal diversity (Apte et al. 2010).

The Saurashtra coast is a locale for industry, harbors, fisheries, and tourism. The area is comprised of rocky flats, and muddy & sandy supratidal zones. The rocky coast has various substrata including zoanthid zones, coral patches, and intertidal pools & puddles, which sustain unique species diversity. The Gulf of Khambhat is about 200km long, and 20km wide in the north and up to 70km wide in the south. The Narmada, Tapi, Mahi, and Sabarmati rivers drain into the gulf to form the estuary. Khambhat comprises mudflats, muddy-sandy zones, rocky patches and sandy supratidal zone. The intertidal zone of Khambhat has sparsely scattered mangrove patches of *Avicennia marina*. This unique habitat supports several marine species.

The authors carried out extensive fieldwork in these coastal areas of Gujarat from 2014 to 2019. A majority of specimens collected are deposited in the Museum of Fisheries Research Station, Junagadh Agricultural University, Sikka. An annotated checklist was prepared based on available literature (Table 1). Scientific names, synonyms and current status were validated and confirmed with the WoRMS (World Register of Marine Species, 2019) database for current taxonomic status (WoRMS Editorial Board 2019). The species identified up to genus, grey literature, popular articles, invalid species data, and reports in local newsletters removed from the present checklist. We collected 60 specimens which have been deposited in the Museum of Fisheries Research Station, Junagadh Agricultural University, Sikka with accession number with FRSMGH-01 to FRSMGH-60. Among those 60 collected specimens, 37 were included in the present checklist (Images 1–5) and 23 species are identified up to the genus and family levels. Classification has changed due to major revisions of families, genera, and species complexes which created many confusion among the taxonomists. The present checklist follows the standard classification method of Bouchet et al. (2017).

A total of 16 species of sea slugs were removed from the present checklist, as they were formerly misidentified (Table 3).

Taxonomic notes on Gujarat sea slugs

Hornell collected seven species sea slug fauna from Gujarat during 1905–06, later identified by Eliot (1909). Among those were the new species *Antiopella indica* Eliot, 1909 (now *Janolus indica* (Eliot, 1909)), which subsequently proved to be a junior synonym of *Janolus toyamensis* Baba & Abe, 1970 (Baba 1986). Hornell wrote a note on the presence of symbiotic algae in *Melibe viridis* (Kelaart, 1858) (now *Melibe rangi* Bergh, 1875) at Kattiawar in 1909. Gideon et al. (1957) reported three species of sea slugs during the primary survey of the Gulf of Kachchh. Menon et al. (1961) reported six species of sea slugs from different coasts of the Gulf of Kutch. The first comprehensive work on sea slug fauna of Gujarat was carried out by Narayanan (1969, 1970, 1971) in different parts of the Gulf of Kachchh, who reported 25 species. Narayanan (1969) reported *Hervia militaris* from Gujarat, which was later identified as *Eolis militaris* by Burn & Narayanan (1970), later it was knows as *Phidiana militaris* (Alder & Hancock, 1864). Narayanan (1969) also described *Phyllidiella zeylanica* from the Gulf of Kachchh, which was later re-described by Burn (1970). Rudman (1973, 1980, 1983) reported four species from the Gulf of Kachchh, including *Mexichromis mariei* (Crosse, 1872) (now *Chromodoris mariei* (Crosse, 1872)) and a new species *Chromodoris krishna* Rudman, 1973, after it was redescribed and given a junior synonym of *Chromodoris fidelis* Rudman (1985) which was later known as *Goniobranchus fidelis* (Kelaart, 1858) (Rudman 1985). Rudman (1980) recorded *Phidiana militaris* (Alder & Hancock, 1864) and described one new species of *Sakuraeolis gujaratica* Rudman, 1980 collected from Adatra reef, Gulf of Kachchh.

Rao (2003) recognized two valid species: *Aplysia argus* Rüppell & Leuckart, 1830 (now *Aplysia benedicti* (Eliot, 1899)) and *Aplysia cornigera* (Sowerby, 1869). Raghunathan et al. (2004) surveyed live corals along the Saurashtra coast of Gujarat, where they found *Aplysia parvula* (Mörch, 1863) as coral-associated. Rao & Sastry (2005) prepared a checklist as of 24 species of sea slugs from the literature, augmented by their surveys from different Islands and reefs of Marine National Park, Gulf of Kachchh (Gujarat). In that checklist, *Haminoea hydatis* (Linnaeus, 1758) was misidentified, being actually *Haloa natalensis* (Krauss, 1848) (Parasharya 2012).

Later, Apte et al. (2010) collected various species of sea slugs from the Gulf of Kachchh, where they recorded 33 species belonging to 19 families, of which 21 were new records from Gujarat and 13 new records for the Indian coast. Parasharya (2012) recorded a list of 43 species of sea slugs from six locations of Gulf of Kachchh during a survey of coral associated fauna in his Ph.D. work. Six species were doubtfully identified: *Atagema alba* (O'Donoghue, 1927), *Carminodoris bifurcata* Baba, 1993, *Cratena capensis* Barnard, 1927, *Cratena peregrina* (Gmelin, 1791), *Oxynoe panamensis* Pilsbry & Olsson, 1943, and *Philinopsis taronga* (Allan, 1933), since they are not found in Indian waters (Table 3).

Carmona et al. (2014) described a new species of *Anteaeolidiella poshitra* Carmona et al., 2014 from Gulf of Kachchh. Poriya et al. (2015) recorded seven species of sea slugs belonging to six families from Saurashtra coast, among them *Phidiana militaris* was associated with *Goniopora* coral and zoanthid colony, whereas *Baeolidia palythoae* was associated with zoanthids. Venkataraman et al. (2015) reported 53 species of sea slug fauna belonging to 19 families and 33 genera from Gujarat waters after that Raghunathan et al. (2016) described and listed diversity of sea slugs of coastal waters of India where he reported 389 species of sea slugs from India among them 56 species were recorded from Gujarat coastal waters. Recently, Apte & Desai (2017) published a book of field guide to the sea slugs of India, where they reported 75 species of sea slugs fauna from the Gujarat water. They reported *Knoutsodonta brasiliensis* (Alvim et al., 2011) from Gujarat waters while the species's distribution is restricted to Brazil (Alvim et al. 2011). From Alang, Gulf of Khambhat, Porbandar, Saurashtra, Bhadreshwar, Pirotan Island, Salaya, Sikka, and Gulf of Kachchh they reported two species of *Haminoea* as *Haminoea elegans* (Gray, 1825) and *Haminoea galba* Pease, 1861 (Gideon et al. 1957; Rao et al. 2004) which are clearly incorrect and their occurrence has not been so far reported from India. Hence, a total of 16 species belonging to 11 genera and nine families were eliminated from the present checklist due to misidentification (Table 3).

RESULTS

Our annotated checklist based on the literature for sea slugs of the Gujarat coast contains 95 species from 62 genera belonging to 29 families (Table 1). A dispute was identified from the reported checklist and removed (*Hervia ceylonica* Farran, 1905), since *Hervia ceylonica* was considered a "nomen dubium" in WoRMS (MolluscaBase 2019). Synonyms of 27 species have been updated with present scientific names (Table 2). The Gulf of Kachchh with its unique and abundant coral and mangrove ecosystems has high species diversity (93 species) relative to the Saurashtra coast (30 species),

Table 1. An annotated checklist of sea slug fauna of Gujarat coast.

	Species	References
Family: Aplustridae Gray, 1847		
1	*Hydatina physis* (Linnaeus, 1758)	Okha, Lamba (Rao et al. 2004); Veraval (Rao et al. 2004; Kumari et al. 2015; Apte & Desai 2017); Gujarat (Raghunathan et al. 2016); Present study
2	*Hydatina zonata* (Lightfoot, 1786)	Bet Dwarka (Menon et al. 1961); Porbandar (Rao et al. 2004); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)
Family: Pleurobranchidae Gray, 1827		
3	*Berthella* stellata (Risso, 1826)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Pirotan Island, Kalubhar Island, Poshitra Reef (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Porbandar (Apte & Desai 2017)
4	*Berthellina citrina* (Rüppell & Leuckart, 1828)	Gulf of Kachchh (Narayanan 1970; Rao & Sastry 2005; Apte et al. 2010; Apte & Desai 2017); Pirotan Island, Goose Island, Narara Reef, Kalubhar Island, Poshitra Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Porbandar, Dwarka, Okha (Apte & Desai 2017); Present study
5	*Berthellina minor* (Bergh, 1905)	Okha, Pirotan Island, Dona Reef (Narayanan 1969); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
Family: Pleurobranchaeidae Pilsbry, 1896		
6	*Pleurobranchaea morula* Bergh, 1905	Pirotan Island (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
Family: Doridiidae Rafinesque, 1815		
7	*Doriopsis granulosa* Pease, 1860	Gulf of Kachchh (Apte & Desai 2017); Present study
8	*Archidoris minor* Eliot, 1904	Okha (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
Family: Discodorididae Bergh, 1891		
9	*Atagema spongiosa* (Kelaart, 1858)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Narara Reef, Kalubhar Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Present study
10	*Atagema tristis* (Alder & Hancock, 1864)	Gulf of Kachchh (Apte & Desai 2017); Present study
11	*Atagema rugosa* Pruvot-Fol, 1951	Gulf of Kachchh (Apte et al. 2010; GEER 2014b; Apte & Desai 2017); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Poshitra Reef, Dwarka, Narara Reef (Bhave et al. 2015); Present study
12	*Jorunna funebris* (Kelaart, 1859)	Okha, Chakhadi (Movado) Island, Khara Mitha Chusna Island, Azad Island, Roji Island (Narayanan 1969); Pirotan Island (Narayanan 1969; Parasharya 2012); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010; GEER 2013, 2014a,b; Apte & Desai 2017); Goose Island, Narara Reef, Kalubhar Island, Ashaba Island (Parasharya 2012); Poshitra Reef (Parasharya 2012; Bhave et al. 2015); Dwarka (Bhave et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Present study
13	*Discodoris boholiensis* Bergh, 1877	Pirotan Island (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)
14	*Platydoris pulchra* Eliot, 1904	Pirotan Island (Narayanan 1971)
15	*Thordisa villosa* (Alder & Hancock, 1864)	Poshitra Reef, Narara Reef (Prasade et al. 2013; Bhave et al. 2015); Gujarat (Apte & Desai 2017); Present study
16	*Thordisa sanguinea* Baba, 1955	Poshitra Reef (Bhave et al. 2015); Gujarat (Raghunathan et al. 2016)
17	*Peltodoris murrea* (Abraham, 1877)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Goose Island, Kalubhar Island (Parasharya 2012); Narara Reef (Parasharya 2012; Bhave et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Poshitra Reef, Dwarka (Bhave et al. 2015); present study
18	*Peltodoris rubescens* Bergh, 1905	Okha (Narayanan 1971)
19	*Carminodoris grandiflora* (Pease, 1860)	Gulf of Kachchh (Apte et al. 2010; GEER, 2013, 2014a,b; Apte & Desai 2017); Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Narara Reef (Bhave et al. 2015)
20	*Sclerodoris apiculata* (Alder & Hancock, 1864)	Poshitra Reef (Bhave et al. 2015)
21	*Sclerodoris tuberculata* Eliot, 1904	Gulf of Kachchh (Apte et al. 2010; GEER 2014a,b; Apte & Desai 2017); Pirotan Island, Goose Island, Kalubhar Island, Ashaba Island (Parasharya 2012); Narara Reef (Parasharya 2012; Bhave et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Poshitra Reef, Dwarka (Bhave et al. 2015); present study
22	*Otinodoris raripilosa* (Abraham, 1877)	Pirotan Island (Narayanan 1969); Gujarat (Venkataraman et al. 2015)
23	*Taringa sublutea* (Abraham, 1877)	Dwarka (Prasade et al. 2015; Apte & Desai 2017); Gujarat (Raghunathan et al. 2016); Gulf of Kachchh, Okha (Apte & Desai 2017); present study
24	*Sebadoris nubilosa* (Pease, 1871)	Porbandar (Rao & Rao 1980)
25	*Tayuva lilacina* (Gould, 1852)	Gulf of Kachchh (Apte et al. 2010; GEER 2014a,b; Apte & Desai 2017); Pirotan Island, Goose Island, Kalubhar Island (Parasharya 2012); Poshitra Reef (Parasharya 2012; Bhave et al. 2015); Narara Reef (Bhave et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study

	Species	References
Family: Polyceridae Alder & Hancock, 1845		
26	*Plocamopherus ocellatus* Rüppell & Leuckart, 1828	Okha (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
27	*Plocamopherus ceylonicus* (Kelaart, 1858)	Kyu Island-Okha Mandal (Eliot 1909); Okha (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010); Poshitra Reef (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai, 2017); present study
28	*Thecacera pennigera* (Montagu, 1813)	Gujarat (Apte & Desai 2017)
29	*Gymnodoris alba* (Bergh, 1877)	Gulf of Kachchh (Apte et al. 2010); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)
30	*Gymnodoris citrina* (Bergh, 1877)	Gujarat (Apte & Desai 2017)
Family: Chromodorididae Bergh, 1891		
31	*Glossodoris pallida* (Rüppell & Leuckart, 1830)	Gulf of Kachchh, Dwarka, Okha (Apte & Desai 2017)
32	*Hypselodoris infucata* (Rüppell & Leuckart, 1830)	Pirotan Island (Narayanan 1969; Parasharya 2012); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010; GEER, 2013, 2014a,b); Goose Island, Kalubhar Island (Parasharya, 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017); Present study
33	*Hypselodoris carnea* (Bergh, 1889)	Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Gulf of Kachchh, Dwarka, Okha (Apte & Desai 2017)
34	*Hypselodoris sagamiensis* (Baba, 1949)	Narara Reef, Kalubhar Island (Parasharya 2012); Gulf of Kachchh (GEER, 2013, 2014a,b)
35	*Goniobranchus tinctorius* (Rüppell & Leuckart, 1830)	Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
36	*Goniobranchus petechialis* (Gould, 1852)	Kathiawar (Eliot 1909)
37	*Goniobranchus fidelis* (Kelaart, 1858)	Sikka, Pirotan Island (Rudman 1973); Gulf of Kachchh (Apte & Desai 2017); present study
38	*Goniobranchus bombayanus* (Winckworth, 1946)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study
39	*Mexichromis mariei* (Crosse, 1872)	Roji Island (Rudman 1973); Adatra (Rudman 1983); Gulf of Kachchh (Apte & Desai 2017); present study
Family: Goniodorididae H. Adams & A. Adams, 1854		
40	*Goniodoris joubini* Risbec, 1928	Gulf of Kachchh, Dwarka (Apte & Desai 2017)
Family: Phyllidiidae Rafinesque, 1814		
41	*Phyllidiella zeylanica* (Kelaart, 1859)	Pirotan Island (Narayanan 1969; Burn 1970); Gulf of Kachchh (Rao & Sastry 2005); Mithapur Reef (Matwal & Joshi 2011); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Gulf of Kachchh (Apte & Desai 2017); present study
Family: Dendrodorididae O'Donoghue, 1924 (1864)		
42	*Dendrodoris fumata* (Rüppell & Leuckart, 1830)	Gulf of Kachchh (Apte et al. 2010); Goose Island, Narara Reef (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017); present study
43	*Dendrodoris nigra* (Stimpson, 1855)	Pirotan Island (Menon et al. 1961); Kyu Island-Okha Mandal (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005; Apte & Desai 2017); Dwarka (Poriya et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
44	*Dendrodoris atromaculata* (Alder & Hancock, 1864)	Present study
45	*Doriopsilla miniata* (Alder & Hancock, 1864)	Dona Reef, Okha (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010; GEER 2014a,b; Apte & Desai 2017); Poshitra Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study
Family: Bornellidae Bergh, 1874		
46	*Bornella stellifera* (A. Adams & Reeve [in A. Adams], 1848)	Chandri Reef (Eliot 1909); Pirotan Island (Menon et al. 1961; Parasharya 2012); Okha (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010; GEER 2013, 2014a,b); Poshitra Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017); present study
Family: Embletoniidae Pruvot-Fol, 1954		
47	*Embletonia gracilis* Risbec, 1928	Gulf of Kachchh (Apte & Desai 2017)
Family: Arminidae Iredale & O'Donoghue, 1923 (1841)		
48	*Armina cinerea* (Farran, 1905)	Pirotan Island (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
49	*Dermatobranchus fortunatus* (Bergh, 1888)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Pirotan Island, Narara Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
50	*Dermatobranchus semistriatus* Baba, 1949	Okha, Kyu Island-Okha Mandal (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
Family: Janolidae Pruvot-Fol, 1933		
51	*Janolus toyamensis* Baba & Abe, 1970	Kyu Island-Okha Mandal (Eliot 1909); Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Gulf of Kachchh (Apte & Desai 2017); present study

	Species	References
Family: Tethydidae Rafinesque, 1815		
52	*Melibe viridis* (Kelaart, 1858)	Kyu Island-Okha Mandal (Eliot 1909; Hornell 1909); Gulf of Kachchh (Rao & Sastry 2005; Apte & Desai 2017); Poshitra Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); Dwarka, Okha (Apte & Desai 2017); present study
Family: Samlidae Korshunova, Martynov, Bakken, Evertsen, Fletcher, Mudianta, Saito, Lundin, Schrödl & Picton, 2017		
53	*Samla bicolor* (Kelaart, 1858)	Gulf of Kachchh (Apte et al. 2010; Poriya et al. 2015); Poshitra Reef, Ashaba Island (Parasharya 2012); Mangrol, Veraval, Diu (Poriya et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)
Family: Eubranchidae Odhner, 1934		
54	*Eubranchus virginalis* (Baba, 1949)	Gulf of Kachchh (Apte & Desai 2017)
Family: Lomanotidae Bergh, 1890		
55	*Lomanotus vermiformis* Eliot, 1908	Poshitra Reef, Ashaba Island (Parasharya 2012); Gulf of Kachchh (Apte & Desai 2017)
Family: Trinchesiidae F. Nordsieck, 1972		
56	*Phestilla lugubris* (Bergh, 1870)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Pirotan Island, Goose Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study
57	*Phestilla minor* Rudman, 1981	Gulf of Kachchh (Apte & Desai 2017)
58	*Trinchesia yamasui* (Hamatani, 1993)	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Poshitra Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study
Family: Aeolidiidae Gray, 1827		
59	*Baeolidia salaamica* (Rudman, 1982)	Gujarat (Apte & Desai 2017)
60	*Baeolidia palythoae* Gosliner, 1985	Mangrol, Veraval, Diu (Poriya et al. 2015); Gujarat (Apte & Desai 2017)
61	*Anteaeolidiella cacaotica* (Stimpson, 1855)	Poshitra Reef (Parasharya 2012)
62	*Anteaeolidiella poshitra* Carmona, Bhave, Salunkhe, Pola, Gosliner & Cervera, 2014	Poshitra Reef (Carmona et al. 2014; Apte & Desai 2017); Gujarat (Raghunathan et al. 2016); present study
Family: Facelinidae Bergh, 1889		
63	*Phidiana militaris* (Alder & Hancock, 1864)	Dona Reef (Narayanan 1969; Burn & Narayanan 1970); Adatra, Okha (Rudman 1980); Gulf of Kachchh (Subba Rao & Sastry 2005; Apte et al. 2010; Poriya et al. 2015); Poshitra Reef, Ashaba Island (Parasharya 2012); Mangrol, Veraval, Diu (Poriya et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017); present study
64	*Facelina lineata* Eliot, 1905	Gulf of Kachchh (Apte & Desai 2017)
65	*Cratena lineata* (Eliot, 1905)	Ashaba Island (Parasharya 2012); Gulf of Kachchh (Apte & Desai 2017)
66	*Cratena poshitraensis* Bharate, Padula, Apte & Shimpi, 2020	Poshitra Reef (Bharate et al. 2020); present study
67	*Pteraeolidia ianthina* (Angas, 1864)	Gulf of Kachchh (Apte et al. 2010; GEER 2014a,b); Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
68	*Pteraeolidia semperi* (Bergh, 1870)	Kyu Island-Okha Mandal (Eliot 1909); Gulf of Kachchh, Dwarka, Okha (Apte & Desai 2017); present study
69	*Noumeaella isa* Ev. Marcus & Er. Marcus, 1970	Gulf of Kachchh (Apte & Desai 2017)
70	*Sakuraeolis gujaratica* Rudman, 1980	Adatra, Okha (Rudman 1980); Gulf of Kachchh (Apte et al. 2010; GEER 2014a,b; Poriya et al. 2015; Apte & Desai 2017); Poshitra Reef, Ashaba Island (Parasharya 2012); Diu (Poriya et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study
Family: Facelinidae Bergh, 1889 (=Myrrhinidae Bergh, 1905)		
71	*Phyllodesmium serratum* (Baba, 1949)	Gulf of Kachchh, Dwarka, Okha (Apte & Desai 2017)
Family: Bullidae Gray, 1827		
72	*Bulla ampulla* Linnaeus, 1758	Gulf of Kachchh (Gideon et al. 1957); Bet Dwarka (Menon et al. 1961); Pirotan Island (Menon et al. 1961; Surya Rao et al. 2004); Sikka, Mithapur Reef (Rao et al. 2004); Gulf of Kachchh (Rao & Sastry 2005; Apte et al. 2010; GEER 2013, 2014a,b); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
Family: Haminoeidae Pilsbry, 1895		
73	*Haminoea tenera* (A. Adams, 1850)	Bet Dwarka, Pirotan Island (Menon et al. 1961); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
74	*Smaragdinella calyculata* (Broderip & G. B. Sowerby I, 1829)	Okha (Apte & Desai 2017)
75	*Haloa natalensis* (Krauss, 1848)	Gulf of Kachchh (Rao & Sastry 2005); Poshitra Reef, Ashaba Island (Parasharya 2012)
76	*Lamprohaminoea ovalis* (Pease, 1868)	Gulf of Kachchh (Apte et al. 2010; Poriya et al. 2015; Apte & Desai 2017); Mangrol (Poriya et al. 2015); Porbandar (Apte & Desai 2017); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)

	Species	References
Family: Aglajidae Pilsbry, 1895 (1847)		
77	*Philinopsis speciosa* Pease, 1860	Gulf of Kachchh (Apte & Desai 2017); Present study
Family: Aplysiidae Lamarck, 1809		
78	*Aplysia argus* Rüppell & Leuckart, 1830	Bet Dwarka, Pirotan Island, Sikka (Narayanan 1969); Gulf of Kachchh (Rao 2003; Rao & Sastry 2005; Apte et al. 2010; GEER 2013, 2014a); Dwarka (Raghunathan et al. 2004); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)
79	*Aplysia oculifera* A. Adams & Reeve, 1850	Gulf of Kutch (GEER 2014b; Poriya et al. 2015); Dwarka, Mangrol, Veraval, Kodinar, Diu (Poriya et al. 2015); Kalubhar Island, Ashaba Island (Parasharya 2012); present study
80	*Aplysia parvula* Mörch, 1863	Veraval, Diu, Mahuva (Raghunathan et al. 2004); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
81	*Aplysia cornigera* G. B. Sowerby I, 1869	Gujarat (Rao 2003; Venkataraman et al. 2015; Raghunathan et al. 2016)
82	*Aplysia rudmani* Bebbington, 1974	Gulf of Kachchh (Rao & Sastry 2005)
83	*Stylocheilus striatus* (Quoy & Gaimard, 1832)	Okha (Apte 2013); Gujarat (Apte & Desai 2017)
Family: Oxynoidae Stoliczka, 1868 (1847)		
84	*Oxynoe viridis* (Pease, 1861)	Gulf of Kachchh (Apte & Desai 2017)
85	*Lobiger viridis* Pease, 1863	Poshitra Reef, Ashaba Island (Parasharya 2012); Gulf of Kachchh (Apte & Desai 2017)
Family: Plakobranchidae Gray, 1840		
86	*Elysia ornata* (Swainson, 1840)	Pirotan Island, Goose Island, Kalubhar Island, Poshitra Reef, Ashaba Island (Parasharya 2012); Gulf of Kachchh (GEER 2013, 2014a,b); Gujarat (Apte & Desai 2017); present study
87	*Elysia grandifolia* Kelaart, 1858	Kyu Island-Okha Mandal (Eliot 1909); Bet Dwarka, Poshitra Reef (Narayanan 1969); Gulf of Kachchh (Rao & Sastry 2005); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
88	*Elysia pusilla* (Bergh, 1871)	Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)
89	*Elysia expansa* (O'Donoghue, 1924)	Gujarat (Apte & Desai 2017); present study
90	*Elysia obtusa* Baba, 1938	Gulf of Kachchh (Apte et al. 2010; GEER 2014b); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016)
91	*Elysia hirasei* Baba, 1955	Gujarat (Apte & Desai 2017)
92	*Elysia thompsoni* Jensen, 1993	Gulf of Kachchh (Apte et al. 2010; Apte & Desai 2017); Goose Island, Kalubhar Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016); present study
93	*Elysia tomentosa* K. Jensen, 1997	Gulf of Kachchh (Apte et al. 2010; GEER 2014a,b); Pirotan Island, Goose Island, Narara Reef, Kalubhar Island, Poshitra Reef, Ashaba Island (Parasharya 2012); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017); present study
94	*Plakobranchus ocellatus* van Hasselt, 1824	Gulf of Kachchh (Apte & Desai 2017)
Family: Limapontiidae Gray, 1847		
95	*Sacoproteus smaragdinus* (Baba, 1949)	Poshitra Reef (Apte et al. 2015); Gulf of Kachchh (Apte & Desai 2017)

which possesses rocky intertidal zones with few patches of corals and mangroves. No sea slugs were reported in the Gulf of Khambhat.

Of the species identified, the largest number belong to the family Discodoridiidae (17 species, 12 genera), followed by Chromodorididae (nine species, four genera), Plakobranchidae (nine species, two genera), Facelinidae (eight species, six genera), Aplysiidae (six species, two genera), Polyceridae (five species, three genera), Haminoeidae (four species, four genera), Aeolidiidae (four species, two genera), Dendrodoridiidae (four species, two genera), Arminidae (three species, two genera), Pleurobranchidae (three species, two genera), Trinchesiidae (three species, two genera), Doriididae (two species, two genera), Oxynoidae (two species, two genera), Aplustridae (two species, one genus). One species each was identified from Aglajidae, Bornellidae, Bullidae, Embletoniidae, Eubranchidae, Goniodoridiidae, Janolidae Limapontiidae, Lomanotidae, Facelinidae (=Myrrhinidae), Pleurobranchaeidae, Phyllidiidae, Samlidae, and Tethydidae.

Present status and threats to sea slugs fauna

Anthropogenic activities, habitat loss, and invasive species are major threats to the biodiversity and sustainability of ecosystems (Imtiyaz et al. 2012). Sea slugs are not targeted for fishing or other human activities, but they are endangered by trawling, industrial discharge, habitat destruction, oil spills (the Gulf of Kachchh contains several large ports including Kandla, Vadinar, Mundra, Mandvi, Mithapur, Bedi, and Sikka), and climate change. The construction of jetties 3–4 km into the sea leads to increased siltation that alters shoreline topography and threatens coral communities.

Table 2. Synonyms of accepted sea slugs fauna recorded from Gujarat coast.

	Current Name	Synonymised Name
1	*Hydatina zonata* (Lightfoot, 1786)	*Hydatina velum* (Gmelin, 1791)
2	*Doriopsis granulosa* Pease, 1860	*Doris granulosa* (Pease, 1860)
3	*Jorunna funebris* (Kelaart, 1859)	*Kentrodoris funebris* (Kelaart, 1859)
4	*Carminodoris grandiflora* (Pease, 1860)	*Hoplodoris grandiflora* (Pease, 1860)
5	*Otinodoris raripilosa* (Abraham, 1877)	*Asteronotus raripilosus* (Abraham, 1877); *Hoplodoris desmoparypha* Bergh, 1880
6	*Taringa sublutea* (Abraham, 1877)	*Taringa caudata* (Farran, 1905)
7	*Sebadoris nubilosa* (Pease, 1871)	*Thordisa crosslandi* Eliot, 1904
8	*Goniobranchus tinctorius* (Rüppell & Leuckart, 1830)	*Chromodoris tinctoria* (Rüppell & Leuckart, 1830)
9	*Goniobranchus petechialis* (Gould, 1852)	*Chromodoris petechialis* (Gould, 1852)
10	*Goniobranchus fidelis* (Kelaart, 1858)	*Chromodoris krishna* Rudman, 1973
11	*Goniobranchus bombayanus* (Winckworth, 1946)	*Chromodoris bombayana* (Winkworth, 1946)
12	*Mexichromis mariei* (Crosse, 1872)	*Chromodoris mariei* (Crosse, 1872)
13	*Phyllidiella zeylanica* (Kelaart, 1859)	*Phyllidia zeylanica* Kelaart, 1859
14	*Bornella stellifera* (A. Adams & Reeve [in A. Adams], 1848)	*Bornella digitata* A. Adams & Reeve, 1850
15	*Armina cinerea* (Farran, 1905)	*Linguella cinerea* Farran, 1905
16	*Janolus toyamensis* Baba & Abe, 1970	*Antiopella indica* (Eliot, 1909); *Janolus indica* (Eliot, 1909)
17	*Melibe viridis* (Kelaart, 1858)	*Melibe rangi* Bergh, 1875
18	*Samla bicolor* (Kelaart, 1858)	*Flabellina bicolor* (Kelaart, 1858)
19	*Phestilla lugubris* (Bergh, 1870)	*Tenellia lugubris* (Bergh, 1870)
20	*Phestilla minor* Rudman, 1981	*Tenellia minor* (Rudman, 1981)
21	*Trinchesia yamasui* (Hamatani, 1993)	*Cuthona yamasui* Hamatani, 1993
22	*Anteaeolidiella cacaotica* (Stimpson, 1855)	*Anteaeolidiella foulisi* (Angas, 1864)
23	*Phidiana militaris* (Alder & Hancock, 1864)	*Hervia militaris* (Alder & Hancock, 1864); *Eolis militaris* Alder & Hancock, 1864
24	*Haloa natalensis* (Krauss, 1848)	*Haminoea natalensis* (Krauss, 1848)
25	*Lamprohaminoea ovalis* (Pease, 1868)	*Haminoea ovalis* Pease, 1868
26	*Aplysia argus* Rüppell & Leuckart, 1830	*Aplysia benedicti* Eliot, 1899
27	*Sacoproteus smaragdinus* (Baba, 1949)	*Stiliger smaragdinus* Baba, 1949

Industrial pollution may also have adverse effects on the water quality of the Gulf of Kachchh, Gulf of Khambhat, and Saurashtra coastline which may directly affect marine fauna. Information concerning the population status and ecology of sea slugs is lacking, but they are known to be sensitive to changes in habitats. Goddard et al. (2018) observed benthic sea slugs found outside of their normal ranges due to the effect of the 2015–16 El Nino. They observed a northern range shift for 52 species (1/4 of the recorded species from the region), and a positive correlation between total nudibranch abundance and El Nino events, sea surface temperature, sea surface height and warm phase of Pacific decadal oscillation, whereas they observed negative correlation with La Nina event.

CONCLUSION

Advance technologies bring the changes in sea slug faunal classifications, as a result, major revision took place in families, genera and species. DNA barcoding technology and taxonomy as radula morphology solved many species complexes and clarified the species identity of sea slug fauna. The species diversity sea slugs are recorded during the survey were mainly observed from intertidal region by direct observation. The snorkelling and scuba diving in the region can add more species from this area. The higher diversity of sea slugs in Gulf of Kachchh water than other areas in Gujarat due to diversified ecosystems exist such as coral reef, mangrove vegetation, sea grass, muddy sandy and rocky shore etc. Sikka coast is unique in terms of

Table 3. Checklist of misidentified sea slugs of Gujarat coast.

	Species	References	Comment	Distribution
1	*Aplysia dactylomela* Rang, 1828	Dwarka (Raghunathan et al. 2004); Gulf of Kachchh (Apte et al. 2010; GEER 2014b); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016; Apte & Desai 2017)	*Aplysia dactylomela* Rang, 1828 misidentified from India. True identity is given as *Aplysia argus* rüppell & leuckart, 1830 (Mollusca: Opisthobranchia: Aplysiidae) from Lakshadweep, with notes on its taxonomy in India (Chandran et al. 2016)	Red Sea (Eales 1960; Bebbington 1974, 1977); Greece (Zenetos et al. 2005); (Çinar 2006; Yokes 2008; Ayas & Ağilkaya 2017); Mediterranean Sea (Schembri 2008; Valdés et al. 2013); Turkey Israel (Pasternak & Galil 2010)
2	*Aplysia fasciata* Poiret, 1789	Gujarat (GSBTM, 2015; Raghunathan et al. 2016)	No occurrence in India	Florida (Heilprin 1887; Golestani et al. 2019); Egypt (Eales 1960); Israel (Susswein et al. 1987; Golestani et al. 2019); Massachusetts to Brazil (Rosenberg et al. 2009); Brazil (Golestani et al. 2019)
3	*Stylocheilus longicauda* (Quoy & Gaimard, 1825)	Okha (Apte 2013)	Species is actually *Stylocheilus striatus* (Quoy & Gaimard 1832)	Andaman & Nicobar Islands (Ramakrishna et al. 2010; Apte & Desai 2017); southwestern coast of India (Chinnadurai et al. 2014)
4	*Philinopsis taronga* (Allan, 1933)	Ashaba Island (Parasharya 2012)	No occurrence in India	Australia (Allan 1933; Burn 2006; Zamora-Silva & Malaquias 2018); New Zealand (Rudman 1972; Morley & Hayward 2015)
5	*Haminoea alfredensis* (Bartsch, 1915)	Gujarat (Raghunathan et al. 2016)	No occurrence in India	South Africa (Bartsch 1915; Macnae 1962; Gosliner 1987; Oskars et al. 2019); Oceania (Oskars et al. 2019)
6	*Haminoea elegans* Gray, 1825)	Sikka, Bhadreshwar, Salaya, Pirotan Island, Porbandar (Rao et al. 2004)	No occurrence in India	Brazil (Marcus 1957); Jamaica (Thompson 1977); Central Africa, Congo, Cuba, Florida, Mexico (Martinez & Ortea 1997); Bermuda to Brazil; E. Atlantic (Rosenberg et al. 2009)
7	*Haminoea galba* Pease, 1861	Pirotan Island (Gideon et al. 1957)	No occurrence in India	Hawaii (Kay 1979)
8	*Haminoea hydatis* (Linnaeus, 1758)	Gulf of Kachchh (Rao & Sastry 2005)	True identity is *Haminoea natalensis* (Krauss, 1848)	Mediterranean Sea (Linnaeus 1758); United Kingdom (Leach 1852); Portugal (Adams 1869); Italy (Alvarez et al. 1993, Castriota et al. 2005); France (Oskars & Malaquias 2019)
9	*Retusophiline lima* (T. Brown, 1827)	Gulf of Kachchh (GEER 2014b)	No occurrence in India	Massachusetts (Couthouy 1838); Scotland (Brown 1827; Ohnheiser & Malaquias 2013); Norway (Ohnheiser & Malaquias 2013); United Kingdom (Ohnheiser & Malaquias 2013)
10	*Hypselodoris capensis* (Barnard, 1927)	Mithapur Reef	True identity is *Hypselodoris carnea* (Bergh, 1889)	South Africa (Barnard 1927; Gosliner 1987; McPhail et al. 1998; Gosliner & Johnson 1999; Johnson & Gosliner 2012)
11	*Atagema alba* (O'Donoghue, 1927)	Narara Reef, Kalubhar Island (Parasharya 2012)	No occurrence in India	California (O'Donoghue 1927; MacFarland 1966; Bertsch & Gosliner 1986); Mexico (Bertsch & Gosliner 1986)
12	*Carminodoris bifurcata* Baba, 1993	Poshitra Reef, Ashaba Island (Parasharya 2012)	No occurrence in India	Hawaii (Kay & Young 1969; Fahey & Gosliner 2003); Japan (Baba 1993); Okinawa Island, Philippines (Fahey & Gosliner 2003)
13	*Cratena capensis* Barnard, 1927	Poshitra Reef (Parasharya 2012)	Endemic to South Africa, No occurrence in India	South Africa (Barnard 1927; Macnae 1954; Gosliner 1987)
14	*Cratena peregrina* (Gmelin, 1791)	Poshitra Reef, Ashaba Island (Parasharya 2012)	No occurrence in India	Italy (Martin 2003; Willis et al. 2017); Croatia, Crveni Otok, France, Spain, Andalucia (Padula et al. 2014)
15	*Knoutsodonta brasiliensis* (Alvim, Padula & Pimenta, 2011)	Gulf of Kachchh (Apte & Desai 2017)	No occurrence in India	Brazil (Alvim et al. 2011)
16	*Oxynoe panamensis* Pilsbry & Olsson, 1943	Poshitra Reef, Ashaba Island (Parasharya 2012)	No occurrence in India	Panama (Pilsbry & Olsson 1943); California, Mexico (Lewin 1970)

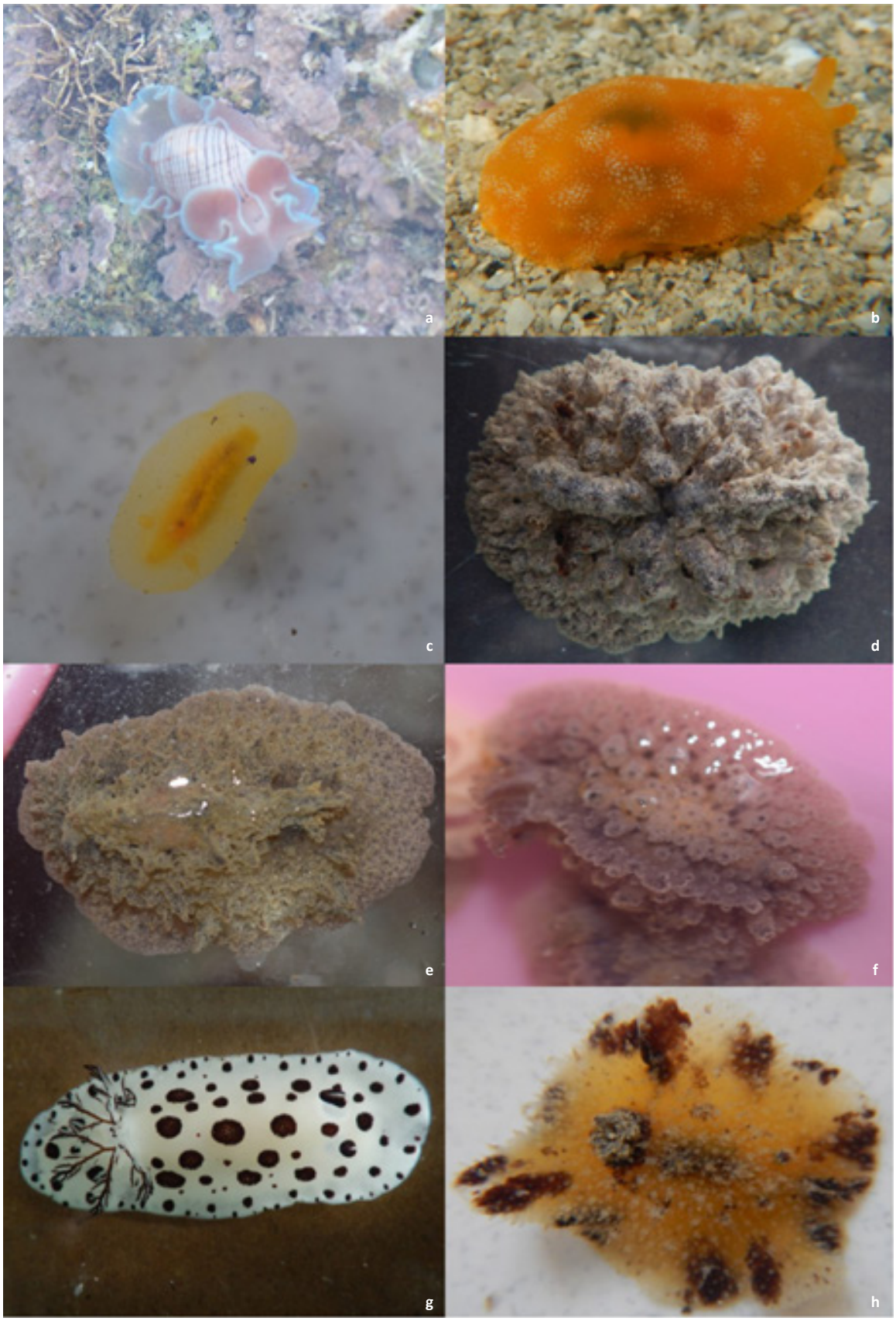

Image 1. a—*Hydatina physis* | b—*Berthellina citrina* | c—*Doriopsis granulosa* | d—*Atagema spongiosa* | e—*Atagema tristis* | f—*Atagema rugosa* | g—*Jorunna funebris* | h—*Thordisa villosa*. © Fisheries Research Station, Junagadh Agricultural University.

Image 2. a—*Peltodoris murrea* | b—*Sclerodoris tuberculata* | c—*Taringa sublutea* | d—*Tayuva lilacina* | e—*Plocamopherus ceylonicus* | f—*Hypselodoris infucata* | g—*Goniobranchus fidelis* | h—*Goniobranchus bombayanus*. © Fisheries Research Station, Junagadh Agricultural University.

Image 3. a—*Mexichromis mariei* | b—*Phyllidiella zeylanica* | c—*Dendrodoris fumata* | d—*Dendrodoris atromaculata* | e—*Doriopsilla miniata* | f—*Bornella stellifera* | g—*Janolus toyamensis* | h—*Melibe viridis.* © Fisheries Research Station, Junagadh Agricultural University.

Image 4. a—*Phestilla lugubris* | b—*Trinchesia yamasui* | c—*Anteaeolidiella poshitra* | d—*Phidiana militaris* | e—*Cratena poshitraensis* | f—*Pteraeolidia semperi* | g—*Sakuraeolis gujaratica* | h—*Philinopsis speciosa.* © Fisheries Research Station, Junagadh Agricultural University.

Image 5. a—*Aplysia oculifera* | b—*Elysia ornata* | c—*Elysia expansa* | d—*Elysia thompsoni* | e—*Elysia tomentosa.* © Fisheries Research Station, Junagadh Agricultural University.

diversity of marine macrofauna and flora. This unique habitat should be conserved for future and further study can be done by exploring more hidden areas of coast. Local people, fishermen, researchers can be aware of this beautiful fauna's important in marine ecosystem through conducting a good awareness and education programs.

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COMMUNICATION

Additional description of the Algae Hydroid *Thyroscyphus ramosus* (Hydrozoa: Leptothecata: Thyroscyphidae) from Palk Bay, India with insights into its ecology and genetic structure

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Abstract: The Algae hydroid *Thyroscyphus ramosus* of the Indian subcontinent is the most easily recognizable fleshy colonial hydroid playing a vital role in benthic communities. Though this fauna is abundant, it has remained unexplored for the past nine decades in India. This study provides a detailed report of the morphology, ecology and geographical locations of *T. ramosus*. Morphological traits such as maximum height, gonophore, and theca twist directions were studied in detail. The molecular biological data confirms the identity of *T. ramosus* and its abundance in Palk Bay, India. Important molecular markers such as 18S, 16S rRNA sequences of *T. ramosus* were analyzed and compared with similar species in NCBI. Using 18S sequence data, it is proven that *T. ramosus* is a distinct and valid species, however, interestingly the 16S rRNA forms clades with other species of the same genera (*T. fruticosus* and *T. bedoti*) rather than the same species. Moreover the *mt*COI forms a different clade with other genera. Furthermore, these data may enhance the advancement of identification in non-monophyletic conditions.

Keywords: Distribution, molecular, morphology, Palk Bay, *Thyroscyphus ramosus*.

இந்திய துணைக் கண்டத்தில் உள்ள ஆல்கா ஹைட்ராய்டாகிய தைரோசிபஸ் ரமோசஸ், மிகவும் எளிதில் அடையாளம் காணக்கூடிய சதைப்பற்றுள்ள காலனித்துவ ஹைட்ராய்டு ஆகும். இவை கடலின் அடிப்பரப்பிலுள்ள உயிரனங்களிடையே மிக முக்கிய பங்கு வகிக்கிறது. இவை இந்தியாவில் ஏராளமாக இருந்தபோதிலும், கடந்த தொண்ணூறு ஆண்டுகளுக்கு மேலாக இந்த உயிரனத்தை பற்றி அறியப்படாமலேயே இருந்தது. தற்போதைய ஆய்வு தைரோசிபஸ் ரமோசஸின் உருவவியல், சூழலியல் மற்றும் புவியியல் இடங்கள் போன்ற விரிவான அறிக்கையை வழங்குகிறது. உருவவியல் பண்புகளான அதிகபட்ச உயரம், இனப்பெருக்கம் மற்றும் உடல்தண்டின் திருப்ப திசைகள் விரிவாக ஆய்வு செய்யப்பட்டன. பால்க் விரிகுடாவில் அதிக அளவில் உள்ள இவை உயிர் மூலக்கூறு வகைப்பாட்டில் மூலமாக, தைரோசிபஸ் ரமோசஸ்தான் என்று மேலும் உறுதிசெய்யப்படுகிறது. தைரோசிபஸ் ரமோசஸில் சிற்றினத்தை கண்டறியக்கூடிய 18S, 16S ரிபோசோம் ஆர்என்ஏ மூலக்கூறு வரிசைகள் பகுப்பாய்வு செய்யப்பட்டு, NCBI இல் இதே போன்ற உயிரினங்களுடன் ஒப்பிடுகையில், 18 எஸ் ஆர்என்ஏ முடிவுகள் டி. ரமோசஸ் என்பதை நிரூபிக்கும்படியாக அமைந்தது. மேலும் சுவாரஸ்யமாக, டி..ரமோசஸ் 16 எஸ் ஆர்ஆர்என்ஏ அதே இனத்தின் (டி. ∴ப்ரூட்டிகோசஸ் மற்றும் டி. பெடோட்டி) பிற சிற்றினங்களுடன் ஒத்தவையாக உள்ளது. மேலும் mtCOI வகைப்பாட்டில் மற்ற வகை வேறுபட்ட ஹைட்ராய்டு சிற்றினங்களுடன் ஒத்தவையாக உள்ளது.. இந்த தரவு மோனோபிலெடிக் அல்லாத நிலையில் இனம்கண்டறிதலில் முன்னேற்றத்தை மேம்படுத்தக்கூடும்.

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Author contribution: GA & RR designed the experiments and analyzed the data; GA performed the sampling; KK & GA associated the experiments; GA, KK & RR wrote the paper.

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INTRODUCTION

Palk Bay on the southeastern coast of India covers ≈296km of coastline and up to 15m depth range considered as a backbone of productivity which supports a wide variety of fauna and flora. Palk Bay is known for its rich marine biodiversity which comprises: 302 marine algae, 51 Foraminifera, 12 tintinnids, 143 flora, 275 sponges, 123 non-coral coelenterates, 128 stony corals, 100 Polyzoa, 75 Polychaeta, 651 Crustacea, 733 Mollusca, 274 Echinodermata, 66 Prochordata, 580 fishes, five turtles, 61 birds, and 11 mammals (Kasim 2015). Palk Bay has a sandy rubble bottom, a shelf region that has a maximum temperature range of 26–28°C, and consists of intense upwelling regions (Kumaraguru et al. 2008). The class Hydrozoa has the largest number of species under the phylum Cnidaria. They are renowned for familiar forms of benthic, pelagic, and combined life cycle stages (Bouillon et al. 2006). Their biomass and life cycle stages are the indicator for food abundance and upwelling regions in the water column (Boero et al. 2008). These omnipresent voracious carnivore hydrozoans are one of the common bio-fouling components. These predators consume larvae of fishes, crustaceans, plankton, and benthic organisms, whereas some hydrozoan species directly consume dissolved organic matter and nutrients (Collins et al. 2006; Di Camillo et al. 2017). These voracious benthic feeders are involved as members in the energy transformation cycle, in the upwelling regions. It is considered so based on their mass and richness (Orejas et al. 2000). *Thyroscyphus ramosus* is one of the widely reported species in the Caribbean region (Germerden-Hoogeven Van 1965; Galea 2008) and regions of southern and western Atlantic coast (Allman 1888; Vervoort 1959; Winston 1982, 2009; Migotto et al. 1993), Mexican Gulf (Calder & Cairns 2009), Brazil (Shimabukuro & Marques 2006), South Africa (Warren 1907), and the Indian Ocean (Leloup 1932). The diversity of the genus *Thyroscyphus* were previously reported from the subtidal zone, at 1m depth (Kelmo & Vargas 2002) and in Cuba the species was reported to a maximum of 183–457 m depth (Nutting 1915). This species is associated with many biotic and abiotic forms and acts as a host for many organisms like other hydroids and sponges. The size ranges from 3cm to 25cm (Kelmo & Vargas 2002) during all the seasons in the breakwater region (Winston 1982). The distribution and composition of marine species, extending their geographical locations based on the suitable climate and environmental changes to survive and maintain their live forms (Hughes et al. 2000). Most research contributions were focused on commercially valuable groups rather than the inconspicuous non-commercial value benthic communities (González-Duarte et al. 2014).

In the marine ecosystem, the morphological similarities of the species and confusions in identification are resolved through DNA barcoding (Moura et al. 2008). This hampering was resolved with genetic analysis (Trivedi et al. 2016). Several gene regions, such as 16S, 18S, 28S, mtCOI and internal transcribed spacer 1 (ITS1), however, were employed to reveal their taxonomic relationships (Schierwater & Ender 2000; Collins et al. 2005; Govindarajan et al. 2006; Schuchert 2014). Mammen (1963, 1965a,b) contributed taxonomic information on c. 126 species of hydroids from southern India. Among hydroids, the genus *Thyroscyphus* is a large fleshy benthic hydroid colony that is easily visible underwater. F.H. Gravely (1927) recorded *Thyroscyphus junces* from the Pamban bridge and chank bed area. Hora (1925) collected three smaller colonies of *Thyroscyphus ramosus* (3cm size) from Shingle Island, Gulf of Mannar. Till date, this is the only known record of this genus from India. In this present study, year round abundance of *Thyroscyphus ramosus* at Rameshwaram coast, Palk Bay, Gulf of Mannar region is documented. The cryptic behavior, distribution information, ecology, habitat, and phylogenetic relationships of the hydroid species are still lacking, particularly in India. The main objective of this study is to re-describe the species and conduct a preliminary assessment of their phylogenetic relationships using morphological observations, 18S rRNA, 16S rRNA, and mtCOI gene of this species.

MATERIAL AND METHODS

Hydroid specimens were collected at Olakuda lighthouse area, Rameshwaram coast, Palk Bay (9.320188°N 79.340040° E) Gulf of Mannar region, Tamil Nadu, India, from September 2016 to September 2017 by snorkeling from shoreline up to 5m depth and as bycatch obtained from crab nets operated at 5–15 m (Figure 1). The collected hydroid specimen colonies were photographed before fixing in 4% neutralized formaldehyde solution to observe the color and morphological traits to avoid post preservation changes (Hissmann 2005; Di Camillo et al. 2010). Part of the whole colony was preserved in 99% ethanol for genetic studies (Nikulina et al. 2013; Maggioni et al. 2016). The diagrammatic details of the colony were obtained using a light microscope and morphological traits were also examined using ΣIGMA-Zeiss-Scanning Electron

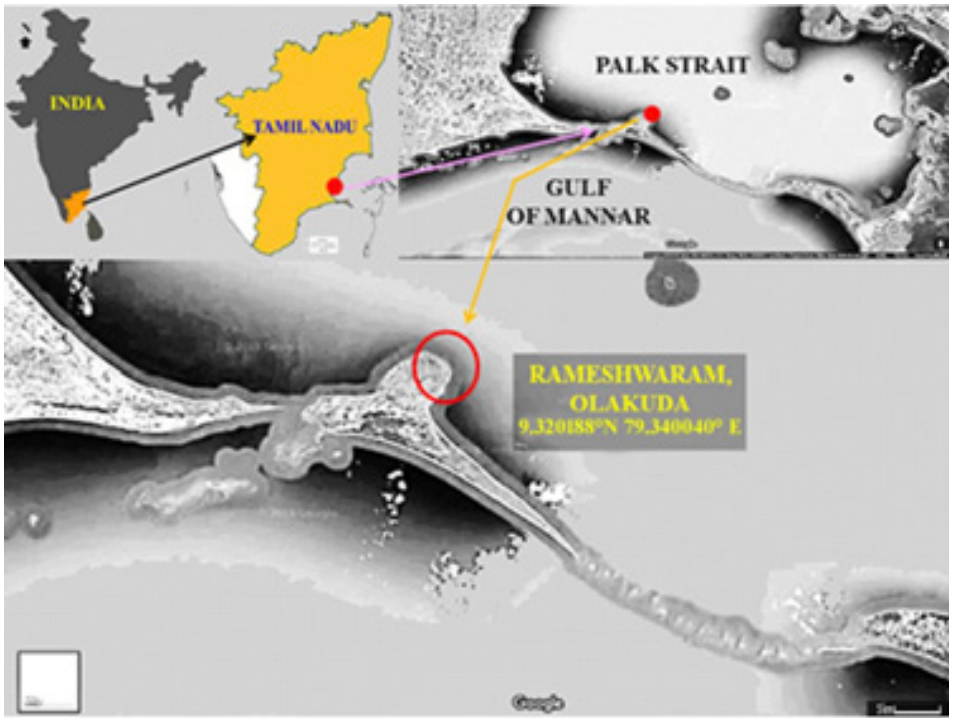

Figure 1. Sampling sites, location of the studied Rameshwaram lighthouse, Palk Bay (Gulf of Mannar, Tamil Nadu, India).

Microscopy.

Samples were identified using pictorial keys (Allman 1877; Winston 1982; Shimabukuro & Marques 2006; Calder & Cairns 2009), and online identification/ literature available in the WoRMS database (Schuchert 2018). Voucher specimen samples were submitted at the museum in the marine science department, Bharathidasan University, Marine Genomics and Barcoding Lab (MGBL) and obtained the specimen code (DMS-RR-HTR1-GoM-2016). The colonies were examined for the presence of gonophores in order to evaluate the period of sexual reproduction. The specimens were fixed with seawater and glutaraldehyde buffer for scanning electron microscopic (SEM) investigation (Di Camillo et al. 2012).

Sequencing genetic regions

The total genomic DNA was extracted in 99% ethanol preserved hydrozoa sample, following a modified protocol (Sambrook et al. 1989) from the ethanol-fixed specimen, by CAGL extraction protocol using Qiagen kit (Mandal et al. 2014). 0.7% agarose gel along with 1Kb DNA ladder was used to assess the quality of obtained DNA and their quality was estimated using a Biophotometer (Eppendorf). Universal Forward & Reverse primers, amplification of 16SrRNA gene 18SrRNA gene and COI gene were carried out and 2% agarose gel along with 100bp DNA ladder were used to confirm the PCR-generated amplicons. The amplified product was subjected to purification using the GeneJET PCR purification kit (Thermo Scientific, EU-Lithuania) in order to remove the primer-dimer and other contaminations. The acquired PCR products were subjected to sequencing using universal primers. For partial 16S rRNA (Forward primer: 5'- CGCCTGTTTATCAAAAACAT-3' and Reverse primer: 5'- GGTTTGAACTCAGATCATGT-3'), for partial 18S rRNA (Forward primer: 5'- CAGCAGCCGCGGTAATTCC-3' and Reverse primer: 5'- CCCGTGTTGAGTCAAATTAAGC -3'), for partial COI gene (Forward primer: 5'- GGTCAACAAATCATAAAGATATTGG -3' and Reverse primer: 5'- TAAACTTCAGGGTGACCAAAAAATCA -3') in forward and reverse directions using Genetic Analyzer 3500 using CAGL standardized protocol for genetic analysis of the hydrozoa species (Mandal et al. 2014). We prepared the dataset from submitted sequences in NCBI and similar sequence from NCBI-BLAST (Basic Local Alignment Searching Tool). The multiple sequence alignment was performed using Clustal X 2.0 and sequence-based evolutionary tree was performed using MEGA 7 (Tamura et al. 2013) for the estimation of genetic variations among the obtained clades of the separate molecular locus.

RESULTS AND DISCUSSION

Kingdom Animalia
Phylum Cnidaria Verrill, 1865
Class Hydrozoa Owen, 1843
Subclass Hydroidolina Collins, 2000
Order Leptothecata Cornelius, 1992
Superfamily Sertularioidea Lamouroux, 1812
Family Thyroscyphidae Stechow, 1920
Genus Thyroscyphus Allman, 1877
***Thyroscyphus ramosus* Allman, 1877**

Species natural history

The colony is transparent, pale yellow in color, smooth outer wall reaches a maximum height from hydrorhyza to tip of hydrocaulus 43.5cm without gonotheca and 24cm with gonophore. Stolen are webbed and entwined tightly with the substrates. Among the total 13 hydrorhyza two are infertile hydrorhyza (Figure 2A). Alternate Polysiphonic hydrocaulus from the hydrorhyza divided with regular intervals after every two hydrothecal pedicle internodes with a slight bent on the left and right alternative of oblique nodes (Figure 2B). Branches 8–34 with length variations were noted, smaller in upper and lower, larger branch in the middle of hydrorhyza. The branch length 3.2cm to a maximum of 8.4cm. The straight basal bottom becomes slender and crooked. Length of unfertile colony tube 1.4cm (Figure 2F). In a fertile colony after 1.8cm the distal apophysis with pedicellate hydrotheca observed distal alternate sides of entire hydrorhyza with regular distance. The supporting apophysis wider. Pedicle spirally twisted alternately (right pedicle twisted clockwise, left pedicles twisted anti-clockwise) ridged and shorter carrying hydrotheca at the upper end of the thick annulus (Figure 2D). Pedicle and hydrotheca joints distinctive (Figure 2C). Hydrotheca base larger than pedicle and cylindrical bottom and the top oblique have thick marginal ring and above the margin four blended cusps (Figure 2E). The lower side of hydrotheca distally straight and aboral side

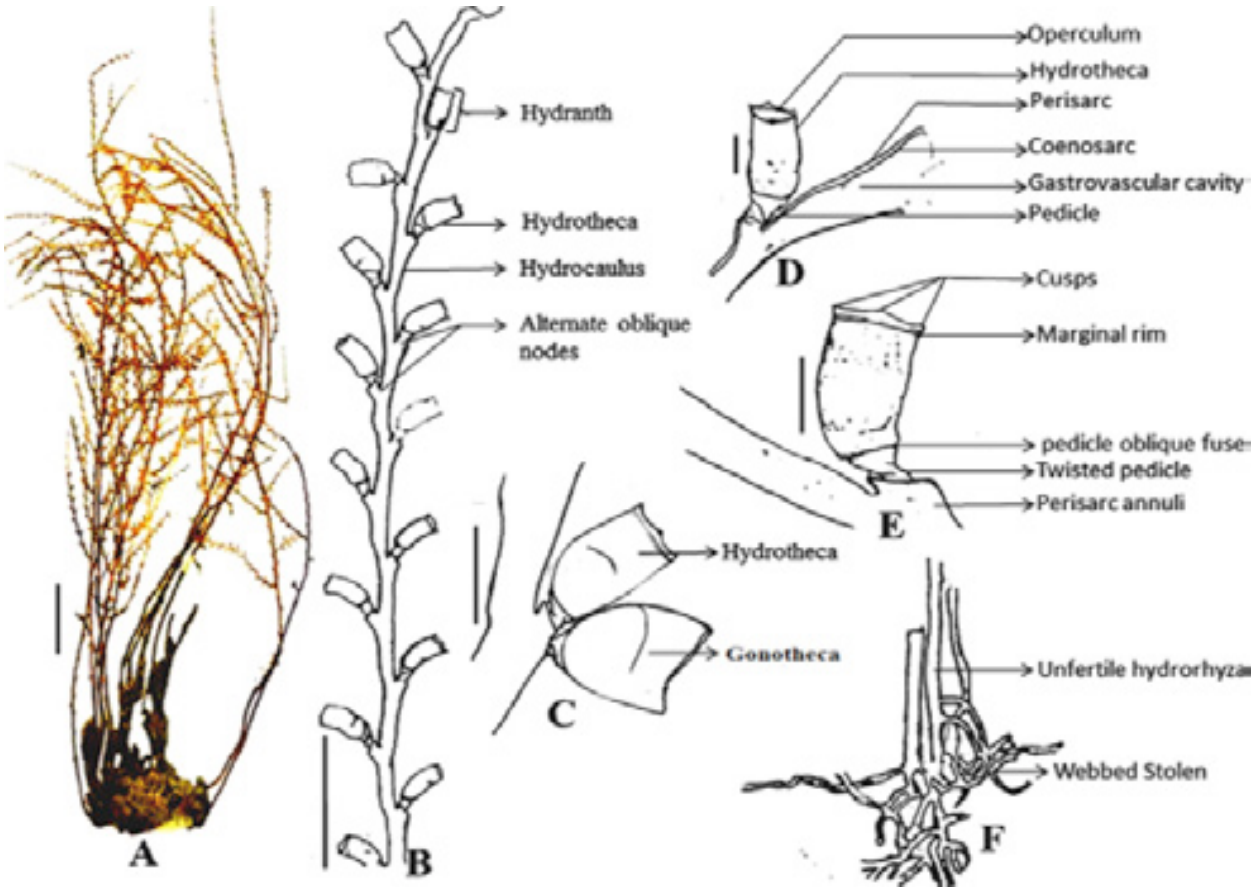

Figure 2. A—*Thyroscyphus ramosus*, specimen arise from webbed stolen with 13 hydrorhyza, 2 unfertiled included, branches upward, alternate, DMS-HA-Tr-Hap-01 | B—Hydrocaulus with15 hydrotheca | C—Arrangement of the hydrotheca and gonotheca on the pedicle stem | D—Parts of hydranth and hydracaulus | E— Cusps on margins of hydrotheca and the twisted pedicle | F—Unfertile hydrorhyza araising from the stolen. Scale bars: A—2 cm | B, D, E—0.3mm | C—0.5mm | F—1cm.

Image 1. A—*Thyroscyphus ramosus*. Colony arises on subtidal reef | B—Hydrocaulus of hydrorhyza with hydrotheca and gonotheca | C—Hydrocaulus with four alternate branched hydrotheca | D—Twisted pedicle with hydrotheca on perisarc annuli | E—hydrotheca and gonotheca arrangement, marginal rim, marginal cusps | F—Webbed stolen with unfertile tubular hydrorhyza. Scale bars: (B) 0.558mm; (C, F) 0.5mm; (D) 100mm; (E) 0.153mm.

slightly convex, basal wall thick, annulus and concave on pedicle joint. Hydrotheca asymmetrical, alternate, thick and oblique wall, and gonotheca rise beneath. Gonotheca conical shaped, situated beneath hydrotheca or on stem, larger and thin perisarc than hydrotheca. Gonothecal pedicle is shorter than hydrothecal pedicle, annulus thicker on the joint to gonothecal base. The gonothecal rim is thick and oblique marginal equidistant on opening. Some are conspicuously funnel-shaped. Measurements of hydrocaulus length between hydranths 1.156–2.983 mm of internode 225µm diameter, at node 356µm, 0–4 pedicel annulations. Hydrotheca length maximum 578µm, marginal cusp height 38–56 µm apophysis length 180–257 µm diameter, 369µm at rim maximal diameter. Gonotheca maximum 643µm length, 475µm on mouth, wider on middle 597µm maximal diameter, marginal ring 26µm height, pedicle 71µm on the aboral side (Image 1). The SEM images show the specimen characteristics of the skeleton and their actual thickness and the parts were clear in the image (Image 2).

The species were collected and described 91 years ago, from Shingle Island, Gulf of Mannar, India by Hora (1925). Morphology was distinguished by four cusps on the hydrotheca marginal ring with a single operculum. Length of the colony 3m to 24cm, with and without gonotheca was recorded. In this present study, the maximum of 43.5cm without gonophore and 24cm with

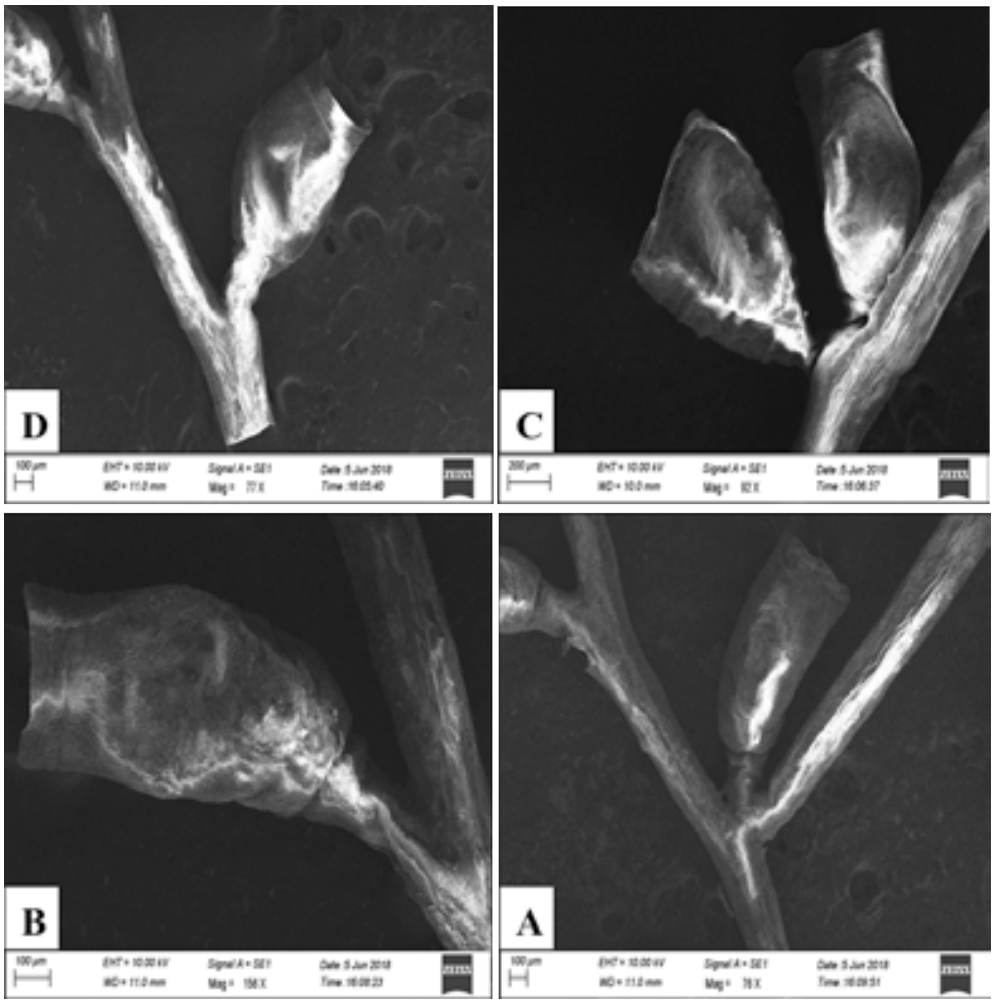

Image 2. A—Lateral view of hydrotheca marginal ring and cusps with widen hydrorhyza | B—Lateral view of one gonotheca on lower side of hydrotheca | C—Detail of hydrotheca apex, operculum, twisted pedicle | D—Internal projections of perisarc located between the branched hydrocaulus. Scale bars: (A, C, D) 100µm; (B) 200µm.

gonophore collected. In the earlier studies of the species from Shingle Island, Gulf of Mannar only 3cm, without gonophore (Leloup 1932; Migotto & Vervoort 1996) was recorded. After Winston's (1982), observation at Fort Pierce, Florida, North Beach breakwater, the year-round abundance of this species was recorded only in Palk Bay, Olakuda lighthouse region.

Ecology

The colonies occur in areas with strong current. This species grows on substratum such as sponges, shells of bivalves, on the sides of coral rock, and the sea surface covered with sandy rubbles also in vertical walls and surf zones. Occurs in shallow areas to a maximum depth of 457m.

Phylogenetic analysis (Graphical representation)

We constructed the phylogenetic tree using the neighbor-joining algorithm with 1,000 bootstrap replicates to identify the origin and replication of *Thyroscyphus ramosus* for 18S rRNA, 16S rRNA and mtCOI gene (Saitou & Nei 1987). The sequence-based evolutionary tree was constructed using MEGA 7.0, (Kumar et al. 2016) with bootstrap values of >50% numbered at the nodes. For the targeted sequence of *T. ramosus* 18S rRNA, 16S rRNA, species sequence from genus *Halecium* was used as outgroup and for the mtCOI gene *Scopalina ruetzleri* UCMPWC992 was used as the out-group due to the unavailability of sequence from the genus Halecium.

From the result of 18S rRNA gene-based tree was separated into two major clades from the out-group lineage of *Halecium labrosum* MHNG INVE29030. Our

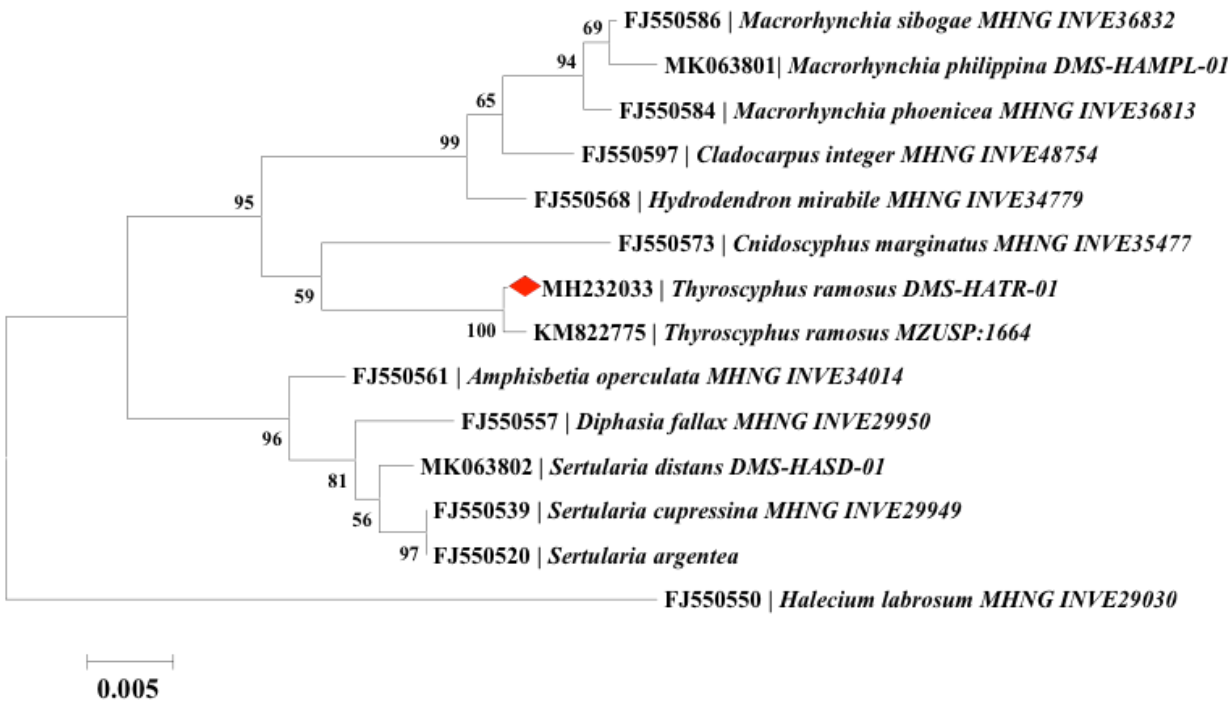

Figure 3. Two dimensional graphical representation of 18S rRNA based phylogenetic tree of *Thyroscyphus ramosus* (Red colour diamond indicates our target species), Numbers at nodes are bootstrap value >50% (*Halecium labrosum* MHNG INVE29030 used as an out group). Bar-0.005 substitutions per nucleotide position.

target species *Thyroscyphus ramosus* DMS-HATR-01 is highly supported with maximum bootstrap value to another specimen of the same species *Thyroscyphus ramosus* MZUSP:1664. The closely related second clade was formed with *Cnidoscyphus marginatus* MHNG INVE35477, which genus was accepted as *Thyroscyphus marginatus* (Allman 1877). Other minor supported clades of the *Hydrodendron mirabile* MHNG INVE34779, *Cladocarpus integer* MHNG INVE48754, *Macrorhynchia phoenicea* MHNG INVE36813, *Macrorhynchia philippina* DMS-HAMPL-01 and *Macrorhynchia sibogae* MHNG INVE36832, species of superfamily Plumularioidea. Second major clade consists of *Amphisbetia operculata* MHNG INVE34014, *Diphasiafallax* MHNG INVE29950, *Sertularia distans* DMS-HASD-01, *Sertularia cupressina* MHNG INVE29949, and *Sertularia argentea* are grouped with each other (Figure 3).

The result of the 16S rRNA gene-based tree was separated into two major clades from the out-group lineage of *Halecium mediterraneum* DNA122. The targeted species clade of *Thyroscyphus ramosus* DMS-HATR-02 highly supported with another specimen of the same genus *T. bedoti* MAL09-048, *T. fruticosus* DNA1250, *T. marginatus* bth.15.89 and *T. fruticosus* REU13-002 with maximum bootstrap value. Another major clade consists of *Sertularella ellisii* DNA1237, *S. mediterranea* MHNG INVE32948, *S. polyzonias* DNA1236, *S. ellisii* MHNG INVE32156, *S. africana* MHNG INVE34017, *S. gayi, S. simplex* MHNG-HYD-DNA1135, *S. sanmatiasensis, S. rugosa* MHNG INVE29032. Interestingly the same species of other strain *Thyroscyphus fruticosus* REU13-002 was In the closest clade and also in the nearest common ancestral clade, similar to the clades of *Sertularella ellisii* DNA1237 and *S. ellisii* MHNG INVE3215 may be originated from various species of *Sertularella* genus (Figure 4).

The result of mtCOI gene-based tree was separated into many sub-clades. The target species *Thyroscyphus ramosus* DMS-HA-Tr-Hap-01 was formed from the separate sub-clade from the same genus of the other species. The *Nanomiacara* Naca53 clade form as the ancestral for all above-mentioned sequences *and the Scopalina ruetzleri* UCMPWC992 act as an out-group for the constructed phylogenetic tree (Figure 5). This is the first report from an Asian country on 16S rRNA analysis and *mt*CO1 gene sequence of *Thyroscyphus ramosus* in the biological database. So, the identified phylogenetic neighbor organisms may act as a reference to our target organism. In future, the reported sequences may use as a reference data to our target species.

Table 1. Pairwise genetic distance was computed for 18S rRNA gene based phylogenetic related species of Thyroscyphus ramosus.

Organism	Access no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
*Thyroscyphus ramosus**	MH232033														
Thyroscyphus ramosus	KM822775	0.002													
Hydrodendron mirabile	FJ550568	0.026	0.027												
Cnidoscyphus marginatus	FJ550573	0.027	0.029	0.043											
Cladocarpus integer	FJ550597	0.028	0.029	0.008	0.041										
Macrorhynchia sibogae	FJ550586	0.033	0.033	0.014	0.042	0.013									
Macrorhynchia phoenicea	FJ550584	0.033	0.033	0.014	0.039	0.010	0.003								
Macrorhynchia philippina	MK063801	0.033	0.033	0.014	0.044	0.013	0.003	0.006							
Sertularia distans	MKo63802	0.037	0.039	0.037	0.046	0.042	0.044	0.044	0.048						
Diphasia fallax	FJ550557	0.038	0.039	0.044	0.046	0.046	0.049	0.049	0.053	0.010					
Amphisbetia operculata	FJ550561	0.039	0.041	0.039	0.044	0.041	0.042	0.042	0.046	0.010	0.014				
Sertularia cupressina	FJ550539	0.039	0.041	0.039	0.044	0.044	0.046	0.046	0.049	0.005	0.010	0.011			
Sertularia argentea	FJ550520	0.039	0.041	0.039	0.044	0.044	0.046	0.046	0.049	0.005	0.010	0.011	0.000		
Halopteris carinata	KT722401	0.039	0.037	0.034	0.049	0.039	0.036	0.039	0.039	0.041	0.046	0.036	0.042	0.042	
Halecium labrosum	FJ550550	0.072	0.072	0.067	0.070	0.072	0.070	0.074	0.074	0.063	0.062	0.055	0.065	0.065	0.062

*Target species

Table 2. Pairwise genetic distance was computed for 16S rRNA gene based phylogenetic related species of *Thyroscyphus ramosus*.

Organism	Access no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
*Thyroscyphus ramosus**	MH392732														
Thyroscyphus bedoti	MH108450	0.008													
Thyroscyphus fruticosus	MG811643	0.015	0.019												
Thyroscyphus fruticosus	MG108467	0.098	0.096	0.091											
Sertularella gayi	AM888340	0.116	0.114	0.116	0.127										
Sertularella ellisii	MG811636	0.120	0.120	0.123	0.124	0.041									
Sertularella polyzonias	MG811635	0.132	0.129	0.134	0.136	0.037	0.019								
Sertularella simplex	KX355446	0.125	0.123	0.129	0.131	0.023	0.029	0.035							
Sertularella sanmatiasensis	FN424141	0.125	0.123	0.130	0.144	0.039	0.039	0.045	0.031						
Sertularellala genoides	FJ550478	0.122	0.120	0.127	0.131	0.037	0.017	0.021	0.017	0.039					
Sertularella africana	FJ550490	0.134	0.132	0.138	0.128	0.039	0.033	0.035	0.021	0.047	0.031				
Sertularella mediterranea	FJ550479	0.124	0.122	0.127	0.135	0.039	0.017	0.023	0.031	0.043	0.021	0.029			
Thyroscyphus marginatus	MH361368	0.118	0.114	0.116	0.117	0.131	0.131	0.143	0.126	0.122	0.135	0.138	0.140		
Sertularella rugosa	AY787906	0.125	0.122	0.129	0.138	0.037	0.045	0.045	0.031	0.027	0.039	0.039	0.045	0.122	
Halecium mediterraneum	MG811603	0.147	0.149	0.154	0.147	0.108	0.097	0.104	0.104	0.108	0.101	0.100	0.108	0.161	0.112

*Target species

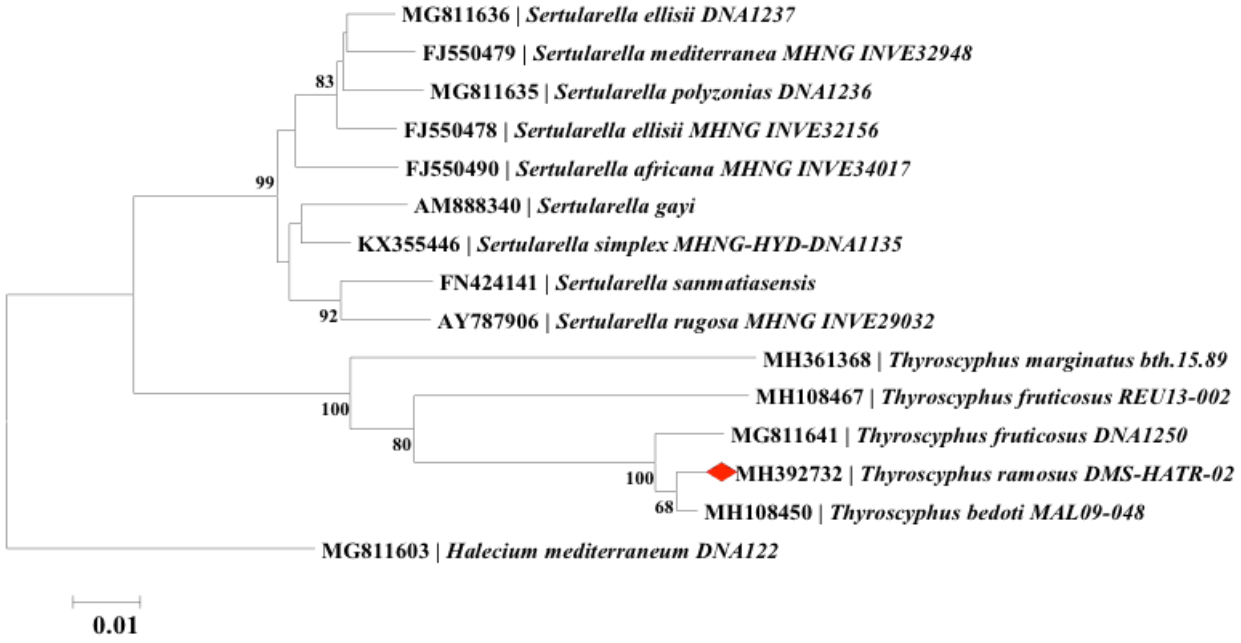

Figure 4. Two dimensional graphical representation of 16S rRNA based phylogenetic tree of *Thyroscyphus ramosus* (Red colour diamond indicates our target species). Numbers at nodes are bootstrap value >50% (*Halecium mediterraneum* DNA122). Bar- 0.01 substitutions per nucleotide position.

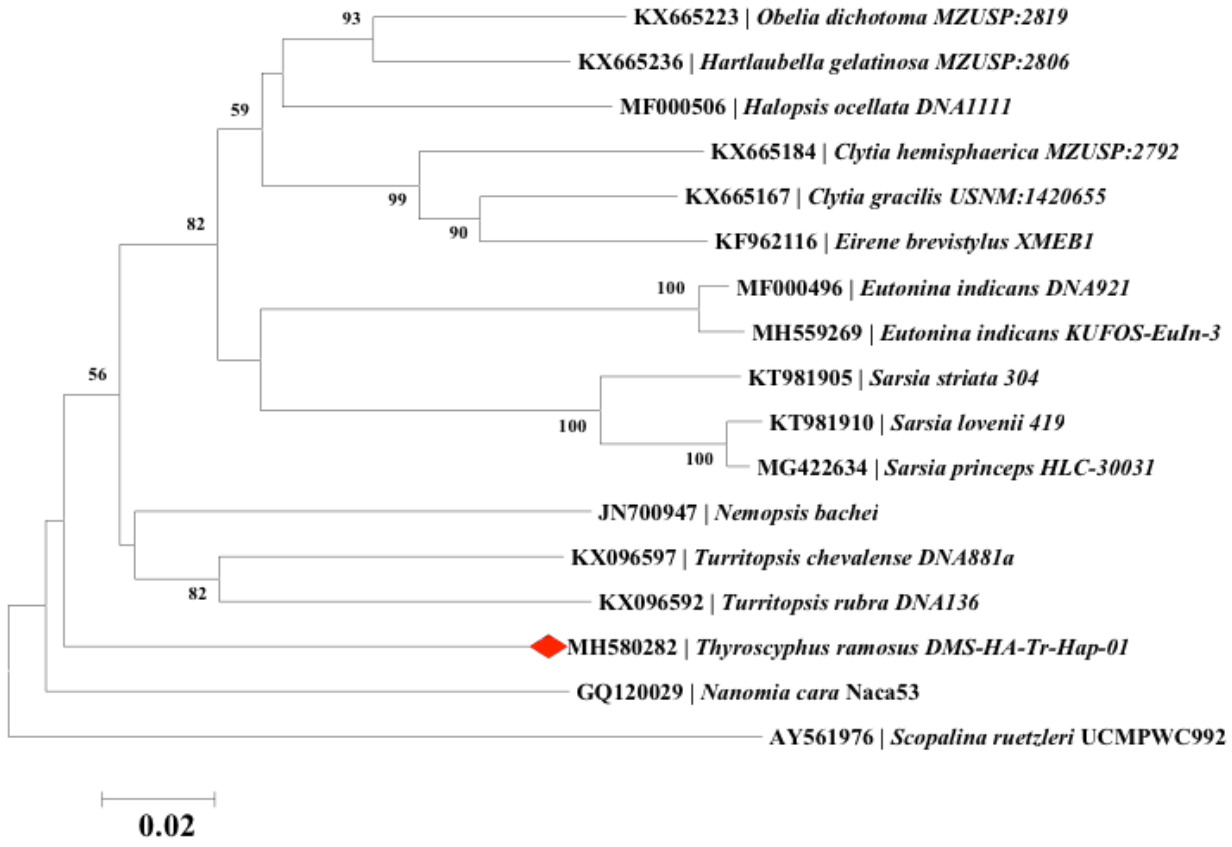

Figure 5. Two dimensional graphical representation of *mt*COI gene based phylogenetic tree of *Thyroscyphus ramosus* (Red colour diamond indicates our target species). Numbers at nodes are bootstrap value >50% (*Scopalina ruetzleri* UCMPWC992). Bar- 0.02 substitutions per nucleotide position.

Table 3. Pairwise genetic distance was computed for mtCOI gene based phylogenetic related species of Thyroscyphus ramosus.

Organism	Access no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nemopsis bachei	JN700947																	
Sarsia striata	KT981905	0.172																
Turritopsis chevalense	KX096597	0.180	0.192															
Obelia dichotoma	KX665223	0.165	0.159	0.180														
Hartlaubella gelatinosa	KX665236	0.196	0.185	0.153	0.168													
Sarsia lovenii	KT981910	0.176	0.177	0.174	0.166	0.080												
Dendrogramma	KU716054	0.188	0.209	0.053	0.176	0.163	0.176											
Nanomiacara	GQ120029	0.199	0.195	0.178	0.189	0.168	0.172	0.172										
Halopsis ocellata	MF000506	0.182	0.191	0.230	0.181	0.192	0.177	0.232	0.187									
Clytia gracilis	KX665167	0.198	0.186	0.165	0.173	0.114	0.115	0.163	0.146	0.184								
Eutonina indicans	MF000496	0.206	0.186	0.196	0.196	0.122	0.112	0.196	0.179	0.195	0.143							
Sarsia princeps	MG422634	0.201	0.189	0.164	0.182	0.158	0.142	0.177	0.182	0.227	0.153	0.167						
Scopalina ruetzleri	AY561976	0.186	0.204	0.052	0.172	0.161	0.174	0.010	0.174	0.230	0.157	0.192	0.176					
Eirene brevistylus	KF962116	0.223	0.236	0.267	0.232	0.249	0.214	0.272	0.260	0.234	0.223	0.241	0.265	0.269				
Eutonina indicans	MH559269	0.208	0.185	0.189	0.204	0.136	0.124	0.198	0.168	0.204	0.151	0.075	0.163	0.198	0.257			
Nemopsis bachei	JN700947	0.203	0.184	0.166	0.182	0.162	0.148	0.178	0.188	0.234	0.155	0.171	0.013	0.178	0.269	0.167		
Sarsia striata	KT981905	0.206	0.184	0.206	0.194	0.149	0.134	0.194	0.180	0.189	0.142	0.100	0.167	0.196	0.250	0.098	0.165	
Turritopsis chevalense	KX096597	0.190	0.160	0.188	0.127	0.168	0.161	0.192	0.173	0.182	0.163	0.176	0.189	0.190	0.254	0.179	0.198	0.182

*Target species

Pairwise genetic distance (statistical representation)

We inferred our result with the second approach using pairwise distance (statistical data). From the result of genetic diversity of 18S rRNA, 16S rRNA and mtCOI gene were identified in the pairwise distance range between (0.0–0.074) in 18S rRNA (shown in Table 1). It reveals that no phylogenetic variation may occur in the 18S rRNA gene whereas, 16S rRNA gene, the distance arises in between the range of (0.008–0.154) and for mtCOI gene (0.052–0.272) (as shown in Tables 2 & 3). This slight genetic variation exposed in both 16S rRNA and the mtCOI gene. Even if the genes and species are different, no higher genetic variation originated from our results; this is due to the similarity between the sequence and its family.

CONCLUSION

The region in Palk Bay supports the highly diverse and abundant benthic Algal Hydroid *T. ramosus*. In places like Fort Pierce, Florida, North Beach breakwater, the species are observed year-round due to favorable environmental conditions. The abundant distribution is due to complex reasons such as nutrient availability, littoral topography and suitable conditions for their production and survival. To preserve biodiversity of the benthic indicator species, stringent environmental management practices have to be implemented in this area.

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COMMUNICATION

Floristic composition and distribution pattern of herbaceous plant diversity in fallow lands of the central districts of Punjab, India

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Abstract: This study explores the change in composition of herbaceous plants with change in season and site in the fallow lands of central districts of Punjab, India. Overall 41 plant species were reported from studied sites. Poaceae and Asteraceae were recorded as dominant families with seven and six plant species, respectively. Density and IVI values of perennial plant species were recorded to be the maximum from July to September and for annuals maximum values were from February to March and from July to September. Diversity indices like Shannon Wiener index, evenness index, Menhinick index, and Simpson diversity index values showed variation with season and site. Similarity index value between studied sites was recorded to be the minimum in July (0.45) which indicates a maximum value of dissimilarity index in this month. The information generated in this study can be exploited by researchers for conservation of natural plant diversity and timely assessments of such areas help to study climate change.

Keywords: Diversity, index, month, site, species, weeds.

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Competing interests: The authors declare no competing interests.

Author details: Jashanpreet Kaur was postgraduate student at Punjab Agricultural University, Ludhiana and she has great interest in plant diversity evaluation along with their taxonomy. She had done the detailed study on herbaceous plants in different landuse systems of Punjab during her masters. Dr. Rajni Sharma currently working as professor in department of botany of Punjab Agricultural University, Ludhiana and she has been working in research project of plant diversity evaluation of Punjab. Dr. Pushp Sharma is Physiologist of oilseeds at Punjab Agricultural University, Ludhiana and she is working in research fields of abiotic stresses.

Author contribution: JK conducted field trips, collected and compiled data related plant diversity. RS planned the outline of this research work and provides necessary guidelines for research. PS helped in statistical analysis.

Acknowledgements: The help provided by the taxonomists of the University Dr Tarundeep Kaur and Antul Choudary in identification of plant species is gratefully acknowledged.

INTRODUCTION

India is one of the mega-diverse centers of the world. About 8.07% land in India and 61ha land in Punjab is reported as fallow lands in 2013–2014 according to a report prepared by the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare in 2016. Throughout the year, the fallow lands are covered with green herbaceous plants. Plant diversity is functional and a structural unit of biotic component of the ecosystem and subjected to change on interaction with a number of biotic and abiotic factors. The study of diversity of an area helps to assess ecosystem health as species distribution has both complementary and supplementary behavior. Naturally growing plants species in ecosystems are diverse to such an extent that most species are not documented till now and sometimes some species become extinct without being identified (Hubbell & Foster 1986). Losing even a few plant species in a diverse ecosystem can reduce the biomass production and impair regulatory, promoting and supporting services of the ecosystem. The concept of wild species evolved when humans started growing plants deliberately for food (Shah et al. 2006). Documentation of composition of the plant diversity of fallow lands and their economic importance has not been done systematically. Thus people are not aware about the economic value of herbaceous plants growing in fallow lands and they overlook them as weeds. So phytosociological surveys of these areas after regular intervals are important to document the variability of plant diversity. This helps in environmental monitoring as a small change in environmental conditions affect diversity of plant species because some plant species are unable to bear transformations. The distribution of plants depends on their genetic makeup and environmental factors such as light, temperature, and edaphic factors like soil composition, texture, and pH (Curtis 1959; Phillips 1959; Misra 1968). This paper focuses on naturally growing herbaceous plant diversity, composition, and their distribution pattern in fallow lands to draw attention of researchers so that they can explore the economic importance and conservation of these plant species. The documentation of plants diversity of the fallow lands of Punjab has not been done so far.

MATERIALS AND METHODS

Study site

The present study was carried throughout year (January–December 2017) in fallow lands of two central districts of Punjab, viz,. site 1 Ludhiana (30°54'14.886"N, 75°49'0.4836"E) and site 2 Sangrur (30°40'59.7504''N & 75°49' 41.1672''E) districts (Figure 1, Image 1). The distance between two districts (sites) was 30km. At each district about 10 fallow lands were explored. The fallow lands selected for the present investigation were with almost negligible anthropogenic disturbances.

The climate of both areas is typical subtropical with long dry season from end of September to early June and wet season from July to early September along with

Figure 1. Study site. (Source: Google)

Image 1. Study sites: A—Fallow land in July and August | B—Fallow land from December to March. © Jashanpreet Kaur.

hot desiccating winds. The average temperature ranged from 5°C to 35°C and maximum rainfall received during August was 131.4mm and 97mm for site 1 and site 2, respectively.

METHODS

Areas were explored by quadrat method. The size and number of quadrats to be laid down were determined by species area curve (Misra 1968). For the present investigation, 15 fixed quadrats (1mÎ1m) were laid randomly in three replications to study ground-level herbaceous vegetation at each study site. Areas were surveyed after 30 days throughout the year commencing from January to December 2017. Shrubs and herbs were documented in the present investigation. The documented plant species were grouped into dicots and monocots (Images 1–41).

A species composition study was carried out by computing various phytosociological characters for each month by standard formulae. Calculations were done using Microsoft Excel 7 and values were counter checked using Paleontological Software (PAST) version 3.

(i) Density / m^2 (Curtis 1959)

$$\text{Density} = \frac{\text{Total number of individuals of the plant species in all quadrats}}{\text{Total number of quadrats studied}}$$

(ii) IVI – Importance Value Index (Phillips 1959)

IVI = Relative density + Relative frequency + Relative Dominance

$$\text{Relative density} = \frac{\text{Density of individual plant species x 100}}{\text{Density of all the species}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of individual plant species x 100}}{\text{Frequency of all the species}}$$

$$\text{Relative dominance} = \frac{\text{Basal area of plant species x 100}}{\text{Basal area of all the species}}$$

(Here Basal area = $\pi d^2/4$)

(iii) Shannon Wiener index (Shannon & Wiener 1963)

Shannon Wiener index (H) = $- \Sigma [P_i (\ln P_i)]$

$$\text{Here } P_i = \frac{\text{Number of individuals of one plant species}}{\text{Total number of all individuals of plant species}}$$

(iv) Menhinick index (Menhinick 1964)

Menhinick index = $S / \sqrt{n}$

S = Number of taxa

n = Number of individuals

(v) Evenness index (Pielou 1977)

Evenness index = H / ln S

Here H = Shannon wiener diversity index

S = Total number of species

(vi) Similarity index (Sorenson 1948)

Similarity index (S) = 2C/ (A+ B)

Here A = Number of species in one system

B = Number of species in another system

C = Number of species common in both systems

(vii) Dissimilarity index (Sorenson 1948)

Dissimilarity index = 1- S

Here S = Similarity index

(viii) Simpson diversity index (Simpson 1949)

Simpson diversity index = $\{1- \Sigma n_i (n_i -1)\} / N(N-1)$

Here N = Number of plants of the species

n_i = Number of plants of a species

Identification of plant species was done with the help of regional floras and taxonomists of the university. Statistical measures for mean and standard deviation was carried out using software SPSS version 16.

RESULTS

a) Species diversity and distribution

Overall 41 species belonging to 19 families were documented from both study sites; 32 were dicots whereas monocots were represented by only nine plant species (Table 1). The fallow land of site 2 was represented by 32 plant species and site 1 by 31 plant species. Twenty-two plant species were common to both sites and 10 plant species were confined to site 2 while nine were confined only to site 1. *Artemisia scoparia*, *Conyza bonariensis*, *Croton bonplandianus*, *Euphorbia hirta*, *Ipomoea pestigridis*, *Gnaphalium purpureum*, *Polygonum plebeium*, *Stellaria media*, and *Xanthium strumarium* were confined to site 1; *Abutilon indicum*, *Cenchrus biflorus*, *C. catharticus*, *C. setiger*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis*, *Poa annua*, *Sida cordifolia*, *Sesamum indicum*, and *Tribulus terestris* were confined to site 2; however, the rest of the plant species were common at both locations. Poaceae (Table 2) with seven plant species was dominant at site 2 while Asteraceae dominated with six plant species at site 1.

b) Density and IVI at two locations

Density values on both study sites were recorded between 0.07–10.5. In the case of perennial plant species, the maximum value (10.5) was observed for *Parthenium hysterophorus* in September at site 2. At site 1, however, the value of this species varied between 1.00–3.53. At site 1, the maximum density was for *Chenopodium album* (7.6) in August. Among annuals, the maximum value was observed for *Anagallis arvensis* (2.13) in March at site 2 and for *Coronopus didymus* (3.26) in April at site 1. For species that are confined to a particular study site, maximum density values were recorded for *Artemisia scoparia* (2.67) in site 1 and *Digitaria sangunalis* (2.93) in site 2 (Appendix 1).

Importance Value Index (IVI) values of the two study sites ranged from 0.26 to 106. Among perennials, *Chenopodium album* (106) showed a maximum value in site 2 while in site 1 values of this index for *C. album* was below 50. Similarly for site 1, *Achyranthes aspera* showed maximum values, i.e., 82.9 while in Site 2 values of IVI for this species were below 50. Among annuals, a maximum value of 71.4 was observed at site 2 for *Anagallis arvensis* in January. *Malva parviflora* was recorded to have maximum IVI, i.e., 11.2 at site 1 in January. *Artemisia scoparia* which was confined to site 1 showed maximum density (27) in September while *Cenchrus biflorus* recorded only at site 2 showed a maximum density, i.e., 8.03 in November (Appendix 2).

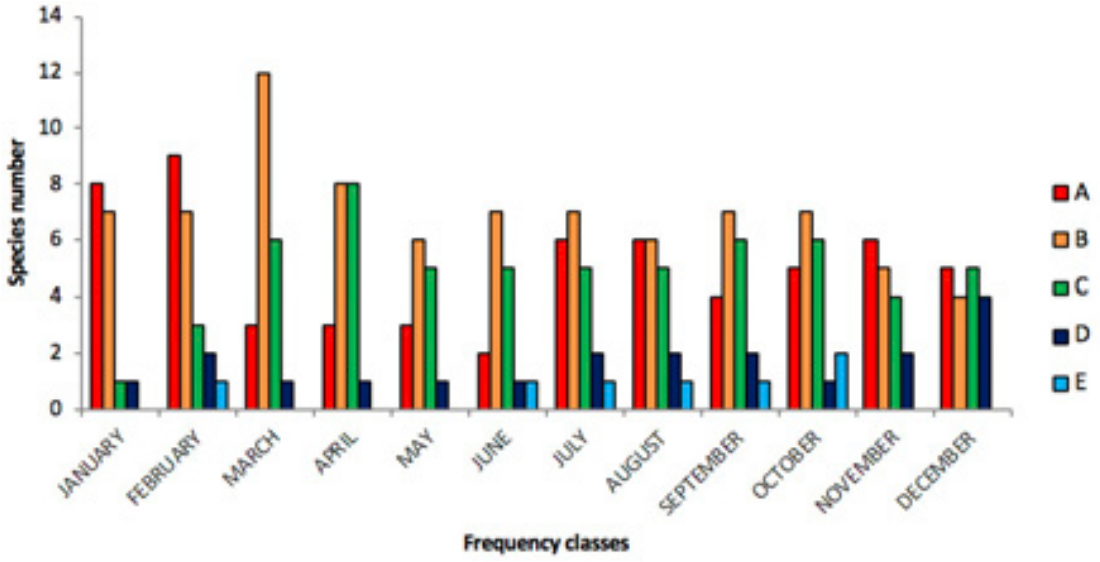

Figure 2. Raunkiaer's frequency class distribution in fallow land of Ludhiana, Punjab, India.

Table 1. Floristic composition of fallow lands of two locations (Ludhiana and Sangrur) in Punjab.

Plant species	Family	Group	Site 1	Site 2
Abutilon indicum (L.) Sweet	Malvaceae	Dicot	-	+
Achyranthes aspera L.	Amaranthaceae	Dicot	+	+
Ageratum conyzoides L.	Asteraceae	Dicot	+	+
Anagallis arvensis L.	Primulaceae	Dicot	+	+
Artemisia scoparia Waldst. & Kit.	Asteraceae	Dicot	+	-
Boerhavia diffusa L.	Nyctaginaceae	Dicot	+	+
Calotropis procera (Aiton) W.T.Aiton	Apocynaceae	Dicot	+	+
Cannabis sativa L.	Malvaceae	Dicot	+	+
Senna occidentalis (L.) Link	Fabaceae	Dicot	+	+
Cenchrus biflorus Roxb.	Poaceae	Monocot	-	+
Cenchrus catharticus Delile	Poaceae	Monocot	-	+
Cenchrus setiger Vahl	Poaceae	Monocot	-	+
Chenopodium album L.	Chenopodiacae	Dicot	+	+
Conyza bonariensis (L.) Cronquist	Asteraceae	Dicot	+	-
Coronopus didymus (L.) Sm.	Brassicaceae	Dicot	+	+
Croton bonplandianus Baill.	Euphorbiaceae	Dicot	+	-
Cynodon dactylon (L.) Pers.	Poaceae	Monocot	+	+
Dactyloctenium aegyptium (L.) Willd.	Poaceae	Monocot	-	+
Dicliptera brachiata (Pursh) Spreng.	Acanthaceae	Dicot	+	+
Digitaria sanguinalis (L.) Scop.	Poaceae	Monocot	-	+
Euphorbia hirta L.	Euphorbiaceae	Dicot	+	-
Gnaphalium purpureum L.	Asteraceae	Dicot	+	-
Indigofera linifolia (L.f.) Retz.	Fabaceae	Dicot	+	+
Ipomoea pes-tigridis L.	Convolvulaceae	Dicot	+	-
Malva parviflora L.	Malvaceae	Dicot	+	+
Medicago polymorpha L.	Fabaceae	Dicot	+	+
Parthenium hysterophorus L.	Asteraceae	Dicot	+	+
Poa annua L.	Poaceae	Monocot	-	+
Polygonum plebeium R.Br	Polygonaceae	Monocot	+	-
Sesamum indicum L.	Pedaliaceae	Dicot	-	+
Sida acuta Burm.f.	Malvaceae	Dicot	+	+
Sida cordifolia L.	Malvaceae	Dicot	-	+
Sisymbrium irio L.	Brassicaceae	Dicot	+	+
Spergula arvensis L.	Caryophyllaceae	Monocot	+	+
Stellaria media (L.) Vill.	Caryophyllaceae	Dicot	+	-
Tephrosia purpurea (L.) Pers..	Fabaceae	Dicot	+	+
Trianthema portulacastrum L.	Aizoaceae	Dicot	+	+
Tribulus terrestris L.	Zagophyllaceae	Dicot	-	+
Urena lobata L.	Malvaceae	Dicot	+	+
Veronica agrestris L.	Plantginaceae	Dicot	+	+
Xanthium strumarium L.	Asteraceae	Dicot	+	-

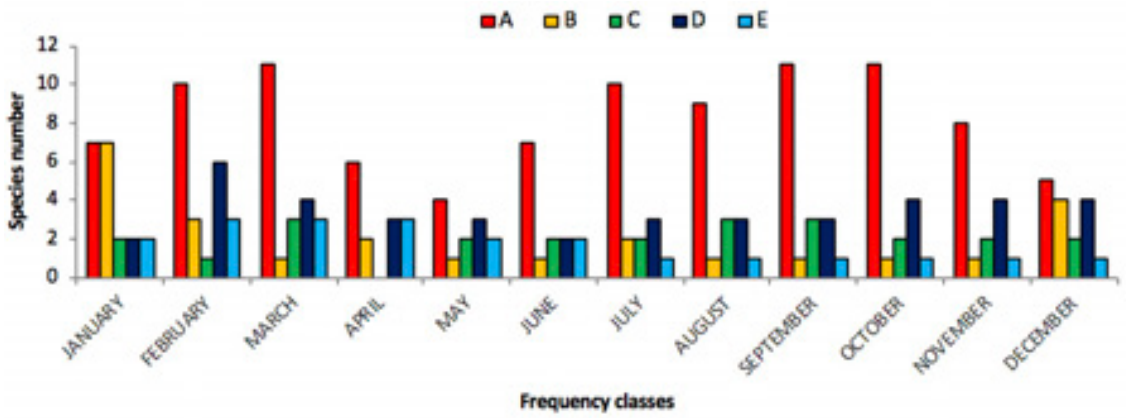

Figure 3. Raunkiaer's frequency class distribution in fallow land of Sangrur, Punjab, India.

Table 2. Distribution of number of plant species among families in fallow lands of Ludhiana and Sangrur in Punjab.

	Family	Site 1	Site 2
1	Asteraceae	6	2
2	Poaceae	1	7
3	Malvaceae	4	6
4	Fabaceae	4	4
5	Brassicaceae	2	2
6	Caryophyllaceae	2	1
7	Amaranthaceae	1	1
8	Primulaceae	1	1
9	Nyctaginaceae	1	1
10	Apocynaceae	1	1
11	Chenopodiaceae	1	1
12	Acanthaceae	1	1
13	Aizoacae	1	1
14	Plantaginaceae	1	1
15	Euphorbiaceae	2	0
16	Convolvulaceae	1	0
17	Polygonaceae	1	0
18	Pedalliaceae	0	1
19	Zagophyllaceae	0	1

c) Raunkiaer's frequency distribution classes

In Raunkiaer's frequency distribution classes curve for site 1 (Figure 2), a number of plant species included in class A decreased up to June followed by an increase in the number of species with a slight decrease in the month of September and October. In frequency distribution class B maximum number of species were recorded in March (12 species) and after March, the species number started decreasing. For class C maximum numbers of plant species were recorded; eight in April with a slight decrease thereafter. For class D the maximum number of plant species was four, recorded in the month of December and in the rest of the months, the number of species for this class distribution was between 1 and 0. Very less number of plant species was recorded for class E. In January, March–May and November–December no plant species were recorded in this category.

In Raunkiaer's frequency distribution classes curve for site 2 (Figure 3), the maximum species were recorded in class A and B. In class A the maximum number of plant species was eleven each recorded in March, September and October. In class B, a maximum number of plant species, i.e., seven were recorded in January after that the number of individuals having frequency in this range decreased with a slight increase in December (4). For frequency class C the number of plant species recorded were 2 or 3 and in April no plant species were recorded for this class. In frequency class D, the maximum number of plant species was six in February. In frequency class E the number of plant species decreased from March to December.

d) Diversity Indices

Values of all diversity indices showed variation for each month (Figure 4). Shannon Wiener index represents entropy in plant community. The values recorded for this index were between 1.73–2.69 at both studied locations. The highest value of this index was reported in March (2.47) from site 1 while in December (2.69) from site 2.

Simpson Diversity index (Table 3) measures diversity of community by taking into consideration dominant taxa. This index values recorded between 0.81–0.93 from both study sites. From site 1 the highest value (0.91) was recorded in January and February, however, from site 2 the highest value (0.93) was recorded in February only.

Evenness index indicated evenness of plant species

Table 3. Monthly Community characteristics of fallow lands at both sites.

Parameter / Month	Fallow land (Site 1)				Fallow land (Site 2)			
	Shannon Wiener index	Simpson diversity index	Evenness index	Menhinick index	Shannon Wiener index	Simpson diversity index	Evenness index	Menhinick index
January	2.33±0.35	0.91±0.01	0.77±0.11	1.71±0.15	2.13±0.2	0.85±0.59	0.56±0.11	1.95±0.21
February	2.46±0.12	0.91±0.01	0.81±0.04	1.47±0.15	2.68±0.18	0.93±0.02	0.70±0.07	1.77±0.06
March	2.47±0.12	0.89±0.01	0.80±0.04	1.47±0.11	2.56±0.27	0.90±0.04	0.65±0.12	1.52 ±0.15
April	2.03±0.10	0.86±0.02	0.77±0.34	1.08±0.22	2.45±0.23	0.88±0.05	0.63±0.13	1.34±0.09
May	1.73 ±0.7	0.81±0.12	0.81±0.21	1.11±0.16	2.09 ±0.22	0.85±0.04	0.64±0.04	1.24 ±0.16
June	1.86 ±0.15	0.82±0.02	0.72±0.06	1.20 ±0.22	2.02±0.18	0.82 ±0.05	0.52 ±0.09	1.10 ±0.16
July	2.02±0.04	0.85±0.13	0.67±0.15	1.38±0.30	1.73±0.23	0.85 ±0.05	0.50±0.11	1.32 ±0.14
August	2.04±0.12	0.86±0.00	0.75 ±0.06	1.30±0.24	2.16±0.45	0.85±0.05	0.52 ±0.11	1.23±0.12
September	2.11±0.06	0.87±0.00	0.73±0.02	1.41 ±0.05	2.34±0.26	0.87±0.04	0.55 ±0.12	1.23 ±0.09
October	2.22±0.09	0.87±0.00	0.77 ±0.04	0.82±0.02	2.49±0.41	0.89±0.03	0.59 ±0.07	1.41 ±0.03
November	2.08±0.11	0.87±0.00	0.77±0.04	0.83±0.00	2.28±0.18	0.88±0.02	0.63 ±0.07	0.83 ±0.04
December	2.34±0.09	0.89±0.00	0.88±0.02	1.46±0.07	2.69±0.16	0.91±0.00	0.70±0.04	1.64 ±0.09
Mean	2.14±0.25	0.87±0.32	0.77±0.90	1.27±0.30	2.30±0.36	0.87±0.05	0.60±0.10	1.38±0.31

(Mean ± Standard deviation).

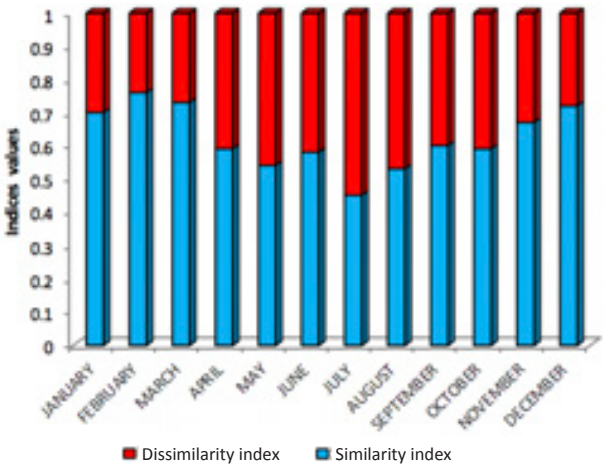

Figure 4. Monthly similarity and dissimilarity indices values between both study sites.

in particular community. The values for this index was recorded as highest in December at both site 2 (0.88) and site 1 (0.70). In site 2 the highest value of 0.70 was also recorded in the month of February.

Species Richness index (Menhinick index) value was recorded between 0.82–1.95 and maximum value of this index was recorded in January for both Site 2 (1.95) and Site 1 (1.75).

Sorenson similarity index predicts similarity between study sites (Figure 3). The highest values of this index were recorded (0.76) in February then values started decreasing and became the lowest in July (0.45) after which value of this index started increasing. Dissimilarity index value was recorded to be the highest in July (0.55).

DISCUSSION

In the present investigation, the difference in the number of individuals between systems, confinement of plant species to particular systems and difference in dominance of plant species may be due to environment, mainly edaphic or some other factors. Literature studies by many workers on a number of plant species and dominant families in different land use systems like Hailu (2017) recorded 58 plant species in rangelands of Ethiopia and 70 plant species (herbs, shrubs, and trees) were recorded by Kaur (2015) in the wasteland of Amritsar. Kaur et al. (2017) reported Asteraceae as the dominant family in Doaba region of Punjab while Poaceae was reported as the dominant family in the wasteland of Amritsar by Kaur (2015).

Among the perennials, density values were a maximum up to 10.5 in September at site 2 while at site 1, the maximum values were up to 7.6 recorded in August. The density values for annuals were below three at both studied locations. Higher density values at site 2 might be due to difference in fertility of soil or other environmental factors.

Analysis of IVI indicated status and pattern of variation of dominant plant species. *Chenopodium album* at site

2 and *Achyranthes aspera* at site 1 were identified as important species throughout the year because their IVI values were higher than 50. Differences in IVI values of two study sites might be due to changes in surrounding conditions and anthropogenic activities. Similarly, Hailu (2017) worked out the IVI values of rangelands with two different management practices and concluded 75.29 as maximum IVI value for the herbaceous species named *Eragrostis aspera*.

In Raunkiaer's frequency distribution classes, there was absence of frequency class E at site 1 in January, March, April, May, November, and December whereas at site 2 class C was non-existent in April. Missing of classes indicates the heterogeneity in species diversity of study sites which might be due to biotic factors (Iqbal 2008). Raunkiaer's frequency classes were also used by Mishra et al. (2004) to study effects of anthropogenic disturbances on plant diversity and community structures in Meghalaya, India.

Shannon Wiener index typical values lies between 0 to 3.5. In the present study, the index value ranged from 1.73 to 2.69. Higher values were recorded at site 2 fallow land which indicated higher number of plant species. Pramanik & Das (2015) calculated Shannon Wiener index to study vegetation of Buxa Tiger Reserve, Gorumara national parks and recorded variation in values from 1.40 to 0.009.

Simpson diversity index indicates diversity of dominant plant species. As values in the present study were less than 1 so we can conclude study sites were not dominated by single plant species. Index values were maximum in month of January (0.91) and February (0.91) at site 1 whereas in February (0.93) at site 2. Iqbal (2008) computed this index for urban localities of Krachi with values from 1.36 to 4.54.

Overall mean values of Evenness index were maximum at site 2 revealing evenness in distribution of individuals of species. With respect to months, species were evenly distributed in February at site 2 and in December at site 1. Similarly, Ismail et al. (2015) used evenness index for herbaceous vegetation of two localities Rashad and Alabassia of Sudan and values reported by him ranged from 1.11 to 1.35.

From Menhinick index values, it is concluded highest species richness was present at site 2. Maximum species richness was recorded in January at both sites in Punjab.

CONCLUSIONS

The present documentation of species suggests that fallow lands which are considered as waste lands have enormous economic plant wealth. Punjab being an agrarian state more stress is laid on use of land for cultivation purposes but there is dire need to explore and document rich plant wealth in fallow lands for medicinal or other economic values. By consulting the literature of medicinal plants, it was concluded that all the plants documented in the study possess medicinal values but due to a lack of awareness and research on these plant species they are considered of no use.

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Image 1. *Abutilon indicum* (L.) Sweet

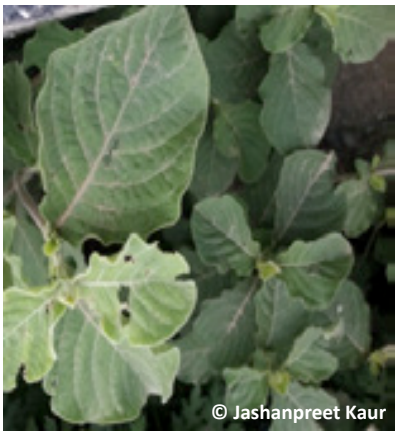

Image 2. *Achyranthes aspera* L.

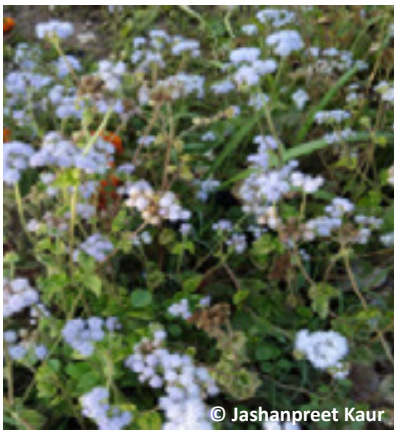

Image 3. *Ageratum conyzoides* L.

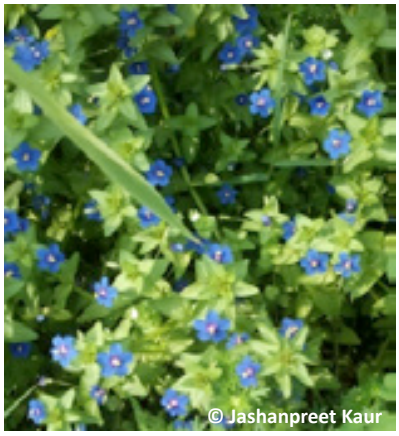

Image 4. *Anagallis arvensis* L.

Image 5. *Artemisia scoparia* Waldst. & Kit.

Image 6. *Boerhaavia diffusa* L.

Image 7. *Calotropis procera* (Aiton)W.T. Aiton

Image 8. *Cannabis sativa* L.

Image 9. *Senna occidentalis* (L.) Link

Image 10. *Cenchrus biflorus* Roxb

Image 11. *Cenchrus catharticus* Delile

Image 12. *Cenchrus setiger* Vahl

Image 13. *Chenopodium album* L

Image 14. *Conyza bonariensis* (L.) Cronquist

Image 15. *Coronopus didymus* (L.) Sm

Image 16. *Croton bonplandianus* Baill

Image 17. *Cynodon dactylon* (L.) Pers

Image 18. *Dactyloctenium aegyptium* (L.) Willd

Image 19. *Dicliptera brachiata* (Pursh) Spreng

Image 20. *Digitaria saguinalis* (L.)

Image 21. *Euphorbia hirta* (L.)

Image 22. *Gnaphalium purpureum* L

Image 23. *Indigofera linifolia* (L.f.) Retz

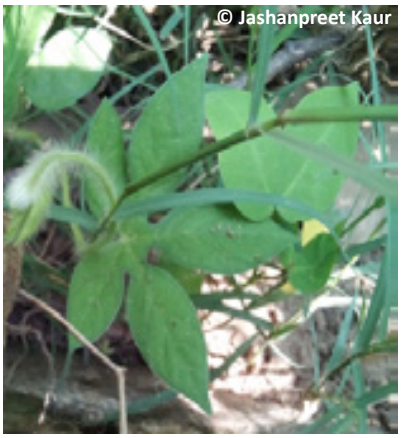

Image 24. *Ipomoea pes-tigridis* L

Image 25. *Malva parviflora* L

Image 26. *Medicago polymorpha* L

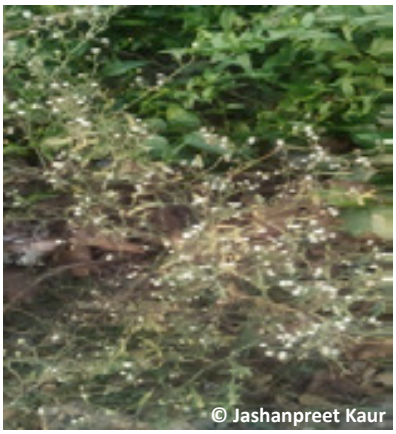

Image 27. *Parthenium hysterophorus* L

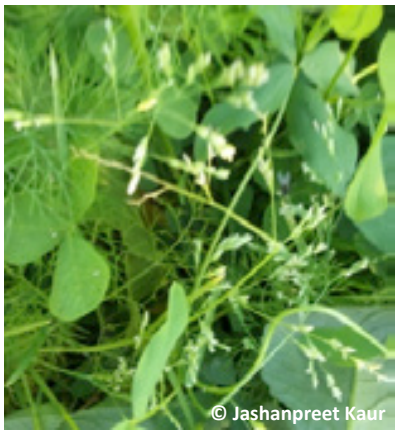

Image 28. *Poa annua* L

Image 29. *Polygonum plebeium* R.Br

Image 30. *Sesamum indicum* L

Image 31. *Sida acuta* Burm.f

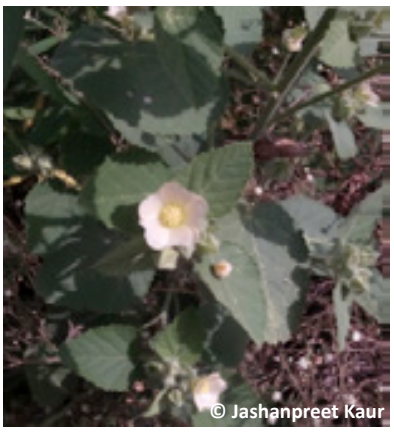

Image 32. *Sida cordifolia* L

Image 33. *Sisymbrium irio* L

Image 34. *Spergula arvensis* L

Image 35. *Stellaria media* (L.) Vill

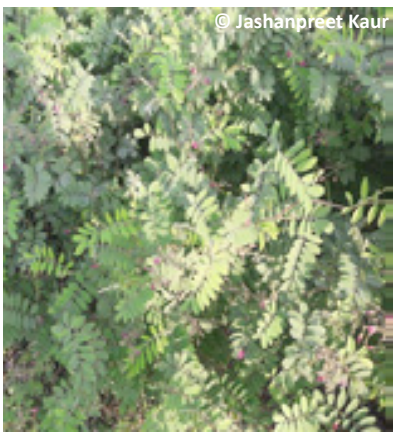

Image 36. *Tephrosia pupurea* (L.) Pers

Image 37. *Trianthema portulacastrum* L

Image 38. *Tribulus terrestris* L

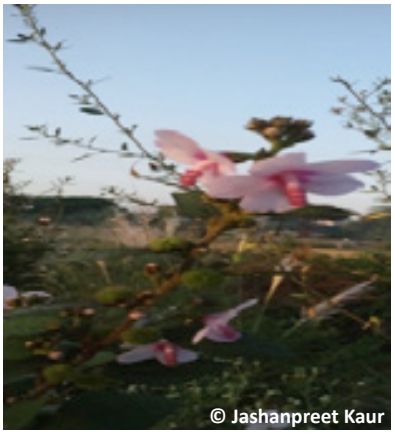

Image 39. *Urena lobata* L

Image 40. *Veronica agrestis* L

Image 41. *Xanthium strumarium* L

Appendix 1. Variation in monthly density of plant species in fallow land at site 1 (L) and site 2 (Sangrur) from January–December 2017: L—Site 1 | S—Site 2 | *—indicates absence of plant species | 0—indicates completion of life-cycle of plant | L—Ludhiana | S—Sangrur.

	Month	Jan		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	Plant species	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
1	*Abutilon Indicum* (L.) Sweet	*	1.4	*	1.4	*	0.8	*	0.8	*	0.8	*	1	*	1.4	*	1.4	*	1.4	*	1.4	*	1.4	*	1.4
2	*Achyranthes aspera* L.	1.86	4.34	2.53	2.67	2.53	2.07	1.93	1.4	1.8	1.6	1.8	1.07	0	0.87	0	0.87	0	1.87	0	2.07	0	1.87	0	1.8
3	*Ageratum conyzoides* L.	0.8	0.27	0.8	0.6	0.8	0.73	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	*Anagallis arvensis* L.	1.07	1	1.67	1.07	1.53	2.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	*Artemisia scoparia* Waldst. & Kit.	0	*	0	*	0	*	0	*	1.67	*	1.67	*	1.87	*	2.33	*	2.27	*	1.31	*	2.27	*	2.67	*
6	*Boerhavia diffusa* L.	0	0	0	0	0	0	0	0	0	0	0.67	0.6	0.67	0.6	0.67	0.87	0.67	0.87	0.67	0.8	0.67	0.73	0	0
7	*Calotropis procera* (Aiton) W.T. Aiton	0.13	0.27	0.13	0.27	0.13	0.73	0.13	0.73	0.13	0.87	0.13	1.13	0.13	0.27	0.27	0.27	0.27	0.27	0.23	0.27	0.27	0.27	0.27	0.27
8	*Cannabis sativa* L.	1.8	0.8	6	2.2	6	6.27	3.87	1	3.4	3.47	3.4	0.53	3	6.07	3	6.07	2.73	6.07	2.03	3.53	2.73	3.53	2.06	1.27
9	*Senna occidentalis* (L.) Link	1.2	0.87	1.2	0.6	1.2	1	2.47	0	0.87	0.67	0.87	0.8	0.87	1.93	0.87	1.93	0.93	2.8	0.75	2.8	0.93	2.6	0.93	2.53
10	*Cenchrus biflorus* Roxb.	*	0.74	*	0	*	0	*	0	*	0	*	4.67	*	0.8	*	0.8	*	0.87	*	0.87	*	0.87	*	1.33
11	*Cenchrus catharticus* Delile	*	0.54	*	0.74	*	0	*	2.07	*	0	*	1.8	*	0.27	*	0.27	*	0.33	*	0.33	*	0.4	*	0.4
12	*Cenchrus setiger* Vahl	*	0	*	1.06	*	1.87	*	2.6	*	0.8	*	0	*	0	*	0	*	0	*	0	*	0	*	0
13	*Chenopodium album* L.	0.33	0	1.2	2.07	1.2	1.07	1.13	1.73	0	3.13	0	5.27	1.33	7.6	1.33	7.6	1.2	7.6	1	5.33	1.13	0	1	0
14	*Conyza Bonariensis* (L.) Cronquist	0	*	0	*	0	*	0	*	0	*	0.07	*	0.07	*	0.07	*	0.07	*	0.08	*	0.07	*	0	*
15	*Coronopus didymus* (L.) Sm.	0.53	0.2	1.8	0.74	1.8	1.93	3.26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.87
16	*Croton bonplandianus* Baill.	0	*	0	*	0	*	0	*	0	*	0	*	0.07	*	0.2	*	0.03	*	0.23	*	0.33	*	0	*
17	*Cynodon dactylon* (L.) Pers.	4	1.8	4	2.13	4.67	2.27	4.67	2.87	4.67	1.8	4.67	1.93	0.67	1.8	4.67	1.8	4.67	1.8	4.67	1.8	4.67	1.8	4.67	1.8
18	*Dactyloctenium aegyptium* (L.) Willd.	*	0	*	0	*	0	*	0	*	0	*	0	*	0.53	*	0.53	*	0.53	*	0.53	*	0.2	*	0
19	*Dicliptera brachiata* (Pursh) Spreng.	0.27	0.33	0.27	0.34	0.27	0.33	0	0	0	0	0	0	0	0	0	0	0.33	0	0.28	0.4	0.33	0.4	0.34	0.4
20	*Digitaria sanguinalis* (L.) Scop.	*	0	*	0	*	0	*	0	*	0	*		*	2.93	*	2.93	*	2.93	*	2.8	*	0	*	0
21	*Euphorbia hirta* L.	0	*	0	*	0	*	0	*	0	*	0	*	0.13	*	0.13	*	0.13	*	0.16	*	0	*	0	*
22	*Gnaphalium purpureum* L.	0.13	*	0.2	*	0.2	*	0.2	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*
23	*Indigofera linifolia* (L.f.) Retz.	0	0	0.2	0.4	0.2	0.67	0.2	1	0.2	0.47	0.2	0.47	0.2	0.4	0	0	0	0	0	0	0	0	0	0

	Month	Jan		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
24	*Ipomoea pes-tigridis* L.	0	*	0	*	0	*	0	*	0	*	0.33	*	0.33	*	0.33	*	0.67	*	0	*	0	*	0	*
25	*Malva Parviflora* L.	0.93	0.27	1.33	0.8	1.53	0.53	0	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.87	1.54
26	*Medicago polymorpha* **L.**	0.4	0.34	0.47	0.4	0.27	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	*Parthenium hysterophorus* L.	1	0.74	1	2.73	1	3.53	1	3.53	1	1.4	1	6.07	2.33	10.5	2.33	10.5	2.47	10.5	1.23	7.53	1.73	3.6	1.73	3.2
28	*Poa annua* L.	*	0	*	0.4	*	1.27	*	1.27	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0
29	*Polygonum plebeium* R.Br	0	*	0.07	*	0.07	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*
30	*Sesamum Indicum* L.	*	0	*	0	*	0	*		*	0.33	*	0.33	*	0.33	*	0.33	*	0.33	*	0.33	*	0.33	*	0.27
31	*Sida acuta* Burm.f.	2.13	0	2.13	1.93	2.13	1.93	2.27	1.93	1.13	0.33	1.13	0.2	1.33	2.6	1.33	2.6	1.27	2.6	1	2.67	1.53	1.33	1.53	1.33
32	*Sida Cordifolia* L.	*	0	*	0	*	0	*	0	*	0	*	0	*	0.27	*	0.27	*	0.87	*	0.87	*	0.53	*	0.53
33	*Sisymbrium irio* L.	0.2	0.4	0.33	1.87	0.33	1.73	0.33	1.73	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	1.2	1.6
34	*Spergula arvensis* L.	1	0	1	1.07	1.13	1.2	0	1.2	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	1	1.2
35	*Stellaria media* (L.) Vill.	0.8	*	1.6	*	0.8	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0.27	*
36	*Tephrosia purpurea* (L.) Pers..	0	0	0	0	0	1	0	1	0.13	0.6	0.13	0.6	0.13	0.73	0.13	0.73	0.13	0.73	0.13	0.73	0.13	0.73	0.13	0
37	*Trianthema portulacastrum*L.	0	0	0	0	0	0	0	0	0	0	0	1.07	0.47	0.6	0	0.6	0.13	1	0.13	1	0.13	0	0	0
38	*Tribulus terrestris* L.	*	0	*	0	*	0	*	0	*	0	*	0.33	*	0.8	*	0.8	*	0.93	*	0.93	*	0	*	0
39	*Urena lobata* L.	0.13	0.67	0.13	0.4	0.13	0.67	0.13	0.73	0.27	0.8	0.27	0.33	0.27	0.47	0.27	0.2	0.13	0.6	0.13	0.53	0.13	0.33	0.13	0.33
40	*Veronica agrestris* L.	0.4	0.8	1.06	0.8	1.07	0.4	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	*Xanthium strumarium* L.	0	*	0	*	0	*	0	*	0	*	0	*	0.2	*	0.2	*	0.2	*	0.67	*	0	*	0	*

Appendix 2. Variation in monthly Importance Value Index(IVI) of plant species in fallow land at Site 1(L) and Site 2(S), January–December 2017.

	Month	Jan		Feb		March		April		May		June		July		August		September		October		November		December	
	Plant species	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
1	*Abutilon Indicum* (L.) Sweet	*	86.2	*	42.6	*	44.5	*	35.1	*	30.8	*	25	*	24.3	*	23.7	*	22.9	*	26.3	*	67.2	*	48.6
2	*Achyranthes aspera* L.	82.9	52.2	72.9	23.1	71.6	15	70.4	13.9	5.35	18.1	5.26	11.7	43.7	8.6	57.4	8.91	58.8	11.2	64.7	10.4	63.1	18.5	69.4	16.5
3	*Ageratum conyzoides* L.	6.96	5.06	4.27	6.01	4.22	4.63	3.46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	*Anagallis arvensis* L.	13.3	71.4	13.9	28.5	11.4	14.4	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	*Artemisia scoparia* Waldst. & Kit.	0	*	0	*	0	*	0	*	12	*	11.9	*	24.1	*	27.4	*	27	*	26.1	*	22.9	*	24.5	*
6	*Boerhavia diffusa* L.	0	0	0	0	0	0	0	0	0	0	0.43	8.81	1.68	5.57	1.5	6.58	1.59	6.18	1.53	7.23	1.61	10.1	0	0
7	*Calotropis procera* (Aiton) W.T. Aiton	8.95	15.8	6.14	8.74	6.06	14.3	7.52	10.8	26.2	11.3	25.6	9.61	9.51	5.94	16.3	5.99	16.7	5.81	15.6	6.97	15.4	13.3	15.3	2.94
8	*Cannabis sativa* L.	19.4	13.1	33.5	15.2	31.6	30.9	34.7	36.1	13.5	29.5	13.3	25.4	30.9	23.3	28.8	23.8	26.4	21.6	25.7	17.4	21	31.3	20	63.2
9	*Senna occidentalis* (L.) Link	18.8	18.7	14.2	5.77	12	10.5	28.7	10.3	12	10.3	11.9	8.27	20.1	12.9	18.5	13.1	17.9	14.9	17.2	16.8	16	31.8	16	19.3
10	*Cenchrus biflorus* Roxb.	*	10.4	*	0	*	0	*	0	*	0	*	0	*	5	*	5.13	*	4.89	*	5.09	*	8.03	*	7.1
11	*Cenchrus catharticus* Delile	*	12.7	*	5.62	*	0	*	0	*	0	*	5.28	*	3.11	*	3.23	*	3.73	*	3.77	*	6.71	*	5.18
12	*Cenchrus setiger* Vahl	*	0	*	7.17	*	9.76	*	9.34	*	3.17	*	0	*	0	*	0	*	0	*	0	*	0	*	0
13	*Chenopodium album* L.	13.9	0	28.5	61.3	28.3	44.5	33	68.5	0	106	0	102	54	99.5	45	100	42.3	7.17	39.5	88	37	0	31.8	0
14	*Conyza Bonariensis* (L.) Cronquist	0	*	0	*	0	*	0	*	0	*	0.61	*	1.62	*	1.56	*	1.62	*	1.55	*	1.28	*	0	*
15	*Coronopus didymus* (L.) Sm.	5.94	5.5	15.4	7.88	13.3	11.8	26.9	11.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.91
16	*Croton bonplandianus* Baill.	0	*	0	*	0	*	0	*	0	*	0	*	1.68	*	3.43	*	3.84	*	5.24	*	4.82	*	0	*
17	*Cynodon dactylon* (L.) Pers.	33.7	15.5	24.3	12.2	24.1	11	36.1	11.6	3.02	10.9	2.98	9.07	42.9	6.47	40.4	6.64	40.7	6.19	39.9	6.94	33.8	11	36.5	9.91
18	*Dactyloctenium aegyptium* (L.) Willd.	*	0	*	0	*	0	*	0	*	0	*	0	*	4.62	*	4.71	*	4.29	*	4.37	*	3.16	*	0
19	*Dicliptera brachiata* (Pursh) Spreng.	4.32	7.39	3.33	4.28	2.77	6.14	0	0	0	0	0	0	0	0	0	0	5.45	0	5.29	3.63	5.18	5.87	4.82	4.57

	Month	Jan		Feb		March		April		May		June		July		August		September		October		November		December	
20	*Digitaria sanguinalis* (L.) Scop.	*	0	*	0	*	0	*	0	*	0	*	0	*	13.2	*	13.4	*	12.3	*	12.8	*	0	*	0
21	*Euphorbia hirta* L.	0	*	0	*	0	*	0	*	0	*	0	*	1.8	*	1.74	*	1.81	*	1.76	*	0	*	0	*
22	*Gnaphalium purpureum* L.	2.75	*	2.37	*	1.8	*	2.17	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*
23	*Indigofera linifolia* (L.f.) Retz.	0	0	2.25	5.64	2.19	4.71	3.09	6.76	1.25	11.4	1.23	9.4	4.84	4.58	0	0	0	0	0	0	0	0	0	0
24	*Ipomoea pes-tigridis* L.	0	*	0	*	0	*	0	*	0	*	0.61	*	4.13	*	3.97	*	1.55	*	3.21	*	0	*	0	*
25	*Malva Parviflora* L.	11.2	6.57	9.95	8.23	10.6	6.86	0	5.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.73	15
26	*Medicago polymorpha* **L.**	6.09	11.6	4.42	19.7	2.99	24.6	0	24	0	15.4	0	0	0	0	0	0	0	0	0	0	0	31.4	0	24.5
27	*Parthenium hysterophorus* L.	7.97	8.13	5.66	3.09	4.82	4.27	11.1	3.98	1.71	15.41	1.7	36.29	24.4	36.67	22.8	37.22	24.7	34.44	20	31.2	18.6	31.86	18.3	24.5
28	*Poa annua* L.	*	0	*	5.41	*	8.78	*	8.39	*	0	*	0	*	0	*	0	*	0	*	0		0	*	0
29	*Polygonum plebeium* R.Br	0	*	1.01	*	0.94	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*
30	*Sesamum Indicum* L.	*	0	*	0	*	0	*	0	*	0	*	0	*	3.36	*	3.48	*	3.24	*	3.32		5.08	*	3.88
31	*Sida acuta* Burm.f.	33.6	0	24.1	26.2	21.5	7.67	32.9	6.77	23.3	7.56	22.8	26.3	25.1	20	22	20.5	21.4	19.3	23.5	21.8	23.3	29.1	22.4	21
32	*Sida Cordifolia* L.	*	0	*	0	*	0	*	0	*	0	*	0	*	3.12	*	3.4	*	5.96	*	6.2		8.02	*	6.83
33	*Sisymbrium irio* L.	3.02	7.19	2.78	15.2	1.83	13.5	5.86	12.9	0	10.6	0	0	0	0	0	0	0	0	0	0	0	0	11.9	15.8
34	*Spergula arvensis* L.	10.5	0	8.41	6.96	7.33	11.4	0	11.1	0	16.6	0	0	0	0	0	0	0	0	0	0	0	0	11	11.1
35	*Stellaria media* (L.) Vill.	9.56	*	13	*	6.76	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	0	*	4.16	*
36	*Tephrosia purpurea* (L.) Pers..	0	0	0	0	0	5.91	0	5.72	0.26	7.51	0.26	5.63	2.03	5.72	1.88	5.91	1.76	5.53	1.7	5.76	1.8	6.89	0	0
37	*Trianthema portulacastrum* L.	0	0	0	0	0	0	0	0	0	0	0	9.49	0	5.14	0	5.27	1.75	5.83	1.69	6.07	1.79	0	1.66	0
38	*Tribulus terrestris* L.	*	0	*	0	*	0	*	0	*	0	*	4.34	*	6.15	*	6.24	*	7.07	*	7.23		0	*	0
39	*Urena lobata* L.	1.54	10.4	1.22	4.59	1.24	4.83	1.75	5.44	1.44	10.9	1.4	3.68	4.12	2.98	3.89	1.67	2.06	4.03	2	4.08	2.08	6.33	1.75	4.93
40	*Veronica agrestris* L.	5.48	71.4	9.57	5.73	8.84	3.7	0	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	*Xanthium strumarium* L.	0	*	0	*	0	*	0	*	0	*	0	*	3.76	*	3.46	*	3.4	*	3.27	*	0	*	0	*

Ludhiana—Site 1 | Sangrur—Site 2 | *—indicates absence of plant species | 0—indicates completion of life-cycle of plant.

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COMMUNICATION

Morphological and molecular phylogenetic studies on *Battarrea phalloides* (Agaricales): a new report to Indian mycobiota

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Abstract: The Scaly-stalked Puffball *Battarrea phalloides* (Dicks.) Pers. is recorded for the first time in India. The fungus is reported from many countries across the continents and typically uncommon and rare in all regions. It is Red Listed in most of the European countries and is under assessment in IUCN Global Fungal Red List Initiative. The Indian sample of *B. phalloides* is reported from Kadur Taluk of Chikkamagaluru District, Karnataka with morpho-molecular data.

Keywords: Elaters, Morpho-molecular, nrITS, Red List, Scaly-stalked Puffball.

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Author contribution: RK carried out the research work, wrote the article. MK guided in every step and corrected mistakes in the article.

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INTRODUCTION

Battarrea phalloides (Sandy Stilt Ball, Sandy Stilt Puffball, Scaly-stalked Puffball), previously known gasteromycete in Battarreaceae (Corda 1842), and now a distinctive saprobic basidiomycetous agaric fungus, easily recognizable with a scaly lacerated stem growing up to 40cm in height, forming a reddish-brown spore case inside a thin greyish skin. It is rare, uncommon and occurs in small scattered populations or sometimes even appears as single basidiomata.

Battarrea phalloides is red-listed in several European countries and is one of the non-lichenized fungi afforded legal protection by being included in schedule 8 of the Wildlife and Countryside Act, 1981 in the United Kingdom (Jeffries & McLain 2004). The species is currently under assessment for addition to the IUCN: The Global Fungal Red List Initiative (http://iucn.ekoo.se/iucn/species_view/159853).

Sixteen species have been described in the genus *Battarrea* Pers. since 1801 (Index Fungorum, http://www.indexfungorum.org/) and most of them are conspecific to *Battarrea phalloides*. Early taxonomic discussions about the worthiness of morphological characters for separating *B. phalloides* and *B. stevenii* were evaluated using modern phylogenetic approach by Martin & Johannesson (2000), Martin et al. (2013) and Jefferies & McLain (2014), the shreds of evidence suggest both taxa are conspecific. In addition, Martin & Johannesson (2000) considered spore ornamentation as a non-molecular character for lineage recognition and depicted three main lineages phylogenetically, they have differences in their spore ornamentation as—(a) spores with anastomosing truncate ridges, (b) finely verrucose, and (c) finely reticulate.

The present study describes *B. phalloides* as a new report to Indian mycobiota based on morphological characters and multigene phylogenetic analysis.

Materials and Methods

The Scaly-stalked Puffball like basidiomata of *Battarrea phalloides* were collected from Aladahalli Village (13.546N & 75.875E) of Kadur Taluk (Figure 1), Western Ghats region of Karnataka during July 2019.

Sampling and morphological characterization

The sporomas of different stages were collected and phenotypic characters were recorded using a field key (Atri et al. 2017). Microscopic characters were recorded using a light microscope (Olympus CH20i) and the sporocarps were shade-dried and stored in the Department of Botany, Kuvempu University for further

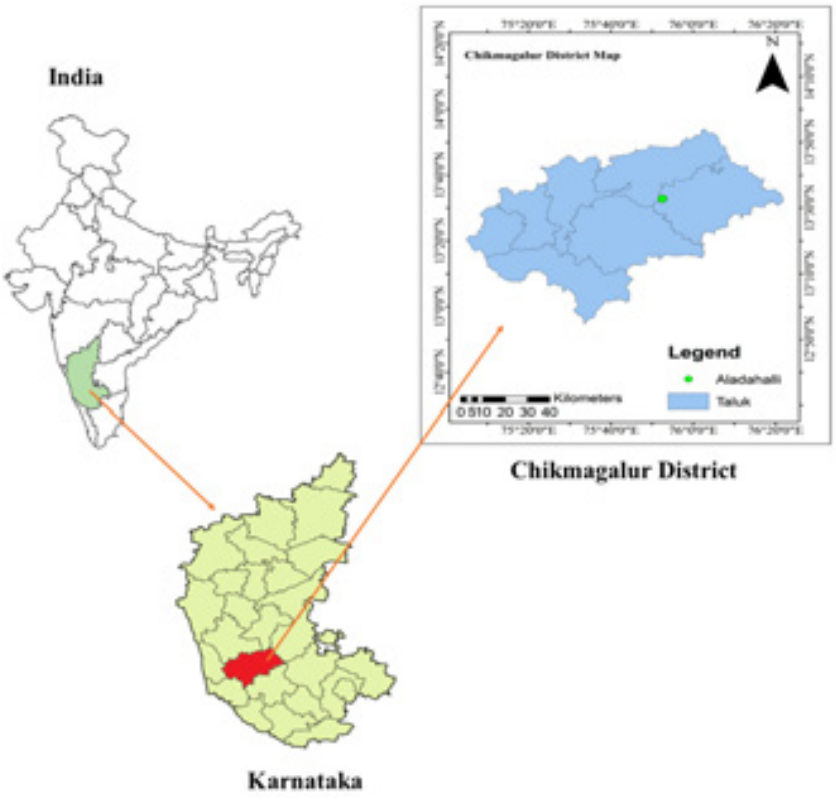

Figure 1. Geographic location of *Battarrea phalloides*

Table 1. List of primers utilized to amplify nrITS and nrLSU gene sequences.

	Primer	Sequence	Amplifying gene	T_m [°C]
1	ITS 1	TCCGTAGGTGAACCTTGCGG	nrITS	60.99
2	ITS 4	TCCTCCGCTTATTGATATGC		55.25
3	LROR	ACCCGCTGAACTTAAGC	nrLSU	52.77
4	LR5	TCCTGAGGGAAACTTCG		52.77

studies (Image 1). To identify the surface ornamentation of spores, scanning electron microscopy was carried out in ZEISS EVO CSEM.

DNA Extraction, PCR and Phylogenetic analysis

The total genomic DNA was extracted from the freshly collected sporocarp using the CTAB method (Doyle & Doyle 1987) with modifications. 100mg of inner stipe tissue was directly homogenized with 500µl of 2X CTAB extraction buffer pre-warmed to 65°C in a 1.5ml microcentrifuge tube with the help of micro-pestle, followed by vortexing and incubated in a water bath at 65°C for 1h. The sample was cooled briefly before centrifugation at 13,000rpm for 30min. To the centrifugate 3µl of RNase A (20mg/ml) was added and incubated for 10min at 37°C, followed by the addition of an equal amount of PCI (25:24:1) with slow invert mixing. The mixture was centrifuged at 10,000rpm for 10min at room temperature and the supernatant was extracted. To precipitate the DNA 500µl of ice-cold isopropanol was added and incubated overnight at 4°C, followed by centrifugation at 10,000rpm for 10min at 10°C to pellet the DNA and washed twice with 70% ethanol, drained and dissolved in 50µl of 1X TE buffer.

PCR reactions were carried out in 0.2ml PCR tubes with 50µl reaction mixture containing, 25µl double distilled water, 8µl 10X PCR buffer A (Himedia). 2.5µl of each primer, 0.5µl of Taq DNA polymerase (3U/µl), 1.5µl dNTP's mixture (Himedia) and 10µl of DNA template. The primer pair ITS 1 and ITS 4 (White et al. 1990) for nrITS region and LROR and LR5 (Vilgalys & Hester 1990) for the nrLSU region were used (Table 1). The thermal profile for nrITS amplification; 4' 94°C, 32 cycles of 30" 94°C, 1' 52°C, 1' 72°C and a final extension step of 7' 72°C, for nrLSU 5' 94°C, 30 cycles of 30" 94°C, 1' 47°C, 1' 72°C and a final extension step of 7' 72°C. The PCR products were examined on 1% Agarose gel stained with Ethidium Bromide and visualized under gel image documentation system (BioRad) followed by cleanup and sequencing.

The electropherograms of both forward and reverse sequences obtained from Eurofins Genomics India Pvt. Ltd. Bengaluru were checked and trimmed using MEGA X (Kumar et al. 2018). Consensus sequences were generated using BioEdit sequence alignment editor v.7.2.5 (Hall, CA) by Clustal W (Madeira et al. 2019). BLAST search in the GenBank (https://blast.ncbi.nlm.nih.gov/Blast.cgi) nucleotide database to identify the related taxa by sequence similarity and both nrITS and nrLSU sequences were deposited to GenBank with accession numbers MN450310 and MN700164, respectively.

Molecular phylogenetic analysis was performed by using nrITS and nrLSU sequences separately. Datasets of 17 nrITS sequences (Table 2) and 15 nrLSU sequences (Table 3) including those retrieved from the NCBI GenBank are used to assess the alignment confidence score in the GUIDANCE web server (http://guidance.tau.ac.il) by MAFFT algorithm (Katoh et al. 2019) to construct 100 alternative guide trees. Using GUIDANCE outputs the columns showing less than 93% confidence scores are removed and aligned in BioEdit v.7.2.5. The alignment file obtained is further used to analyze the maximum likelihood in RAxML GUI v.2.0.0.0 using the GTRGAMMA+I model as suggested by jModelTest

Image 1. Specimen submitted to herbarium.

v.2.1.10 (Darriba et al. 2012) with 1,000 bootstrap replications. The best trees obtained are inferred by Mr. Bayes.

RESULTS

Taxonomy

***Battarrea phalloides* (Dicks.) Pers.,**

MycoBank No.: 159853

GenBank Accession No.: MN450310 (nrITS), MN700164 (nrLSU).

Basionym: *Lycoperdon phalloides* Dicks., Fasciculus plantarum cryptogamicarum Britanniae 1: 24 (1785)

Etymology: The specific epithet *phalloides* refers to the similarity of volva with genus *Phallus.*

Basidiomata medium to large, 20–30 cm in length (Images 2 & 3). Spore case 3–5.2 cm diam. Greyish membranous skin when young, shedding to become convex rusty brown abundant spore mass at maturity (Image 4). *Stipe* 10-25cm in length, 1.8–3 cm diam., light brownish, hairy to lacerated scaly, base include underground membranous volva. Gleba pulverulent includes capillitia and elaters. Spores 5–7×4–6 µm, globose to almost elliptical (Image 5), finely reticulate (Image 6), inamyloid in Melzer's reagent. Elaters 50–80+ µm long 4–7µm wide, cylindrical to fusiform, annular to spiral thickenings (Image 6), ochraceous in KOH.

Ecology: Saprophytic, growing alone or scattered in dry sandy soil. Cited twice in July and August 2019 in Kadur Taluk (13.546N & 75.875E).

Specimens: India, Karnataka, Chikmagaluru District, Kadur Taluk, 28 July 2019 (KUABMK-162) and 15 August 2019, Kantharaja R & Krishnappa M.

Image 2. *Battarrea phalloides* in habitat.

Image 3. Specimen with membranous volva.

Image 4. Gleba with rusty brown spore mass.

Image 5. Basidiospores and Elaters (scale 10µm). © R. Kantharaja.

Table 2. List of species, geographic origin and GenBank accession numbers of nrITS sequences used in molecular phylogeny analysis.

	Species	Geographic origin and year	GenBank accession number
1	*Battarrea phalloides*	Spain, 2013	HF913784
2	*Battarrea phalloides*	Spain, 2013	HF913785
3	*Battarrea phalloides*	USA, 2017	MF422608
4	*Battarrea phalloides*	UK, 2005	DQ184685
5	*Battarrea stevenii*	Spain, 1999	AF215655
6	*Battarrea phalloides*	UK, 2005	DQ184690
7	***Battarrea phalloides***	**India, 2019**	**MN450310**
8	*Battarrea stevenii*	UK, 2005	DQ184688
9	*Battarrea phalloides*	UK, 2005	DQ184687
10	*Tolustoma calongei*	Spain, 2016	KU518973
11	*Tolustoma kotlabe*	Sweden, 2005	DQ112629
12	*Tolustoma obesum*	Sweden, 2016	KU518987
13	*Tolustoma obesum*	Sweden, 2016	KU518988
14	*Tolustoma grandisporum*	Sweden, 2016	KU519003
15	*Tolustoma grandisporum*	Sweden, 2016	KU519006
16	*Tolustoma grandisporum*	Sweden, 2016	KU519001
17	*Lycoperdon perlatum*	China, 2007	EU622257

Table 3. List of species, geographic origin and GenBank accession numbers of nrLSU sequences used in molecular phylogeny analysis.

	Species	Geographic origin and year	GenBank accession number
1	*Chlorophyllum agaricoides*	China, 2017	MG742020
2	*Chlorophyllum agaricoides*	Spain, 2015	KR233498
3	*Chlorophyllum agaricoides*	China, 2017	MG742021
4	*Chlorophyllum agaricoides*	Spain, 2015	KR233494
5	*Chlorophyllum olivieri*	China, 2017	MG742037
6	*Chlorophyllum olivieri*	China, 2017	MG742036
7	*Disciseda bovista*	Hungary, 2018	MK277947
8	*Tolustoma fimbriatum*	Hungary, 2018	MK278635
9	*Tolustoma albicans*	Hungary, 2018	MK278628
10	*Tolustoma macrocephala*	USA, 2002	AF518663
11	*Tolustoma simulans*	Hungary, 2018	MK278639
12	*Tolustoma simulans*	Hungary, 2018	MK278634
13	***Battarrea phalloides***	**India, 2019**	**MN700164**
14	*Battarrea lacinata*	USA, 1999	AF208534
15	*Lycoperdon ericaeum*	Japan, 2014	KU507401

Phylogenetic Analysis

The specimen KUABMK-162 was subjected to molecular identification initially based on sequences of the nrITS region via. BLAST search analysis in the GenBank database and found >99% similarity with unpublished sequences (DQ184690, DQ184688, and DQ184687). The maximum likelihood analysis using RAxML and MrBayes drawn by the GTRGAMMA+I model as suggested by jModelTest v.2.1.10 confirms the closest relation of newly generated sequences with *Battarrea phalloides* with 97% bootstrap support (Figure 2). Due to unavailability of nrLSU sequences of *B. phalloides* the generated nrLSU sequences were found clustered with *Battarrea lacinata* (Figure 3).

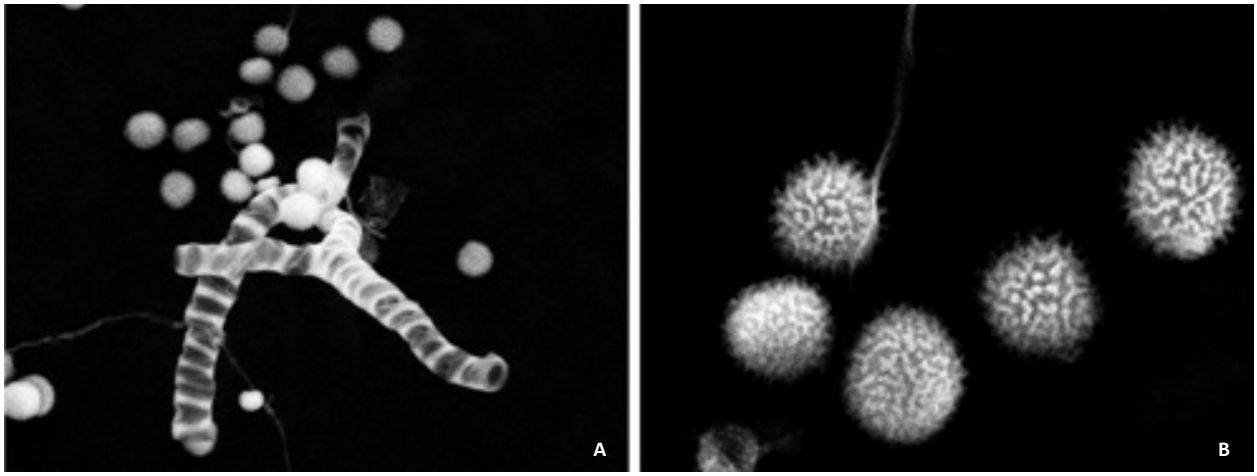

Image 6. Scanning Electron Microscopic view of A—Elaters | B—spores. © R. Kantharaja.

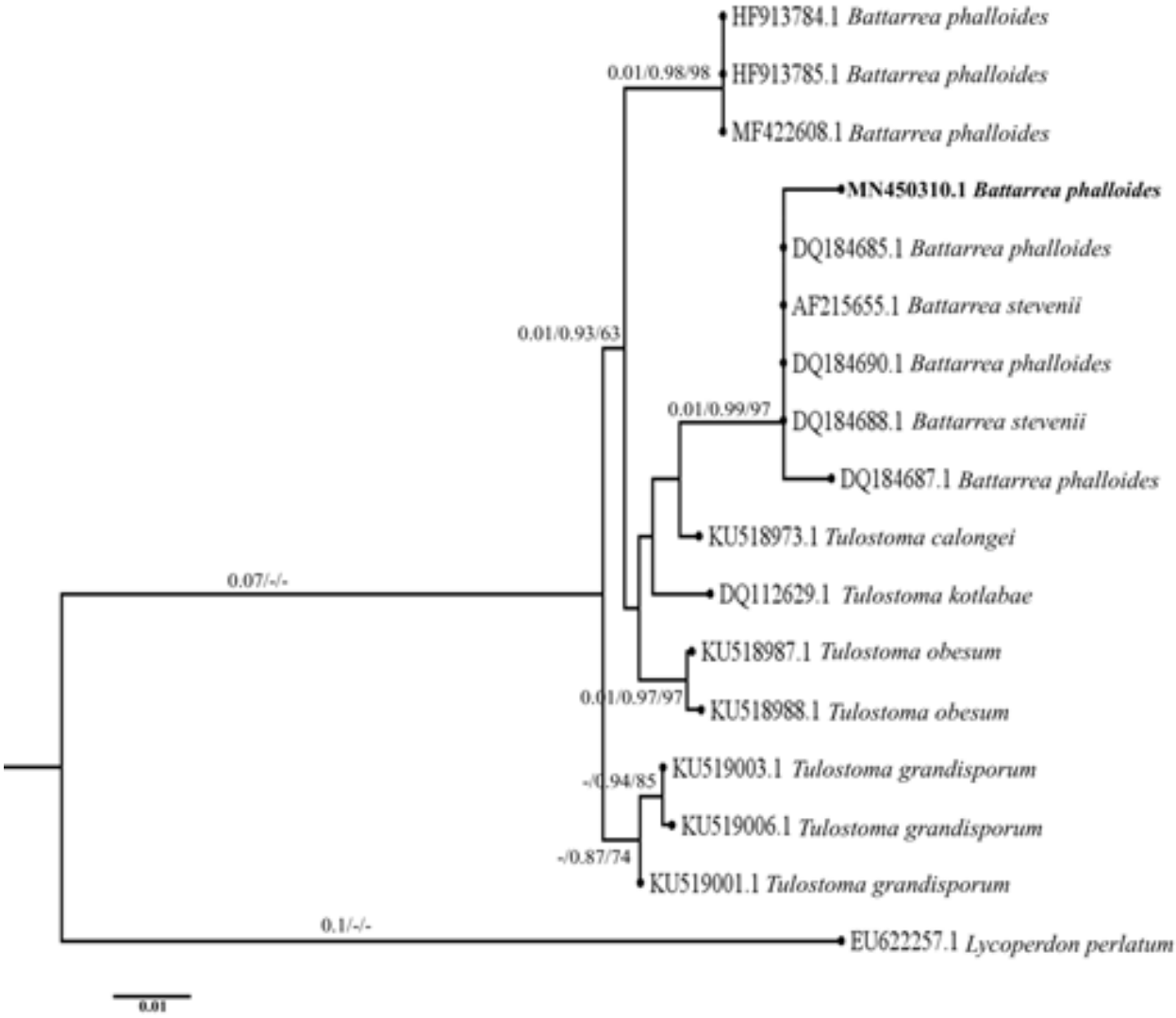

Figure 2. RAxML tree of *Battarrea phalloides* generated by maximum likelihood analysis of nrITS sequences using GTRGAMMA+I model with *Lycoperdon perlatum* as an outgroup showing bootstrap support (BS>50%) and Bayesian posterior probability values (PP>0.7). (BL/PP/BS).

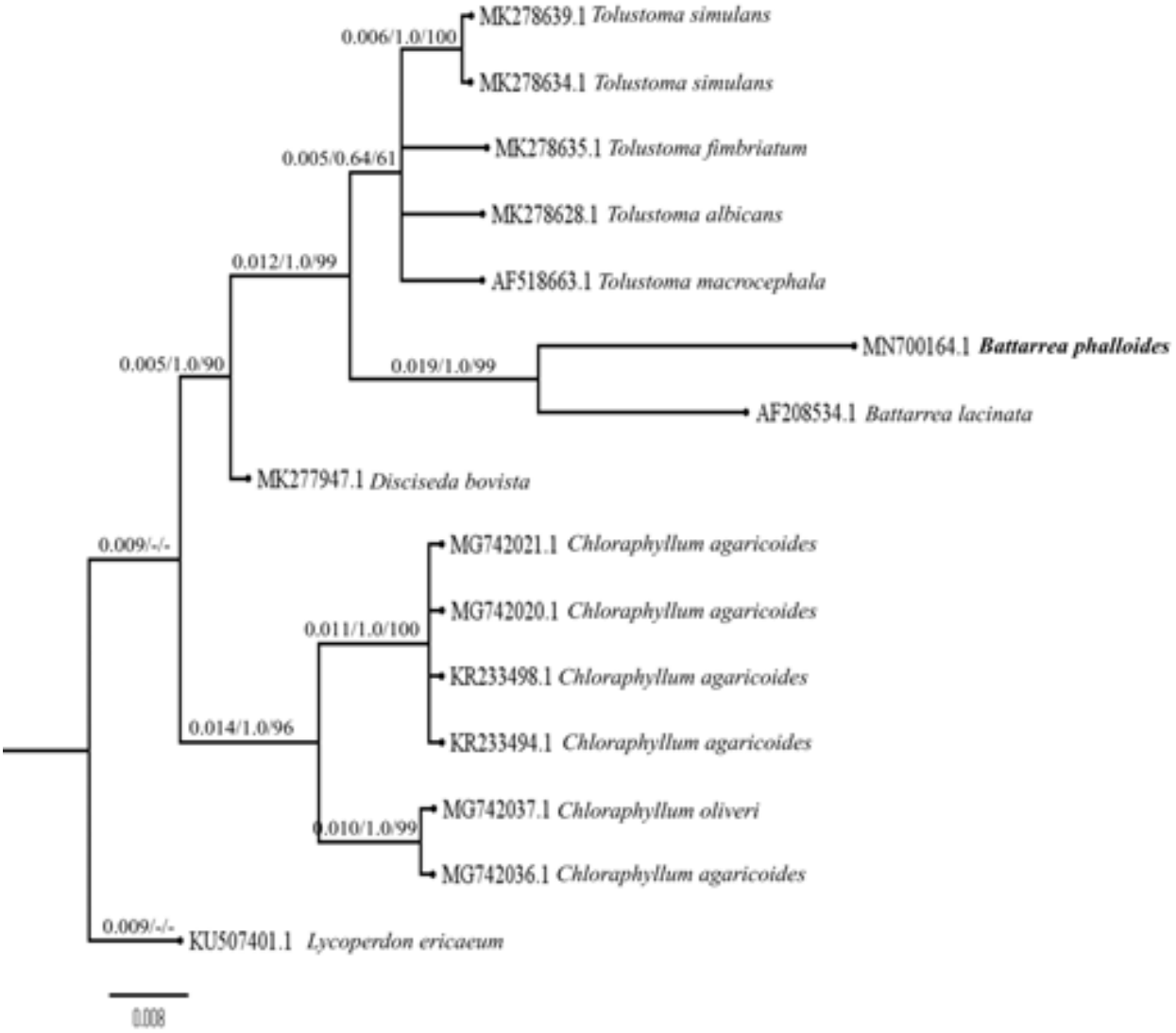

Figure 3. RAxML tree of *Battarrea phalloides* generated by maximum likelihood analysis of nrLSU sequences using GTRGAMMA+I model with *Lycoperdon ericaeum* as an outgroup showing bootstrap support (BS>50%) and Bayesian posterior probability values (PP>0.6). (BL/PP/BS).

DISCUSSION

Previous reports of *Battarrea phalloides* showed the species is found in arid and semi-arid habitats like desserts and dry Savanna (Martin & Johannessen 2000; Howladar et al. 2013; Ivancevic et al. 2016). The present study claims that *B. phalloides* is found in Chikmagalur District, Western Ghats region of Karnataka, India. The climatic conditions in Kadur Taluk support the habitat preference of the species, where the average annual rainfall (620mm) is almost similar to the dry areas. Howladar et al. (2013), stated *Battarrea phalloides* is rare everywhere but distributed worldwide, cited the reports from across continents and this report adds another vicinity of occurrence.

Martin & Johannessen in 2000 identified three main lineages in a phylogenetic study of *B. phalloides* and *B. stevenii* herbarium collections from various parts of the world by considering spore ornamentation as a non-molecular character. Contrary to this, Garrido-Benevent in 2014 tried to represent cryptic speciation and predicted the presence of three to four putative species within the *Battarrea phalloides-stevenii* complex. but, he also noted the requirement of further data to build a consistent taxonomy. The current taxonomic data according to Mycobank and Index Fungorum, however, suggests *B. stevenii* as a synonym of *B. phalloides*. In our study, the SEM image of spore confirms the presence of reticulate ornamentation which is highly similar to the previous reports.

The nrITS sequences of specimen KUABMK-162 (MN450310) is found clustered with specimens from Israel, Cyprus and UK (DQ184685, DQ184687, and DQ184690) with a well-supported bootstrap value of 97% and maximum Bayesian posterior probability value of 0.99. Based on morpho-molecular characters the present study confirms the identity of the specimen as *Battarrea phalloides* and is a new record to Indian mycobiota.

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COMMUNICATION

Diversity of polypores in Kerala Agricultural University main campus, Vellanikkara, Kerala, India

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Abstract: A survey of polypores was conducted from January 2013 to December 2015 in the Kerala Agricultural University (KAU) main campus garden lands, botanical gardens, and plantations visited during pre-monsoon, monsoon, and post monsoon periods. A total of 43 polypore species in 28 genera belonging to seven families were recorded during the study. Their distributions were analyzed by family, rot, and habit. Polyporaceae dominated with 29 species, followed by Hymenochetaceae with nine, Meruliaceae with five, Ganodermataceae with three, and Meripilaceae & Fomitopsidaceae represented by two species each. Forty species were white rot polypores and three were brown rotters; annuals and perennials were represented by 28 and 15 species, respectively. This survey emphasizes the importance of university campuses in biodiversity conservation.

Keywords: Basidiomycota, biodiversity, brown rotters, decomposition, mushrooms, Polyporaceae, Polyporales, Thrissur, wood-rotting.

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INTRODUCTION

The Polyporales are a large and taxonomically complex order of mushrooms in the division Basidiomycota. Polypores are among the most efficient decomposers of lignin and cellulose, the main components of wood. These wood-rotters assist in the decomposition of dead wood and act as pathogens on living wood. Polypores play an important role in decomposition and nutrient cycling in forest ecosystems, where they dominate other communities of wood-rotting organisms.

Bakshi (1971) gave an account of 355 species of polypores belonging to 15 genera in his outstanding work Indian Polyporaceae (on trees and timber). Roy & De (1996) listed 114 species in Polyporaceae of India based on exhaustive studies of fungi collected from different parts of the country. Florence (2004) reported 555 species of basidiomycetes under 179 genera from Kerala State. Bhosale et al. (2005) gave a tabulated account of 251 species of order Aphyllophorales from the Western Ghats. Leelavathy & Ganesh (2000) reported 78 species belonging to 26 genera under families Ganodermataceae, Hymenochaetaceae, and Polyporaceae in their classical work 'Polypores of Kerala'. Florence & Yesodharan (2000) reported 35 polypores from Peechi-Vazhani Wildlife Sanctuary. Florence (2004) recorded 93 species of polypores from the state. Lately, Mohanan (2011) identified and described a total of 89 species of polypores belonging to 32 genera from different forest ecosystems of Kerala. Recently, Iqbal et al. (2016) reported 36 polypores under 21 genera belonging to six families from Peechi- Vazhani wildlife sanctuary. In Kerala, polypore studies have been less exhaustive compared to those of mushrooms (Agaricales). While the polypores of Kerala were studied in detail by Bakshi (1971), Leelavathy & Ganesh (2000) and Mohanan (2011), much of the forest area remains unexplored. A total of 148 polypore species under eight families belonging to 68 genera were recorded from Kerala State till now (Adarsh et al. 2018).

In the present study, an attempt was made to document the richness of polypores in Kerala Agricultural University (KAU) main campus, southern India.

STUDY AREA

The Kerala Agricultural University (KAU) main campus is located at Vellanikkara, Thrissur District, Kerala (Figure 1). The area lies between 10.032–10.033 ^{0}N and 76.016–76.017 ^{0}E and is located 5km from the Peechi-Vazhani Wildlife Sanctuary, Western Ghats. The campus has a total area of 391.44ha. Major habitats include garden lands, botanical garden, plantations of rubber, coconut, plantain & cocoa, and orchards of mango, jackfruit, sapota & guava. KAU campus enjoys a moderate climate. The 10-year mean minimum temperature is 23.3^{0}C and 10-year mean maximum of 31.8^{0}C. The area receives

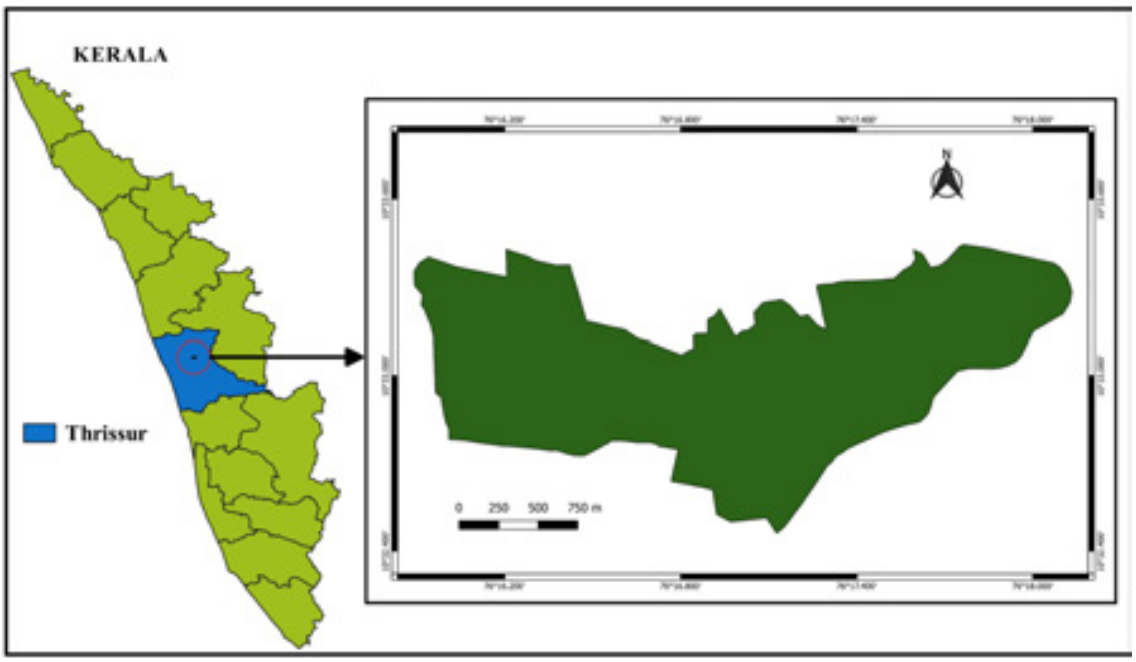

Figure 1. Location map of Kerala Agricultural University main campus, Vellanikkara, Thrissur, Kerala.

both south-west and north-east monsoons, with the greatest portion of the rainfall received from the south-west monsoon between June and September. The mean annual rainfall is 2,763mm. The mean number of rainy days per year is 110 (KAU weather station 2010).

Methods: Survey, Collection and Identification of fungi

The survey was conducted from January 2013 to December 2015 in the Kerala Agricultural University (KAU) main campus for collection of polypores. The garden lands, botanical gardens and plantations were visited during pre-monsoon, monsoon and post monsoon periods for the documentation of polypores. The observations were done by collection of sporocarps, labelling with specimen number, rot character identification, details of host, taking photographs & recording macro morphological characters, and details of substratum in the illustrated data sheet. Collection of polypores was made by opportunistic survey in the study area for maximizing the documentation of polypore diversity and distribution.

The polypore specimens were properly air dried or oven dried and stored in polythene zip-cover under low humid conditions. The specimens were identified by analyzing macro and micro morphological features based on the identification key provided by Bakshi (1971), Leelavathy & Ganesh (2000), and Ryvarden (1976). Some of the specimens were compared with those in the herbaria at Forest Research Institute, Dehradun and Kerala Forest Research Institute, Peechi. All the specimens collected during the study period were catalogued and stored in the Department of Natural Resource Management, College of Forestry at Kerala Agricultural University. The taxonomy and nomenclature are as per indexfungorum (http://www.indexfungorum.org/Names/Names.asp), and the authors of scientific names are according to the 'Authors of Fungal Names' (http://www.indexfungorum.org/AuthorsofFungalNames.htm).

RESULTS AND DISCUSSION

A total of 43 polypore species in 28 genera belonging to seven families were recorded during the study (Images 1–43), which accounts for 29% of the polypores recorded from Kerala (Adarsh et al. 2018). Their distribution was analyzed family-wise, rot-wise, and habit-wise (Table 1, Figures 2–4). The family Polyporaceae dominated with 29 species followed by Hymenochaetaceae with nine species, Meruliaceae with five species, and Ganodermataceae with three species. The families Meripilaceae and Fomitopsidaceae were represented by two species each (Figure 2). Out of the total species recorded 40 species were white rot polypores and only three were brown rotters (Figure 3). Among the 43 polypores identified, annuals and perennials were represented by 28 and 15 species, respectively (Figure 4).

The white rot polypores shows significant dominance over brown fungi with 40 number of species (Figure 3). Among these species, *Junghunia nitida* and *Oxyporus pellicula* were found to be new records from the southern Western Ghats.

The polypore-host analysis revealed that the trees in the family Leguminosae provided habitats for 25 polypore species (Figure 5). The family Anacardiaceae hosted 17 polypore species followed by Euphorbiaceae (11) and Combretaceae (5). Host specificity is a relationship in which a particular fungus is restricted to a single host or a group of related species but does not occur in association with other unrelated plants in the same

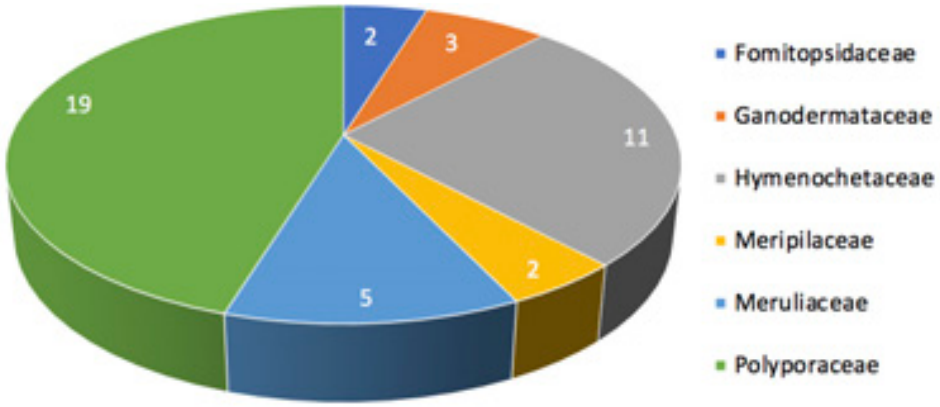

Figure 2. Family-wise distribution of polypores in KAU main campus.

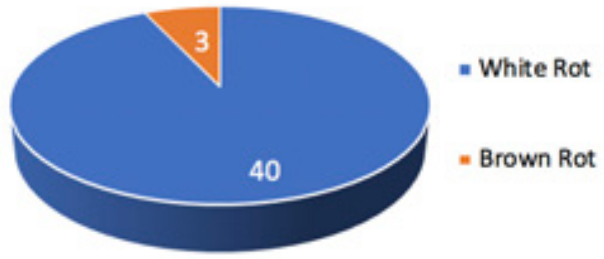

Figure 3. Rot-wise distribution of polypores.

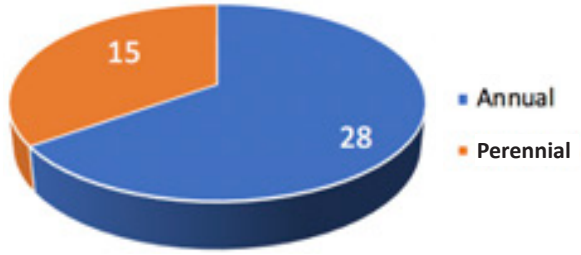

Figure 4. Habit-wise distribution of polypores.

habitat (Holliday 1998). The causes of host selectivity of wood-decay species are complex and include wood chemistry, wood microclimate, gaseous regime and the ways in which fungi become established (Boddy 2001). The host specificity of polypores and other wood-inhabiting basidiomycetes is widely considered to be low in tropical areas because of high host plant species richness (Schmit 2005)

Among the substrate type log harbored the maximum occurrence of polypores (89) followed by snag (23), stump (16), twig (17), and living tree (10) (Figure 6). Logs, especially the larger ones are more prone to harbour high species richness which is partially due to greater surface area and volume (Bader et al. 1995; Kruys & Jonsson 1999). Additionally, the decay rate varies even on the same log, resulting in heterogeneous microhabitats (Crites & Dale 1998). Logs with a high degree of soil contact are likely to be buffered against fluctuations in temperature and especially water content compared to logs with little soil contact (Heilmann-Clausen & Christensen 2003). All these factors are responsible for the high species richness and occurrence of polypores on logs during the present study. Among the substrata, living tree harboured the least number of polypores. This may be due to the different species adaptations to the defense mechanisms present in the living trees.

Thirty-five polypore species were recorded from substrate under diameter class 31–40 cm followed by 11–20 cm, and 21–30 cm diameter classes (Figure 7). The substrate size was found to be influencing the hymenial surface area per log as well as the density of polypores. A large log can support a greater mycelial biomass simply because of the larger volume, corresponding to a greater

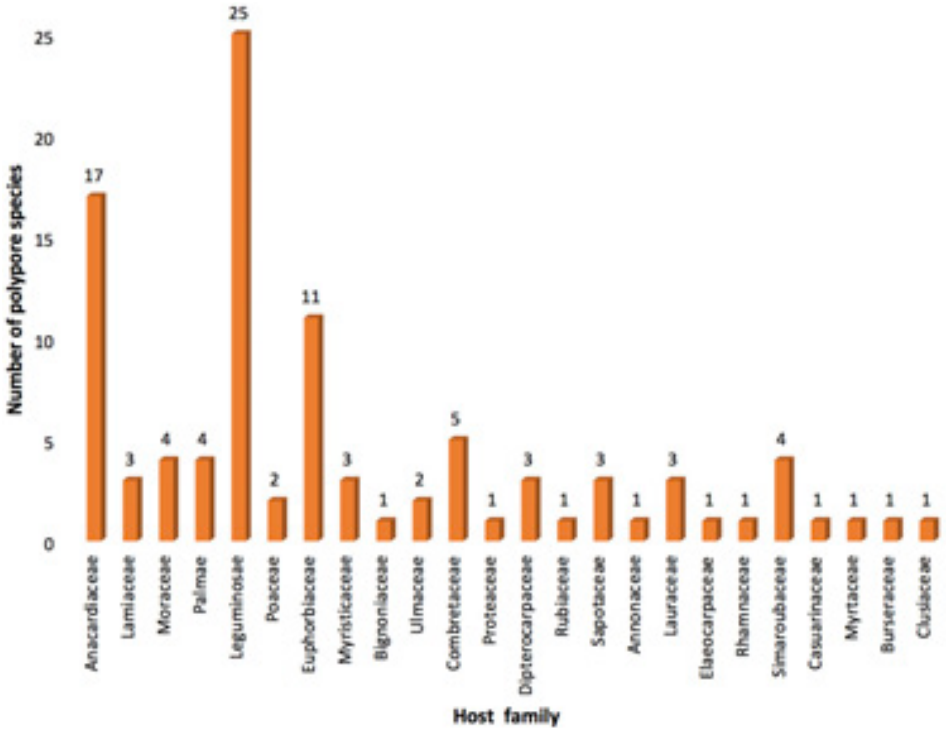

Figure 5. Diversity of polypores on different tree host family

Table 1. Distribution of polypores in Kerala Agricultural University campus.

	Family & Species	Habit (A/P)	Rot (W/B)	Host species	Host family	Substrate type	GBH (cm)
I	**Fomitopsidaceae**						
1.	*Fomitopsis feei* (Fr.) Kreisel 1971	A	B	*Tectona grandis* L. f.	Lamiaceae	Log	39
2	*Fomitopsis palustris* (Berk. & M.A. Curtis) Gilb. & Ryvarden, 1985	A	B	*Cassia fistula* L.	Leguminosae	Snag	31
				Anacardium occidentale L.	Anacardiaceae	Snag	56
				Peltophorum pterocarpum (DC.) Baker ex Heyne	Leguminosae	Log	65
II	**Ganodermataceae**						
3	*Ganoderma australe* (Fr.) Pat. 1889	P	W	*Albizia odaratissima* (L.f.) Benth.	Leguminosae	Snag	215
				Manilkara zapota (L.) P. Royen	Sapotaceae	Log	40
				Cocos nucifera L.	Palmae	Snag	89
				Cocos nucifera L.	Palmae	Snag	72
				Cocos nucifera L.	Palmae	Snag	68
				Annona reticulata L.	Annonaceae	Living tree	32
4	*Ganoderma lucidum* (Curtis) P. Karst. 1881	A	W	*Briedelia retusa* (L.) A. Juss. (L.) A.Juss	Euphorbiaceae	Living tree	22
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	35
				Vateria indica L.	Dipterocarpaceae	Log	63
				Cocos nucifera L.	Palmae	Tree stump	68
				Caesalpinia coriaria Willd.	Leguminosae	Snag	30
				Delonix regia (Boj.) Rafin.	Leguminosae	Tree stump	450
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Log	54
				Albizia odaratissima (L.f.) Benth.	Leguminosae	Tree stump	215
5	*Ganoderma subresinosum* (Murrill) C.J. Humphrey 1938	P	W	*Myristica fragrans* Houtt.	Myristicaceae	Log	31
III	**Hymenochetaceae**						
6	*Inonotus* sp.	P	W	*Vateria indica* L.	Dipterocarpaceae	Tree stump	48
7	*Phellinus caryophylli* (Racib.) G. Cunn. 1965 Fisch	P	W	*Leucaena leucocephala* (Lamk.) de Wit	Leguminosae	Living Tree	32
8	*Phellinus nilgheriensis* (Mont.) G. Cunn. 1965	P	W	*Leucaena leucocephala* (Lamk.) de Wit	Leguminosae	Log	50
9	*Phellinus adamantinus* (Berk.) Ryvarden, 1972	P	W	*Ailanthus triphysa* (Dennst.) Alston	Simauorubaceae	Log	38
10	*Phellinus ferrugineovelutinus* (Henn.) Ryvarden 1972	P	W	*Anacardium occidentale* L.	Anacrdiaceae	Tree stump	56
11	*Phellinus rimosus* (Berk.) Pilát 1940	P	W	*Artocarpus heterophyllus* Lamk.	Moraceae	Log	22
12	*Phellinus* sp. 1	P	W	*Anacardium occidentale* L.	Anacrdiaceae	Log	40
13	*Phellinus* sp. 2	P	W	*Delonix regia* (Boj.) Rafin.	Leguminosae	Log	46
14	*Tropicoporus dependens* (Murrill) L.W. Zhou, Y.C. Dai &Vlasák 2015	P	W	*Mangifera indica* L.	Anacardiaceae	Log	35
				Manilkara zapota (L.) P. Royen	Sapotaceae	Snag	43
15	*Phellinus fastuosus* (Lév.) S. Ahmad 1972	P	W	*Mangifera indica* L.	Anacardiaceae	Tree stump	40
				Pongamia pinnata (L.) Pierre	Leguminosae	Living tree	125

	Family & Species	Habit (A/P)	Rot (W/B)	Host species	Host family	Substrate type	GBH (cm)
16	*Phellinus gilvus* (Schwein.) Pat. 1900 =	A	W	*Terminalia catappa* L.	Combretaceae	Snag	48
				Anacardium occidentale L.	Anacardiaceae	Log	92
				Grevillea robusta A. Cunn.	Proteaceae	Log	68
				Anacardium occidentale L.	Anacardiaceae	Snag	22
				Anacardium occidentale L.	Anacardiaceae	Tree stump	56
				Mangifera indica L.	Anacardiaceae	Living tree	25
				Mangifera indica L.	Anacardiaceae	Stump	38
				Vateria indica L.	Dipterocarpaceae	Log	49
				Mitragyna parvifolia (Roxb.) Kunth	Rubiaceae	Log	41
				Racosperma auriculiformae (Benth.) Pedley	Leguminosae	Log	38
				Terminalia catappa L.	Combretaceae	Stump	48
				Anacardium occidentale L.	Anacardiaceae	Log	92
IV	**Meripilaceae**						
17	*Rigidoporus crocatus* (Pat.) Ryvarden 1983	P	W	*Cinnamomum malabatrum* (Burm.f.) Blume	Lauraceae	Snag	41
18	*Rigidoporus lineatus* (Pers.) Ryvarden 1972	A	W	*Delonix regia* (Boj.) Rafin.	Leguminosae	Snag	206
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	88
				Cocos nucifera L.	Palmae	Log	90
				Ailanthus triphysa (Dennst.) Alston	Simorubaceae	Log	38
				Terminalia paniculata Roth	Combretaceae	Living tree	28
				Hevea braziliensis (H.B.K.) Muell.-Arg.	Euphorbiaceae	Log	>100
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	85
				*Bambusa gigantea*Wall.	Poaceae	Log	38
				Albizia odaratissima (L.f.) Benth.	Leguminosae	Snag	56
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	128
V	**Meruliaceae**						
19	*Flavodon flavus* (Klotzsch) Ryvarden 1973	A	W	*Delonix regia* (Boj.) Rafin.	Leguminosae	Twig	10
				Peltophorum pterocarpum (DC.) Baker ex Heyne	Leguminosae	Log	64
				Peltophorum pterocarpum (DC.) Baker ex Heyne	Leguminosae	Log	16
				Trema orientalis (L.) Blume	Ulmaceae	Log	68
				Cassia nodosa Ham. ex Roxb.	Leguminosae	Log	16
				Delonix regia (Boj.) Rafin.	Leguminosae	Twigs	10
20	*Irpex lacteus* (Fr.) Fr. 1828	A	W	*Anacardium occidentale* L.	Anacardiaceae	Log	18
				Trema orientalis (L.) Blume	Ulmaceae	Log	98
21	*Junghuhnia crustacea* (Jungh.) Ryvarden 1972	A	W	*Macaranga peltata* (Roxb.) Muell.-Arg.	Euphorbiaceae	Twig	8
22	*Junghuhnia nitida* (Pers.) Ryvarden 1972	A	W	*Mangifera indica* L.	Anacardiaceae	Twig	8
				Macaranga peltata (Roxb.) Muell.-Arg.	Euphorbiaceae	Twig	5
23	*Poria* sp.	A	W	*Anacardium occidentale* L.	Anacrdiaceae	Log	55
VI	**Polyporaceae**						
24	*Cerrena* sp.	A	W	*Mangifera indica* L.	Anacardiaceae	Log	15
25	*Trametella telfairii* (Klotzsch) M. Pieri& B. Rivoire 2008	A	W	*Tectona grandis* L. f.	Lamiaceae	Snag	30

	Family & Species	Habit (A/P)	Rot (W/B)	Host species	Host family	Substrate type	GBH (cm)
26	*Trametes flavida* (Lév.) Zmitr., Wasser &Ezhov 2012	A	W	*Cocos nucifera* L.	Palmae	Log	88
				Albizia odaratissima (L.f.) Benth.	Leguminosae	Log	55
				Bambusa bamboos	Poaceae	Log	34
				Albizia odaratissima (L.f.) Benth.	Leguminosae	Log	46
				Racosperma auriculiformae (Benth.) Pedley	Leguminosae	Snag	73
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Snag	56
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Log	38
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Living tree	29
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Log	105
				Racosperma auriculiformae (Benth.)Pedley	Leguminosae	Snag	65
				Mangifera indica L.	Anacardiaceae	Log	35
27	*Earliella scabrosa* (Pers.) Gilb. &Ryvarden 1985	A	W	*Mangifera indica* L.	Anacardiaceae	Log	128
				Macaranga peltata (Roxb.) Muell.-Arg.	Euphorbiaceae	Twig	9
				Delonix regia (Boj.) Rafin.	Leguminosae	Twig	33
				*Myristica fragrans*Houtt.	Myristicaceae	Tree stump	32
				Spathodea companulata Beaux.	Bignoniaceae	Snag	203
				Hevea braziliensis (H.B.K.) Muell.-Arg.	Euphorbiaceae	Log	34
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	49
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Log	36
				Delonix regia (Boj.) Rafin.	Leguminosae	Tree stump	68
				Hevea braziliensis (H.B.K.) Muell.-Arg.	Euphorbiaceae	Log	72
28	*Favolus tenuiculus* P. Beauv. 1806	A	W	*Hevea braziliensis* (H.B.K.) Muell.-Arg.	Euphorbiaceae	Log	51
29	*Neofomitella rhodophaea* (Lév.) Y.C. Dai, Hai J. Li &Vlasák 2015	A	B	*Delonix regia* (Boj.) Rafin.	Leguminosae	Log	117
30	*Hexagonia tenuis* (Fr.) Fr. 1838	A	W	*Delonix regia* (Boj.) Rafin.	Leguminosae	Twig	36
				Mangifera indica L.	Anacardiaceae	Snag	85
				Anacardium occidentale L.	Anacardiaceae	Living tree	22
				Racosperm amangium (Wild.) Pedley	Leguminosae	Snag	15
				Hevea braziliensis (H.B.K.) Muell.-Arg.	Euphorbiaceae	Log	32
				Litsea glutinosa (Lour.) C. Robs.	Lauraceae	Log	32
				Elaeocarpus serratus L. var. serratus	Elaeocarpaceae	Log	56
				Albizia lebbeck (L.) Wild.	Leguminosae	Log	16
				Mangiferaindica L.	Anacardiaceae	Twig	6
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	37
31	Lenzites sp.	A	W	*Cinnamomum malabatrum* (Burm.f.) Blume	Lauraceae	Tree stump	48
32	*Loweporus tephroporus* (Mont.) Ryvarden 1980	P	W	*Mangifera indica* L.	Anacardiaceae	Log	39

	Family & Species	Habit (A/P)	Rot (W/B)	Host species	Host family	Substrate type	GBH (cm)
33	*Microporus affinis* (Blume & T. Nees) Kuntze 1898	A	W	Unidentified		Log	82
				Terminalia cuneata Roth	Combretaceae	Tree stump	6
				Terminalia elliptica Willd.	Combretaceae	Twig	18
				Bauhinia purpurea L.	Leguminosae	Log	16
34	*Microporus xanthopus* (Fr.) Kuntze 1898	A	W	*Terminalia paniculata* Roth	Combretaceae	Twig	34
				Terminalia elliptica Willd.	Combretaceae	Twig	8
				Butea parviflora	Leguminosae	Log	26
				Zizyphus mauritiana Lamk.	Rhamnaceae	Log	34
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Living tree	19
35	*Nigroporus vinosus* (Berk.) Murrill 1905	A	W	*Racospermamangium* (Wild.) Pedley	Leguminosae	Log	60
				Albizialebbeck (L.) Wild.	Leguminosae	Log	13
36	*Lentinus arcularius* (Batsch) Zmitr. 2010	A	W	*Casuarina litorea* L.	Casuarinaceae	Log	18
				Artocarpus heterophyllus Lamk.	Moraceae	Log	130
				Xylia xylocarpa (Roxb.) Taub.	Leguminosae	Twig	10
37	*Favolus grammocephalus* Lloyd 1924	A	W	*Garuga pinnata* Roxb.	Burseraceae	Log	42
				Macaranga peltata (Roxb.) Muell.-Arg.	Euphorbiaceae	Twig	5
				Peltophorum pterocarpum (DC.) Baker ex Heyne	Leguminosae	Log	15
				Ailanthus triphysa (Dennst.) Alston	Simaroubaceae	Twig	11
38	*Pyrofomes albomarginatus* (Zipp. ex Lév.) Ryvarden 1972	P	W	*Pterocarpus santalinus*L.f.	Leguminosae	Log	45
39	*Trametes cotonea* (Pat. & Har.) Ryvarden 1972	A	W	*Myristica fragrans* Houtt.	Myristicaceae	Log	31
				Phyllanthus emblica L.	Euphorbiaceae	stump	12
				Anacardium occidentale L.	Anacardiaceae	Log	30
				Senna siamea (Lamk.) Irwin & Barneby	Leguminosae	Living tree	34
				Macaranga peltata (Roxb.) Muell.-Arg.	Euphorbiaceae	Log	58
				Racosperma mangium (Wild.) Pedley	Leguminosae	Snag	40
				Racosperma mangium (Wild.) Pedley	Leguminosae	Tree stump	36
40	*Trametes hirsuta* (Wulfen) Lloyd 1924.	A	W	*Peltophorum pterocarpum* (DC.) Baker ex Heyne	Leguminosae	Snag	88
				Mangifera indica L.	Anacardiaceae	Log	12
				Artocarpus heterophyllus Lamk.	Moraceae	Log	116
				Albizia odaratissima (L.f.) Benth.	Leguminosae	Snag	68
				Samanea saman (Jacq.) Merr.	Leguminosae	Log	48
				Hevea braziliensis (H.B.K.) Muell.-Arg.	Euphorbiaceae	Log	21
				Hevea braziliensis (H.B.K.) Muell.-Arg.	Euphorbiaceae	Twig	10
41	*Trametes* sp.	A	W	*Bauhinia purpurea* L.	Leguminosae	Log	48

	Family & Species	Habit (A/P)	Rot (W/B)	Host species	Host family	Substrate type	GBH (cm)
42	*Trichaptum byssogenum* (Jungh.) Ryvarden 1972	A	W	*Mangifera indica* L.	Anacardiaceae	Log	20
				Tectona grandis L. f.	Lamiaceae	Log	18
				Artocarpus heterophyllus Lamk.	Moraceae	Log	80
				Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Log	85
				Delonix regia (Boj.) Rafin.	Leguminosae	Log	14
				Garcinia gummi-gutta (L.) Robs.	Clusiaceae	Twig	6
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Log	18
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Log	60
				Gliricidia sepium (Jack.) Kunth ex Walp.	Leguminosae	Tree stump	28
				Manilkara zapota (L.) P. Royen	Sapotaceae	Log	36
				Mangifera indica L.	Anacardiaceae	Log	22
				Syzygium cumini (L.) Skeels	Myrtaceae	Log	25
				Peltophorum pterocarpum (DC.) Baker ex Heyne	Leguminosae	Log	20
				Albizia odaratissima (L.f.) Benth.	Leguminosae	Log	35
				Macaranga peltata (Roxb.) Muell.-Arg.	Euphorbiaceae	Log	10
				Ailanthus triphysa (Dennst.) Alston	Simauorubaceae	Log	45
				Mangifera indica L.	Anacardiaceae	Log	18
VII	**Schizoporaceae**						
43	*Oxyporu spellicula* (Jungh.) Ryvarden 1980	A	W	*Delonix regia* (Boj.) Rafin.	Leguminosae	Log	12

A—Annual | P—Perennial | W—White rot | B—Brown rot.

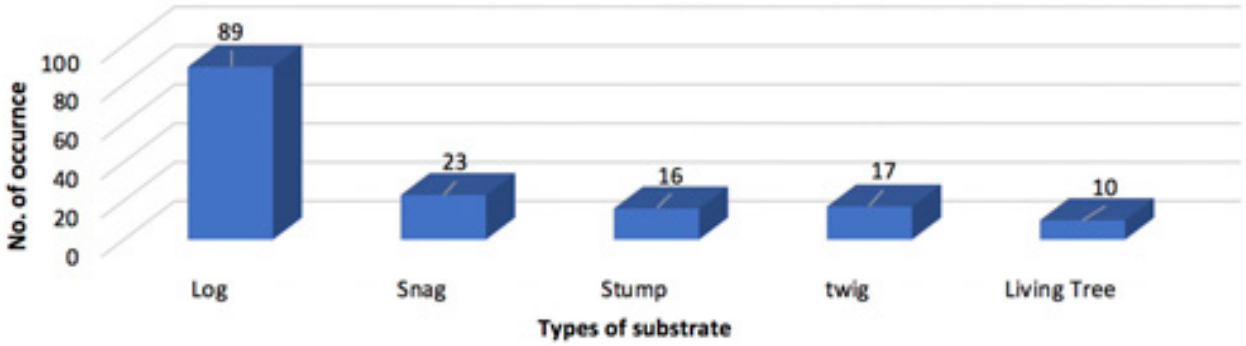

Figure 6. Polypores on different substrate types.

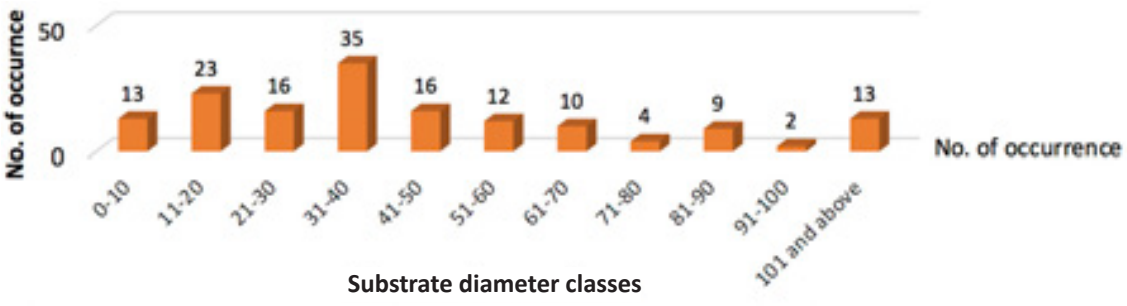

Figure 7. Polypores on different substrate diameter classes

amount of resources (Bader et al. 1995), however, in the present study the abundance of substrate under diameter class 31–40 cm is much higher than others. Understanding local host selectivity is important since it affects patterns of spread, density-dependent population dynamics, and in turn the maintenance of biological diversity and aspects of ecosystem function (Gilbert et al. 2008).

There are only few studies done on the diversity of polypores in Kerala. The present study attempts to document the diversity of polypores in KAU main campus. The present study reiterates the significance of KAU main campus in conserving the biodiversity of the region. Earlier studies on the fauna of KAU main campus have reported 139 species of birds (Nameer et al. 2000), 139 species of butterflies (Aneesh et al. 2013), 48 species of odonates (Adarsh et al. 2014), and 86 species of spiders (Adarsh & Nameer 2015). This is quite significant and thus emphasizes the importance of university campuses in biodiversity conservation.

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Image 1. *Fomitopsis feei*

Image 2. *Fomitopsis palustris*

Image 3. *Ganoderma australe*

Image 4. *Ganoderma lucidum*

Image 5. *Ganoderma subresinosum*

Image 6. *Inonotus* sp.

Image 7. *Phellinus caryophylli*

Image 8. *Phellinus nilgheriensis*

Image 9. *Phellinus adamantinus*

Image 10. *Phellinus ferrugineovelutinus*

Image 11. *Phellinus rimosus*

Image 12. *Phellinus* sp. 1

Image 13. *Phellinus* sp. 2

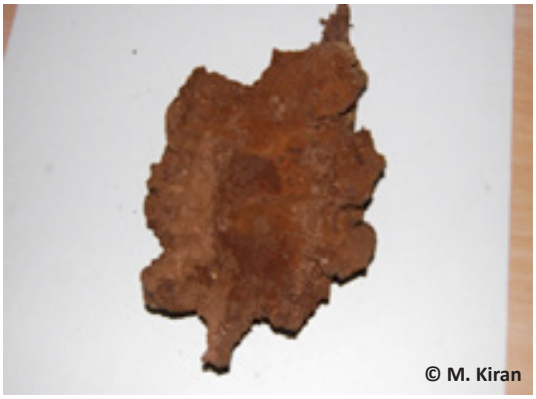

Image 14. *Tropicoporus dependens*

Image 15. *Phellinus fastuosu*

Image 16. *Phellinus gilvus*

Image 17. *Rigidoporus crocatus*

Image 18. *Rigidoporus lineatus*

Image 19. *Flavodon flavus*

Image 20. *Irpex lacteus*

Image 21. *Junghuhnia crustacea*

Image 22. *Junghuhnia nitida*

Image 23. *Poria* sp.

Image 24. *Cerrena* sp.

Image 25. *Trametella telfairii*

Image 26. *Trametes flavida*

Image 27. *Earliella scabrosa*

Image 28. *Favolus tenuiculus*

Image 29. *Neofomitella rhodophaea*

Image 30. *Hexagonia tenuis*

Image 31. *Lenzites* sp.

Image 32. *Loweporus tephroporus*

Image 33. *Microporus affinis*

Image 34. *Microporus xanthopus*

Image 35. *Nigroporus vinosus*

Image 36. *Lentinus arcularius*

Image 37. *Favolus grammocephalus*

Image 38. *Pyrofomes albomarginatus*

Image 39. *Trametes cotonea*

Image 40. *Trametes hirsuta*

Image 41. *Trametes* sp.

Image 42. *Trichaptum byssogenum*

Image 43. *Oxyporus pellicula*

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SHORT COMMUNICATION

On the evidence of the Irrawaddy Dolphin *Orcaella brevirostris* (Owen, 1866) (Mammalia: Cetartiodactyla: Delphinidae) in the Hooghly River, West Bengal, India

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Abstract: We report the presence and status of the Irrawaddy Dolphin *Orcaella brevirostris* in the Hooghly River of West Bengal, India. These observations were made while conducting our field work on the Ganges River Dolphin, which involved vessel-based surveys as well as intensive monitoring from an anchored boat.

Keywords: Ganges River Dolphin, India, tides, West Bengal.

The Irrawaddy Dolphin *Orcaella brevirostris* is a euryhaline species of the family Delphinidae found in estuaries as well as freshwater river systems. In India it is found in Chilika Lake, Odisha (Sutaria 2009) and the Sundarbans, West Bengal (Smith et al. 2006) where it co-occurs with the Ganges River Dolphin *Platanista gangetica*. Recent survey reports and observations from rivers in southern West Bengal (India) indicate the extirpation of the Ganges River Dolphin from the Indian Sundarbans (Mitra & Choudhary 2018). Globally, it is found along the coasts of southern and southeastern Asia, and in three river systems: the Ayeyarwady (Myanmar), the Mahakam (Indonesian, Borneo), and the Mekong (Baird & Beasley 2005). Three other sub-populations inhabit marine-appended brackish water bodies: Chilika Lagoon in India, Songkhla Lagoon in Thailand (Beasley et al. 2002), and Malampaya Sound in the Philippines. Recently, the threat status of the species has been elevated to the Endangered category on the IUCN Red List (Minton et al. 2017).

The Irrawaddy Dolphin is identified by a bulging forehead, a very short beak, triangular pectoral fin and a small dorsal fin on the back. It mainly feeds on fish and crustaceans (Mörzer Bruyns 1966). It relies on sound for communication, as well as for sensing their environment

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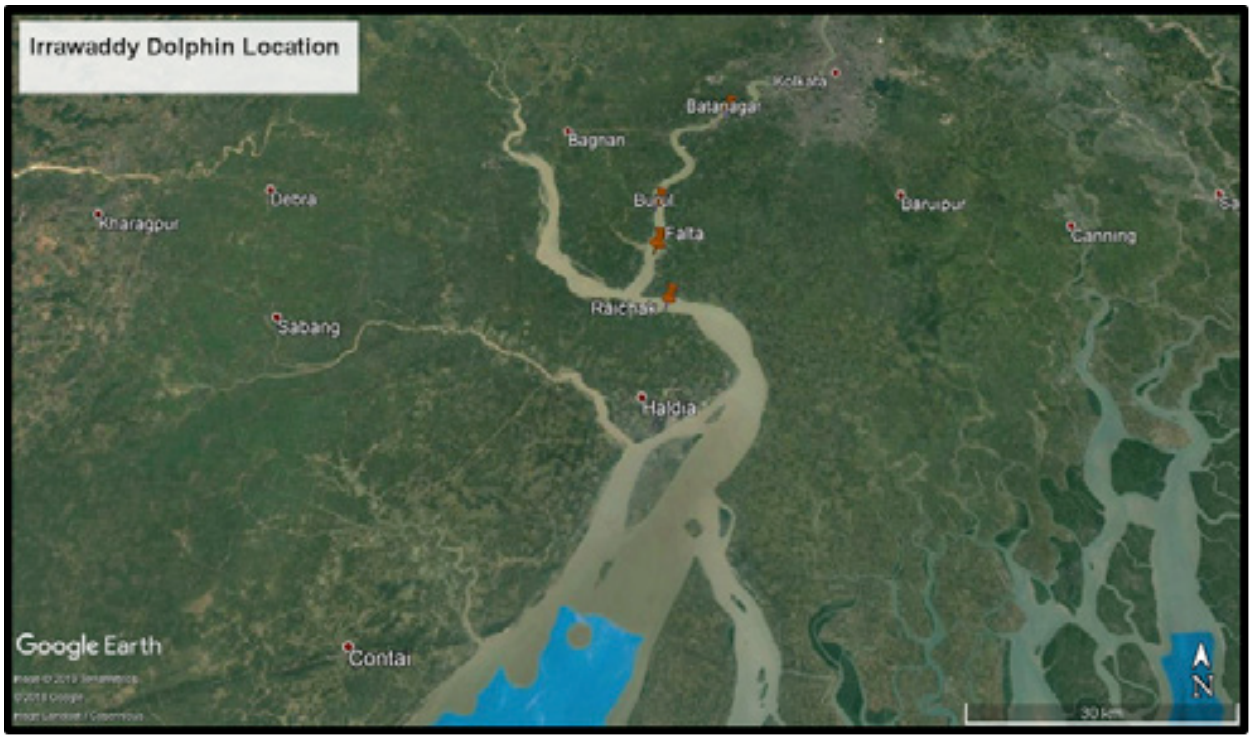

Image 1. Irrawaddy Dolphin sighting location in the River Hooghly in the state of West Bengal, India from March 2018 to March 2019.

and detection of both prey & predators underwater (Tyack & Clark 2000). They are also known to help fishermen in fishing (Anderson 1878; Tun 2008). The primary threat faced by them is accidental entanglement in fishing nets (Smith et al. 2003).

The lower Hooghly is a tidal river and an important conduit of national and international cargo movement. Kolkata Port is a key hub, and heavy shipping traffic is commonly seen. The river witnesses two tides a day, has a high sediment load with high water turbidity. It is an important habitat for the commercially important fish Indian Shad or 'Hilsa' *Tenualosa ilisha* which ascends the river for spawning. Here, we report the sighting of Irrawaddy Dolphin from four locations in the Lower Hooghly along with its persistence in the region. We also report on acoustic characteristics, which were briefly captured in our passive acoustic monitoring device.

Methods

Our work involves both systematic boat-based surveys for Ganges River Dolphin and observations from an anchored boat. We use independent double observer-based capture-recapture for systematic boat-based survey in Hooghly River except upstream of Kolkata where a single observer survey was done due to the narrow width of the river. We covered 123km in our first survey from Kolkata to Kakdwip (1–2 March 2018) and 114km during our repeat survey (19–20 March 2018). We surveyed for approximately five hours each day.

For acoustic monitoring, we anchored our boat for 1,058 hours totally on 45 occasions. We deployed our acoustic data loggers (C-POD, Chelonia Limited) moored with the anchor of our survey boat at each site to prevent drifting of the logger. It was a passive acoustic monitoring device which uses digital waveform characterization to detect cetacean echolocation clicks (http://www.chelonia.co.uk). The time of detection was logged together with other click features which were extracted from the custom-built software CPOD. exe freely available from the manufacturer. The data from the C-POD was used to record dolphin presence at each deployment site. It included automatic click train detection using the KERNO classifier and encounter classifiers. We used only high and medium quality acoustic detection and low-quality data were discarded.

During the systematic double observer surveys and while commuting on the river to and from the acoustic monitoring localities, all the observers stayed vigilant for any dolphin surfacing activity in the vicinity. The observers were experienced with identifying the Ganges River Dolphin, ruling out the possibility of misidentification.

Image 2. Enlarged shot extracted from the video taken from a moving boat near Raichak (22.271°N & 88.087°E) showing melon and dorsal fin of Irrawaddy Dolphin. Photo by Kanad Roy.

Results & Discussion

Earlier surveys and reports of Irrawaddy Dolphin

Previous surveys in this stretch for the Ganges River Dolphin (Sharma 2010; Mallick 2013; Chowdhury et al. 2016) had not reported the presence of the Irrawaddy Dolphin. Anecdotal reports of Irrawaddy Dolphin exist in a social media post by Suvrajyoti Chatterjee from South 24 Parganas dated 17 February 2018 (https://m.facebook.com/story.php?story_fbid=2095872860437875&id=100000455455739). We also note that at least two Irrawaddy Dolphins (a male and a female reported to be "possibly pregnant") were translocated into the Roopnarayan River (a tributary of Hooghly) in 2004 (Jana 2004). These dolphins were rescued from fisher's nets in the Kalighai (Kelaghai) River, near Haldia.

Observations of Irrawaddy Dolphin during the present study

While conducting our research (March 2018–March 2019) on the Ganges River Dolphins on the lower Hooghly River between Kolkata and Diamond Harbour, we sighted the Irrawaddy Dolphin at four locations (Table 1), Falta, Raichak, Burul, and Batanagar (Images 1,2). One of the sightings, in Batanagar, was 22km downstream of Kolkata (seen from a close range of 10m). Single individuals were seen on all four occasions.

Table 1. Location, date and time of Irrawaddy River Dolphin sightings.

Location	GPS location	Date and time	Distance from sea
Falta	22.271 88.087	24 March 2018 16.54h	65km
Raichak	22.201 88.108	28 June 2018 11.07h	51km
Burul	22.349 88.097	21 July 2018 10.15h	73km
Batanagar	22.508 88.202	09 January 2019 12.20h	98km

The respective geographical coordinates were recorded by a handheld GPS (GARMIN e-trex 30x).

Since the sightings encompasses both wet and dry seasons, and the number of observations has been small taking into account the considerable time spent on the river, we believe that a resident but small population of the Irrawaddy Dolphin is present in this stretch of the river.

On 28 June 2018 near Raichak, our acoustic data logger which was moored for four hours with our survey boat, where we opportunistically recorded Irrawaddy Dolphin click trains (four trains) at the same time as we visually observed the individual. These were confirmed as the time of sighting matched precisely with that of the recordings. We confirmed that the Ganges River Dolphin

Table 2. Click characteristics of Irrawaddy River Dolphin recorded in C-POD.

Train duration (µ seconds)	No of clicks	Modal frequency of clicks (KHz)	Minimum frequency (KHz)	Maximum frequency (KHz)	Maximum sound pressure level (Pascals)	Average sound pressure level (Pascals)	Minimum inter-click interval (µ seconds)	Maximum inter-click interval (µ seconds)
743240	20	51	39	63	89	37	29540	54115
488380	20	49	35	79	37	19	22220	50980
851965	21	52	39	63	62	28	38450	82155
1272315	34	61	39	63	52	21	34730	79710

was absent from the area, thus ruling out confounding with the species (C-Pod does not discriminate between dolphin species). The data recorded were analyzed in CPOD.exe software. The click characteristics are given in Table 2. These are within range of the acoustic characteristics of the species (Jensen et al. 2013).

This is the first report of the Irrawaddy Dolphin from the river Hooghly in the literature; they have been observed in winter as well as monsoon suggesting a year-round presence. Although more frequent surveys are required for confirmation and future research in this data deficient region should be taken up as a priority.

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SHORT COMMUNICATION

Avifaunal diversity of Tilyar Lake, Rohtak, Haryana, India

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Abstract: Avian diversity of Tilyar Lake (28.883–28.879 ^{0}N & 76.637 –76.634 ^{0}E) located on the eastern outskirts of Rohtak, Haryana was conducted from May 2017 to April 2018. A total of 73 avian species belonging to 62 genera and 31 families under 15 orders was observed. Order Passeriformes with 21 species in 12 families dominated the avifauna whereas orders Bucerotiformes, Podicipediformes, and Psittaciformes were poorly represented with a single species each. Family Anatidae was the most dominant representing 13.89% (n=10) of the total species recorded. Among the reported species 75% (n=54) were resident while 25% (n=18) were migrant. Common Pochard *Aythya ferina* assessed globally as Vulnerable, while Painted Stork *Mycteria leucocephala*, Oriental Darter *Anhinga melanogaster* and Black-headed Ibis *Threskiornis melanocephalus* are assessed as Near Threatened, whereas the rest of the species were in the Least Concern category of the IUCN Red List 2019. The omnivorous feeding habit was shown by the maximum number of species while frugivorous and granivorous bird species were in the least numbers. The rich avifaunal diversity of the Tilyar Lake confirms it as a suitable habitat for both resident and migrant bird species. Therefore, the present study suggests the need for incorporation of appropriate protective measures for conservation of the avian heritage of Tilyar Lake, Rohtak.

Keywords: Anthropogenic activities avian heritage, frugivorous, granivorous, migrant birds.

The Indian subcontinent harbours nearly 1,340 bird species accounting for more than 13% of the world's avian diversity (Chakdar et al. 2016). In Haryana, about 450 species of birds have been reported at times (Goyal et al. 2014). The water bodies, whether flowing or static, form an essential constituent of different ecosystems and attract a large number of birds by fulfilling their feeding and other needs. Haryana with 42,480ha area of wetlands (National Wetland Atlas 2010) provides a home to a huge diversity of wildlife including birds. Many avifaunal studies have been done on the wetland birds of Haryana (Kumar & Gupta 2009; Gupta et al. 2010, 2012; Tak et al. 2010; Gupta & Kaushik 2012, 2013; Goyal et al. 2014; Kaushik & Gupta 2014; Kumar & Dhankhar 2015; Kumar et al. 2016; Kumar & Sharma 2018). Among the wetlands of Haryana, Tilyar Lake in Rohtak occupies a prominent position. It has four islands with thick vegetation cover, green lawns and waterlogged land along the Jawahar Lal Nehru canal on its western margin; all this attracts a variety of resident and migratory birds.

The presence of water birds, a mini zoo, boating facility, and amusement zone attracts urban people to picnic at Tilyar Lake making it a popular tourist destination. Despite its economic importance, little scientific work has been done towards the assessment of its avian diversity.

Study Area

Tilyar Lake is located between 28.883–28.879 ^{0}N & 76.637 –76.634 ^{0}E (Figure 1). The lake extends over 132 acres, and is situated adjacent to the Jawahar Lal Nehru canal, beside the national highway of Rohtak-Delhi on the eastern outskirts of Rohtak city in Haryana. It is only 66.1km away from the national capital of India, New Delhi. Tilyar Lake is a perennial stagnant water body with no outflow, having an average depth of 3m. It has four

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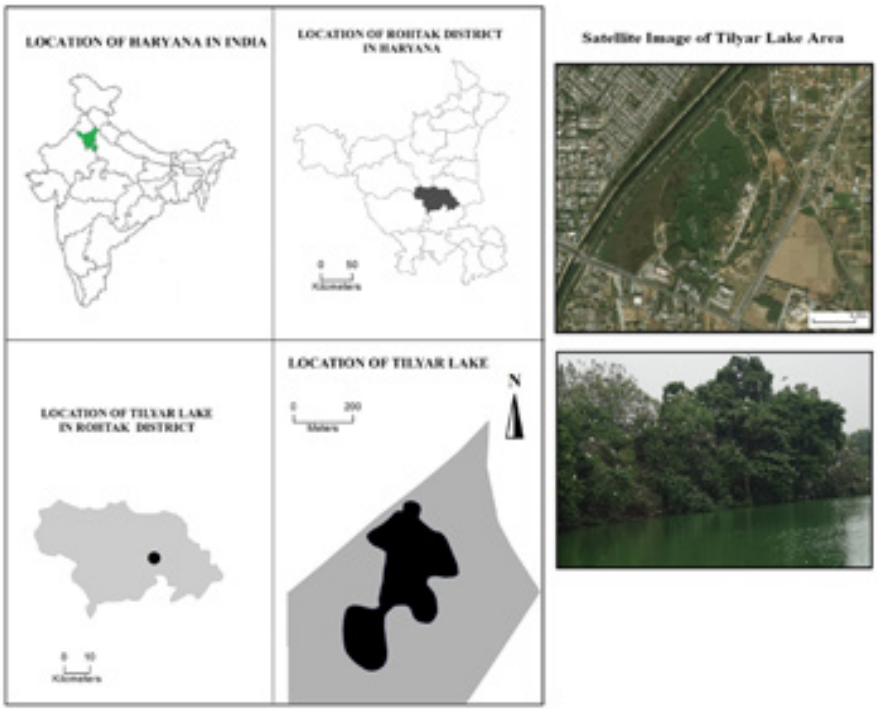

Figure 1. Tilyar Lake, Rohtak with adjacent area.

small islands with high tree density out of which three are least affected by human activities. The lake harbours aquatic weeds supporting a large number of aquatic zooplankton. The periphery is also covered with trees and bushes providing suitable habitat for a variety of birds.

Material and Methods

The diversity and seasonal migration of avian fauna was studied for a period of one year at Tilyar Lake from May 2017 to April 2018. Regular weekly surveys were conducted in the morning (from 07.00–09.00 h in winter; 05.00–07.00 h in summer) and before sunset in the evening. The line transect method was used to observe the birds in this open habitat with the aid of Olympus binoculars (8X40) and birds were photographed using a Nikon D5300 DSLR camera. Birds were identified as per field guides of Grimmett et al. (2013). A checklist was prepared following the nomenclature used in the IUCN Red Data List 2019.

The identified birds were then categorized according to their residence status as Resident (R), Winter migrant (WM), Summer migrant (SM) following Grimmett et al. (2013). The composition of bird community, species abundance and richness, feeding habits and relative diversity were observed and calculated.

Feeding habits were assigned according to observations during the study. Birds feeding on larvae, eggs, small amphibians, fishes, crustaceans, and small birds were placed under carnivorous feeding habit whereas, the birds feeding on algae, tender foliage, aquatic weeds, and vegetation were categorized as herbivorous; birds feeding on insects and moths were listed as insectivorous, while the omnivorous habit include both carnivory and herbivory. The frugivorous and granivorous habits refer to fruit-eaters and grain-eaters, respectively.

Relative Diversity (RDi) denotes percentage occurrence of various families concerning the whole bird community and is a powerful tool for the population study related to family diversity and dominance. It was calculated following Koli (2014).

$$RDi = \frac{Number\ of\ species\ in\ a\ family}{Total\ number\ of\ species} \times 100$$

Results

The present study revealed a total of 73 avian species of 62 genera belonging to 31 families and 15 orders in the studied area of Tilyar Lake, Rohtak (Table 1; Images 1–20).

In Tilyar Lake Passeriformes (21 species in 12 families) was the most dominant order followed by Anseriformes (10 species in one family), Charadriiformes (10 species in three families); Pelecaniformes (eight species in two families); Gruiformes (four species in one

Table1. Checklist of birds recorded in Tilyar Lake, Rohtak.

	Common name	Scientific name	Resident status	IUCN Red List status	Feeding habit
Order: Accipitriformes					
Family: Accipitridae					
1	Shikra	*Accipiter badius* (Gmelin, 1788)	R	LC	CV
2	Black-shouldered Kite	*Elanus caeruleus* (Desfontaines*, 1789)*	R	LC	CV
3	Black Kite	*Milvus migrans* (Boddaert, 1783)	R	LC	OV
Order: Anseriformes					
Family: Anatidae					
4	Bar-headed Goose	*Anser indicus* (Latham, 1790)	WM	LC	HV
5	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	WM	LC	HV
6	Indian Spot-billed Duck	*Anas poecilorhyncha* Forester, 1781	R	LC	OV
7	Lesser Whistling-duck	*Dendrocygna javanica* (Horsfield, 1821)	R	LC	OV
8	Comb Duck	*Sarkidiornis melanotos* (Pennant, 1769)	R	LC	OV
9	Gadwall	*Mareca strepera* Linnaeus, 1758	WM	LC	OV
10	Common Teal	*Anas crecca* Linnaeus, 1758	WM	LC	OV
11	Northern Pintail	*Anas acuta* Linnaeus, 1758	WM	LC	OV
12	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	WM	VU	OV
13	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	WM	LC	OV
Order: Charadriiformes					
Family: Scolopacidae					
14	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	WM	LC	OV
15	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	WM	LC	OV
16	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	WM	LC	CV
17	Common Greenshank	*Tringa nebularia* (Gunner, 1767)	WM	LC	CV
18	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	WM	LC	CV
19	Ruff	*Calidris pugnax* (Linnaeus, 1758)	WM	LC	OV
Family: Burhinidae					
20	Eurasian Thick-knee	*Burhinus oedicnemus* (Linnaeus, 1758)	R	LC	CV
Family: Charadriidae					
21	White-tailed Lapwing	*Vanellus leucurus* (Lichtenstein, 1823)	WM	LC	CV
22	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	R	LC	CV
23	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	R	LC	CV
Order: Ciconiiformes					
Family: Ciconiidae					
24	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	R	LC	CV
25	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	R	NT	CV
Order: Columbiformes					
Family: Columbidae					
26	Rock Dove	*Columba livia* Gmelin, 1789	R	LC	OV
27	Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)	R	LC	OV
28	Laughing dove	*Spilopelia senegalensis* (Linnaeus, 1766)	R	LC	OV
Order:Coraciiformes					
Family: Alcedinidae					
29	White-breasted kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	R	LC	OV
30	Pied kingfisher	*Ceryle rudis* (Linnaeus, 1758)	R	LC	OV
Family: Meropidae					
31	Green bee-eater	*Merops orientalis* Latham, 1801	R	LC	IV
Order:Bucerotiformes					
Family: Upupidae					
32	Common Hoopoe	*Upupa epops* Linnaeus, 1758	R	LC	OV

	Common name	Scientific name	Resident status	IUCN Red List status	Feeding habit
Order: Cuculiformes					
Family: Cuculidae					
33	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	R	LC	OV
34	Asian Koel	*Eudynamys scolopacea* (Linnaeus, 1758)	R	LC	OV
Order: Galliformes					
Family: Phasianidae					
35	Indian Peafowl	*Pavo cristatus* Linnaeus, 1758	R	LC	OV
36	Grey Francolin	*Francolinus pondicerianus* (Gmelin, 1789)	R	LC	OV
Order: Gruiformes					
Family: Rallidae					
37	Common Coot	*Fulica atra* Linnaeus, 1758	WM	LC	OV
38	Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	R	LC	OV
39	Purple Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	R	LC	OV
40	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	R	LC	OV
Order: Passeriformes					
Family: Cisticolidae					
41	Ashy Prinia	*Prinia socialis*	R	LC	IV
42	Plain Prinia	*Prinia inornata* Sykes, 1832	R	LC	IV
43	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	R	LC	OV
Family: Corvidae					
44	House Crow	*Corvus splendens* Vieillot, 1817	R	LC	OV
45	Large- billedCrow	*Corvus macrorhynchos* Wagler, 1827	R	LC	OV
Family: Estrildidae					
46	Red Avadavat	*Amandava amandava* (Linnaeus, 1758)	R	LC	OV
47	Indian Silverbill	*Lonchura malabarica* (Linnaeus, 1758)	R	LC	OV
Family: Motacillidae					
48	White Wagtail	*Motacilla alba* Linnaeus, 1758	WM	LC	OV
49	Western Yellow Wagtail	*Motacilla flava* Linnaeus, 1758	WM	LC	OV
Family: Nectariniidae					
50	Purple Sunbird	*Nectarinia asiatica* (Latham, 1790)	R	LC	OV
Family: Passeridae					
51	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	R	LC	GV
Family: Ploceidae					
52	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	R	LC	OV
53	Black-breasted Weaver	*Ploceus benghalensis* (Linnaeus, 1758)	R	LC	OV
Family: Pycnonotidae					
54	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	R	LC	OV
Family: Sturnidae					
55	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	R	LC	OV
56	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	R	LC	OV
Family: Leiothrichidae					
57	Common Babbler	*Turdoides caudatus* (Dumont, 1823)	R	LC	OV
58	Jungle Babbler	*Turdoides striatus* (Dumont, 1823)	R	LC	OV
Family: Hirundinidae					
59	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	SM	LC	IV
Family: Muscicapidae					
60	Bluethroat	*Luscinia svecica* (Linnaeus, 1758)	WM	LC	OV
61	Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	R	LC	OV
Order: Pelecaniformes					
Family: Ardeidae					
62	Black-crowned Night-heron	*Nycticorax nycticorax* (Linnaeus, 1758)	R	LC	OV

	Common name	Scientific name	Resident status	IUCN Red List status	Feeding habit
63	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	R	LC	CV
64	Great White Egret	*Casmerodius albus* (Linnaeus, 1758)	R	LC	CV
65	Little Heron	*Butorides striatus* (Linnaeus, 1758)	R	LC	CV
66	Indian Pond-heron	*Ardeola grayii* (Sykes, 1832)	R	LC	OV
67	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	R	LC	CV
Family: Threskiornithidae					
68	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	R	NT	CV
69	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	R	LC	CV
Order:Podicipediformes					
Family: Podicipedidae					
70	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	R	LC	CV
Order: Psittaciformes					
Family: Psittacidae					
71	Rose-ringed Parakeet	*Psittacula krameria* (Scopoli, 1769)	R	LC	FV
Order:Sulliformes					
Family: Phalacrocoracidae					
72	Indian Cormorant	*Phalacrocorax fuscicollis* Stephens, 1826	R	LC	CV
Family: Anhingidae					
73	Oriental Darter	*Anhinga melanogaster* Pennant, 1769	R	NT	CV

R—Resident | SM—Summer migrant | WM—Winter migrant | LC—Least concerned | NT—Near threatened | VU—Vulnerable | CV—Carnivorous | HV—Herbivorous | IV—Insectivorous | OV—Omnivorous.

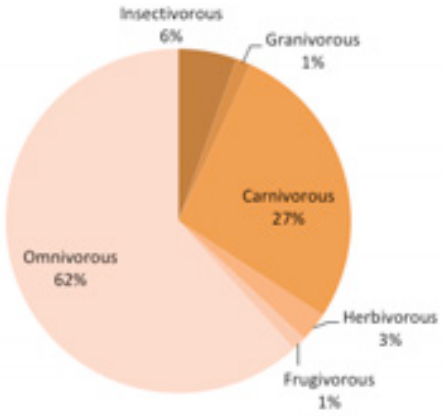

Figure 2. Distribution of bird species according to their feeding habits.

family); Coraciiformes (three species in two families); Accipitriformes, Columbiformes (three species each in single family each); Sulliformes (two species in two families); Ciconiiformes, Cuculiformes, Galliformes (two species each in single family each). While Bucerotiformes, Psittaciformes, and Podicipediformes were the least represented orders with a single species each (Table 1).

Anatidae with relative diversity of 13.70% (n=10 species) was the most dominant family; followed by Ardeidae and Scolopacidae 8.22% (n=6 species each), family Rallidae 5.48% (n=4 species) while families Accipitridae, Columbidae, Charadriidae, and Cisticollidae represented 4.11% (n=3 species each) whereas families Ciconiidae, Alcedinidae, Cuculidae, Phasianidae, Corvidae, Estrildidae, Motacillidae, Ploceidae, Sturnidae, Leiothrichidae, Muscicapidae, and Threskiornithidae reported 2.74% each (n= 2 species each). Burhinidae, Meropidae, Upupidae, Nectariniidae, Passeridae, Pycnonotidae, Hirundinidae, Podicipedidae, Psittacidae, Phalacrocoracidae, and Anhingidae were the least represented families showing 1.37% each (n= 1 species each) (Table 2).

Non-passerine birds dominated the diversity with percentage occurrence of 71.23% (n=52) as compared to passerine birds with 28.77% (n=21). The data on residential status revealed that out of 73 species 73.98% (n=54) were the resident species recorded at Tilyar Lake whereas the remaining 26.03% (n=19) showed seasonal migration; in which 24.65% (n=18) were winter migrant while only 1.37% (n=1) was summer migrant. *Anser indicus, Spatula clypeata, Mareca strepera, Anas crecca, Anas acuta, Aythya farina, Tadorna ferruginea, Actitis hypoleucos, Gallinago gallinago, Tringa totanus, Tringa nebularia, Tringa ochropus, Vanellus leucurus, Fulica atra, Motacilla alba, Motacilla flava, Luscinia svecica*, and *Calidris pugnax* were spotted during the winter season from December to March, while *Hirundo smithii*, the sole

Table 2. Family-wise distribution of genera and species of birds.

	Family	No. of Genera	No. of Species	Relative Diversity (RDi)
1	Accipitridae	3	3	4.11
2	Anatidae	8	10	13.70
3	Scolopacidae	4	6	8.22
4	Burhinidae	1	1	1.37
5	Charadriidae	1	3	4.11
6	Ciconiidae	2	2	2.74
7	Columbidae	3	3	4.11
8	Alcedinidae	2	2	2.74
9	Meropidae	1	1	1.37
10	Upupidae	1	1	1.37
11	Cuculidae	2	2	2.74
12	Phasianidae	2	2	2.74
13	Rallidae	4	4	5.48
14	Cisticolidae	2	3	4.11
15	Corvidae	1	2	2.74
16	Estrildidae	2	2	2.74
17	Motacillidae	1	2	2.74
18	Nectariniidae	1	1	1.37
19	Passeridae	1	1	1.37
20	Ploceidae	1	2	2.74
21	Pycnonotidae	1	1	1.37
22	Sturnidae	1	2	2.74
23	Leiothrichidae	2	2	2.74
24	Hirundinidae	1	1	1.37
25	Muscicapidae	2	2	2.74
26	Ardeidae	6	6	8.22
27	Threskiornithidae	2	2	2.74
28	Podicipedidae	1	1	1.37
29	Psittacidae	1	1	1.37
30	Phalacrocoracidae	1	1	1.37
31	Anhingidae	1	1	1.37
	Total	62	73	100

summer migrant was observed from April to August.

It was found that 69 species are Least Concern category of the IUCN Red List 2019—three species (*Mycteria leucocephala*, *Anhinga melanogaster,* and *Threskiornis melanocephalus*) are Near Threatened and one species *Aythya ferina* Vulnerable. Besides these, Painted Stork *Mycteria leucocephala* is protected under Schedule IV of the Indian Wildlife Protection Act, 1972.

The feeding habits of the recorded birds showed that the maximum number of species (45 species) were omnivorous followed by carnivorous (20 species), insectivorous (four species), herbivorous (two species), frugivorous (one species) and granivorous (one species). A significant number of the omnivorous species suggested the presence of a very heterogeneous habitat in terms of availability of food (Figure 2).

Discussion

The presence of a variety of birds in the diverse habitats of the Tilyar Lake suggests it an important bird habitat. The lake islands, green lawns, and the peripheral waterlogged area provide a heterogeneous habitat which supports a rich diversity of birds. We report an updated and extended checklist of Tilyar Lake, Rohtak. The sighting of the additional bird species suggests the need for further scientific studies and more field works on the lake and adjacent area. The lake, therefore, serves as an excellent stopover site for many migrant species as well as a favourable roosting and nesting site for a large number of resident species. The variety of habitats and heterogeneous environments of Tilyar Lake attracts and supports a good number of bird species. It is, therefore, proposed that developmental and other anthropogenic activities should be avoided or minimized in and around the lake area. Adequate measures should, therefore, be adopted for the protection and conservation of the lake's avian heritage.

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Image 1–20. Some important birds of Tilyar Lake, Rohtak: 1—Indian Spot-billed Duck | 2—Pied Kingfisher | 3—Red Avadavat | 4—Ruff | 5—Bar-headed Goose | 6—Green Sandpiper | 7—Northern Pintail | 8—Common Pochard | 9—Eurasian Thick knee | 10—Red-naped Ibis | 11—Northern Shoveler | 12—Lesser Whistling-duck | 13—Grey Francolin | 14—Painted Stork | 15—Comb Duck | 16—Bank Myna | 17—Oriental Darter | 18—Black-headed Ibis | 19—Yellow-wattled Lapwing | 20—Black-crowned Night Heron. © Vinay Malik.

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SHORT COMMUNICATION

Life-history traits and courtship behaviour of four poorly known endemic bush frogs (Amphibia: Anura: Rhachophoridae) from the Western Ghats of India

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Abstract: The Western Ghats have a high level of anuran endemism. Although there has been an extensive focus on their taxonomy, the ecology of most species are poorly known. In this note we describe the reproductive life-history traits and breeding behavior of four species of endemic bush frogs, *Pseudophilautus wynaadensis*, *Raorchestes akroparallagi*, *Raorchestes glandulosus*, and *Raorchestes ponmudi* (Amphibia: Anura: Rachophoridae) from Wayanad region of Western Ghats.

Keywords: Clutch-size, reproduction, metamorphosis, direct metamorphosis, coffee plantation, *Pseudophilautus wynaadensis, Raorchestes akroparallagi, Raorchestes glandulosus, Raorchestes ponmudi*

The Western Ghats mountain ranges is one of the global biodiversity hotspots (Myers et al. 2000). The area has a high diversity of amphibians, many of which are endemic (Das et al. 2006; Dahanukar & Molur 2020). In the past two decades, while researchers have extensively focused on amphibian taxonomy and systematics, the knowledge about their basic life-history traits (e.g., time to first reproduction, clutch size, weight at hatching) are still limited. This information can be vital for understanding both the ecology and conservation status of a species.

In this note, we describe the egg-laying behavior, and two life-history traits (clutch size, and time to metamorphosis) for four species of endemic bush frogs, *Pseudophilautus wynaadensis*, *R. akroparallagi, R. glandulosus,* and *R. ponmudi*, all of which have direct development (Vijayakumar et al. 2016). All these species are known to breed during the monsoon season.

Previously, one paper each has described the breeding behavior of *R. akroparallagi* (originally reported as *R. glandulosus* by Biju (2003) but species identity rectified in Biju & Bossuyt (2009)) and *R. glandulosus* (Krishnamurthy et al. 2002). However, after reviewing Krishnamurthy et al. (2002), we realized that *R. glandulosus* had been misidentified (it is likely *R. tuberohumerus* since the groin and anterior surfaces of thighs in their Figure 1 is dark brown with yellow blotches). No article, to the best of our knowledge, has reported the breeding behavior or life-history traits of the other two species (*R. ponmudi* and *P. wynaadensis)*.

We report observations that were made in a coffee plantation situated next to Kalloor, Sulthan Bathery (Wayanad, Kerala), around half a kilometer away from Wayanad Wildlife Sanctuary, Kerala (11.664^{0}N &

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76.331^{0}E). For detailed observations, each amplecting pair was transferred to a terrarium (a plastic circular 20L tub – 80cm diameter and ~1m height), which was installed outdoors in a shaded area to maintain the ambient temperature and humidity. The terrarium was covered with a mesh and consisted of a layer of soil collected from the same area (7–8 cm thick), leaf litter, and vegetation (a few branches of a coffee tree with intact leaves, grass). All the adult individuals were released back to the same location from which they were captured the previous night, assuming there is no parental care (as suggested by Biju 2003). All the observations were done using a LED torch whenever necessary.

Pseudophilatus wynaadensis

Two amplecting pairs were found on coffee plant (about 50–100 cm from the ground), the first on 15 May 2016 and second on 15 July 2019 (Image 1a). Both the pairs were transferred to the terrarium, and by morning the pairs had finished laying eggs. The frogs had transformed into a duller brown color over the night in both cases.

After inspecting the terrarium, in both cases the eggs (Image 1b) were found underneath a small layer of soil (1–2 cm deep). The number of eggs in the first and second clutch were 29 and 33, respectively. In the successive days, the froglets underwent direct development (Image 1c) and hatched synchronously after 22 and 25 days, respectively (Image 1d).

We weighed the eggs from the 2019 clutch throughout the developmental period. The average weight of the eggs was 0.074g (N=10; measured on 11th, 18th, 22th, and 25th day after the egg laying). A newly hatched froglet weighed 0.019g (N=3).

Raorchestes akroparallagi

An amplecting pair of *R. akroparallagi* (Image 2a) was found during late evening (20.25h) on 10 June 2019, during a slight drizzle. The pair was observed sitting on a coffee plant leaf (about 160cm above ground). After around half hour of observation, they were transferred

Image 1. *Pseudophilautus wynaadensis*: a—amplecting pair | b—eggs | c—eggs after 22 days of development | d—froglets. © Abhijith A.V.

to a terrarium. The frogs were inspected every few hours, and throughout the night the male remained attached to the female's dorsum. The greenish colored frogs had transformed into shades of brown by morning (Image 2b).

At 11.54h, we found that the female had already started laying eggs (5 eggs were visible). The pair was closely observed throughout the egg-laying period (Image 2b). After egg-laying (12.17h), the male detached himself from the female and positioned himself in a restful manner on one of the coffee leaves. Meanwhile, the female covered up the eggs with soil particles that surrounded it. During this process, the female rolled the eggs in the soil such that the whitish-cream colored egg turned into a reddish-brown color (same as the soil). An earlier study had recorded the egg-laying on a coffee leaf (Biju 2003).

On 11 June 2019, we carefully exposed all the eggs (a total of 49 eggs) from the soil. The eggs underwent direct development (Image 2c), and after 21 days of laying the eggs, all the froglets hatched synchronously (Image 2d).

Raorchestes glandulosus

On 07 June 2019, at around 19.30h a female *R. glandulosus* was located on the leaf of a coffee plant at a height of approximately 200cm. The female approached a calling male (also situated around 2m from the ground level) on the same plant. After about 15 minutes, the male gave out a distinct call and pounced onto the female. The female reacted by jumping away from the male after which the male started calling again. The male and female responded to each other in this manner three times. On the fourth try, the male managed to successfully hold onto the female's dorsum facing the opposite direction (Image 3a). After a while, the male realigned himself facing towards the female, head following which the amplecting pair was transferred to a terrarium.

The amplecting pair laid eggs inside the soil (1–2 cm

Image 2. *Raorchestes akroparallagi*: a—amplecting pair | b—pair laying eggs, note the change in color | c—eggs after 22 days of development | d—a froglet. © Abhijith A.V.

Image 3. ***Raorchestes glandulosus***: a—amplecting pair, male sitting on the female facing the opposite direction | b—eggs laid in the soil | c—eggs after 15 days of development | d—froglet. © Abhijith A.V.

in depth; Image 3b), even though they had the choice to lay their eggs on the leaf of a branch. The yellowish-green frogs transformed into shades of brown during the process of egg-laying (at 02.33h), and the female covered the eggs using soil particles that surrounded the egg clutches. A total of 55 eggs were laid and underwent direct development (Image 3c). The froglets synchronously hatched after 21 days (Image 3d).

Although the above mentioned observations were recorded from a terrarium, similar observations have been reported from a natural setting near Madikeri, Karnataka (Abhishek Jain pers. comm. June 2019). A pair of amplecting individuals was located on 12 June 2019. The female laid 39 eggs in a cluster about 3cm below the leaf litter mixed with soil. The frogs changed their colours to dull brown within 15 minutes of heading down to the leaf litter. Even in this case, all the eggs underwent direct development and hatched synchronously.

Raorchestes ponmudi

We observed two different clutches of this species. The first pair of *R. ponmudi* was found during late evening (19.55h) on 18 May 2019, after a short rain (5.8mm). The temperature that night was 22.6˚C and a humidity of 86%. The pair was observed in an amplexus, on a horizontal coffee branch about 150cm above ground. Two other males were calling from the same plant, frequently giving out a territorial call and showing a tendency for fighting. The amplecting pair (Image 4a) was observed for around an hour.

Following this, the pair was transferred to a terrarium. The frogs were inspected every few hours for around 15min, and their activities were recorded. The female carried the male from leaf to leaf and finally settled down on a small patch of bare soil at around 02.30h. The male remained firmly attached to the female's dorsum. When the frogs were inspected the following morning (~ 06.00h), the male had detached himself from the female and was resting on a coffee leaf. Since the previous

Image 4. ***Raorchestes ponmudi*****: a—amplecting pair | b—eggs laid in the soil | c—eggs after 18 days of development | d—froglet. © Abhijith A.V.**

observation was taken at 03.30h, the egg laying must have happened sometime between 03.30h and 06.00h.

At 06.00h, the female looked lean (when compared to the previous night), and was seen covering up the eggs using soil particles that surrounded the egg clutch. This activity went on for another one and a half hours, after which the individual settled down and rested on the soil.

After a day (12 June 2019), a total of 81 eggs were carefully collected from the soil (1–2 cm). Each egg was unpigmented, whitish-cream colored, and covered by a thick jelly coat (Image 4b). Water was sprayed once in two days to prevent the eggs from drying. The egg clutch was observed every day and photographs of its developmental phases were taken. The eggs underwent direct development (Image 4c), and after 19 days, the froglets hatched (Image 4d).

The second amplecting pair of *R. ponmudi* was found at 21.31h (same coffee plantation as above), on 25 May 2019. The average rain that night was 8mm, and the pair was located around 1m from the ground level. Interestingly, the male was sitting on the female facing the opposite direction. Only after a few hours did the male align himself properly on the female. In both the amplecting pairs, the frogs changed their color to dark brown during the egg-laying process.

This pair was also transferred to a terrarium (similar dimension as the previous pair), where the female laid the eggs in the soil at a depth of around 1–2 cm. Egg-laying started at approximately 05.00h. After the male detached himself, the female covered the eggs with soil. The female laid a total of 78 eggs. This time, the eggs were not disturbed, and the soil was sprayed with water to prevent it from drying up, however, after a few days we observed fungal growth on the soil, and the development of the froglets ceased. Later the eggs dried up.

Conclusions

To summarize, all the four species of bush frogs laid their eggs in moist soil, under a layer of leaf litter, where they underwent direct metamorphosis. The clutch size for the three *Raorchestes* species ranged from 49 (*R. akroparallagi*), 55 (*R. glandulosus*) to an average of 83 eggs (for *R. ponmudi*). Their time to hatching ranged from 19 (for *R. ponmudi*) to 21 days (*R. akroparallagi; R. glandulosus*). *Pseudophilatus wynaadensis,* on the other hand, had an average clutch size of 31 eggs and hatched between 22 and 25 days. To the best of our knowledge, there is only one record of the breeding biology of *R. akroparallagi* (Biju & Bossuyt 2009). Apart from this, these are the only known records of some of the reproductive life-history traits of the other three species of bush frogs.

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SHORT COMMUNICATION

A first record of *Camacinia harterti* Karsch, 1890 (Odonata: Libellulidae) from Arunachal Pradesh, India

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Abstract: The large forest dwelling libellulid dragonfly *Camacinia harterti* Karsch, 1890 is recorded from Arunachal Pradesh and India for the first time in 115 years. The present record is based on a single male specimen collected from Namdapha Tiger Reserve, Arunachal Pradesh, India. We provide detailed diagnostic characters in photographs and information on the global distribution of the species.

Keyword: Eastern Himalaya, Namdapha Tiger Reserve, new record, northeastern India, Odonata.

The genus *Camacinia* Kirby, 1889 (Libellulidae) includes three known species globally, viz.: *Camacinia gigantea* Brauer, 1867, *Camacinia harterti* Karsch, 1890, and *Camacinia othello* Tillyard, 1908 (Schorr & Paulson 2019). Species of *Camacinia* are found from southeastern Asia to the Solomon Islands, northern Australia, and New Guinea. Among the three species, *C. othello* occurs in New Guinea, Aru Islands, Solomon Islands, and northern Australia (Kalkman 2009). *C. gigantea* is widely distributed, ranging from India to Vietnam and southwards to New Guinea (Sharma 2010) and *C. harterti* is recorded from southern China, Sumatra, peninsular Malaysia, Borneo, and Thailand (Wilson & Dow 2013). Until recently *Camacinia* was considered to be represented by one species In India, *C. gigantea* (Fraser 1936; Subramanian & Babu 2017), however, Wilson (2018), synonymized *C. harmandi* Martin, 1900 with *C. harterti*, as proposed by Ris (1913), thus adding Martin's (1900) record from Sikkim to the historical distributional range of *C. harterti*.

Here, we report for the first time the occurrence of *C. harterti* Karsch, 1890 from Arunachal Pradesh in northeastern India, based on a single male specimen. We also provide updated global distribution of the species and detailed additional description of the specimen along with photographs.

Materials and Methods

A single male specimen was collected from Namdapha Tiger Reserve in Arunachal Pradesh. Field photographs of the individual were taken using a Nikon

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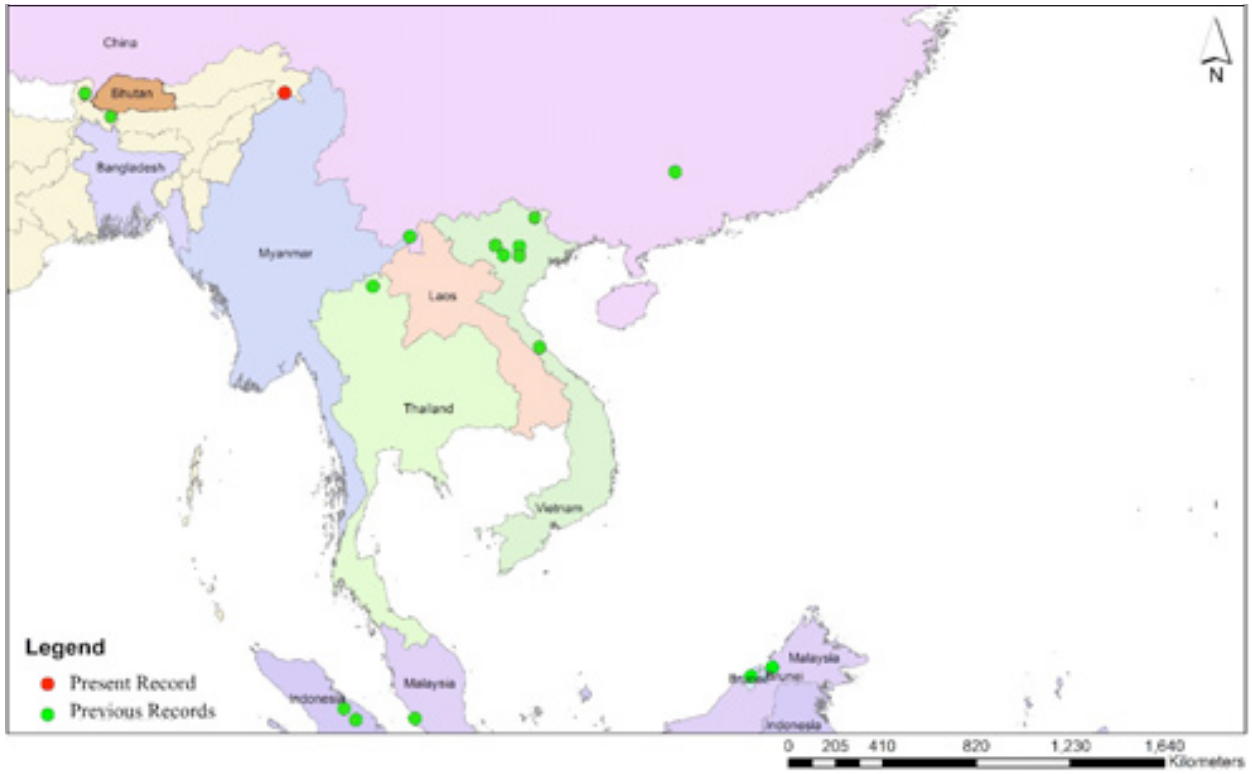

Figure 1. Distribution of *Camacinia harterti* Karsch, 1890.

P900 camera. The geo-coordinates of the collection locality was recorded using a Garmin (E-trex 30) GPS. The length of the different parts of the specimen was measured by using a digital vernier calliper. Photos of anal appendages and secondary genitalia of the collected specimen were taken using a Leica S8APO with MH120 HD camera. The specimen is deposited in the National Zoological Collection of the Zoological Survey of India, Kolkata.

Results

Camacinia harterti Karsch, 1890 (Image 1 A–F)

Material examined

ZSI 7806/H13, 1 male, Loc. Near Deban, Namdapha Tiger Reserve, Changlang District, Arunachal Pradesh, India (27.493°N & 96.376°E, 410m), 23.vi.2017, coll. Arajush Payra & Atum Rumdo.

Detailed description of male and measurements

Length (in mm): abdomen + anal appendages – 41; forewing – 49.8; hindwing – 48.5.

Head: dorsal side of eyes encircled with maroon and rest of the eyes brownish to pale blue with small black blotches. Oceili white; vertex coppery; frons and post clypeus orange fading to yellow. Anteclypeus yellowish to brown, with a narrow horizontal yellow line above. Labrum orange; labium matt yellow.

Thorax: area of humeral suture broadly brownish; mesepisternum to metepimeron orange to matt yellow.

Legs: coxae and trochanter brownish-orange in all legs. Posterior of femora in first pair coppery and remaining segments are black.

Wing: hyaline; pterostigma black, covering 2.5 cells. Nodal index in forewing: 14–17/16–13; hindwing: 17–13/ 12–16. One cubital nerve in forewing and two in hind wing. The discoidal cell of fore wing three-celled and in hind wing two-celled. Single row of cell between IR3 and Rspl. The base of forewing was tinted with dark brown to golden yellow. Subcostal space and cubital space with blackish-brown streaks. The base of hindwing was dark brown to golden yellow. Area of subcostal space, cubital space, up to discoidal cell tinted with dark brown to black. Posterior to cubital space, discoidal cell, area of tornus and anal loop tinted with golden yellow.

Abdomen: S1 to S3 light yellow; S4 light orange above and yellowish bellow; S5 to S9 bright red; S10 brownish to black with an orange patch on dorsum. Epiprocts dark brown, as long as S9; paraprocts orange as seen in dorsal view, more than half the length of epiprocts. Anterior lamina of secondary genitalia black to brown; orange rounded hamule lobe with blackish apex. Genital lobe

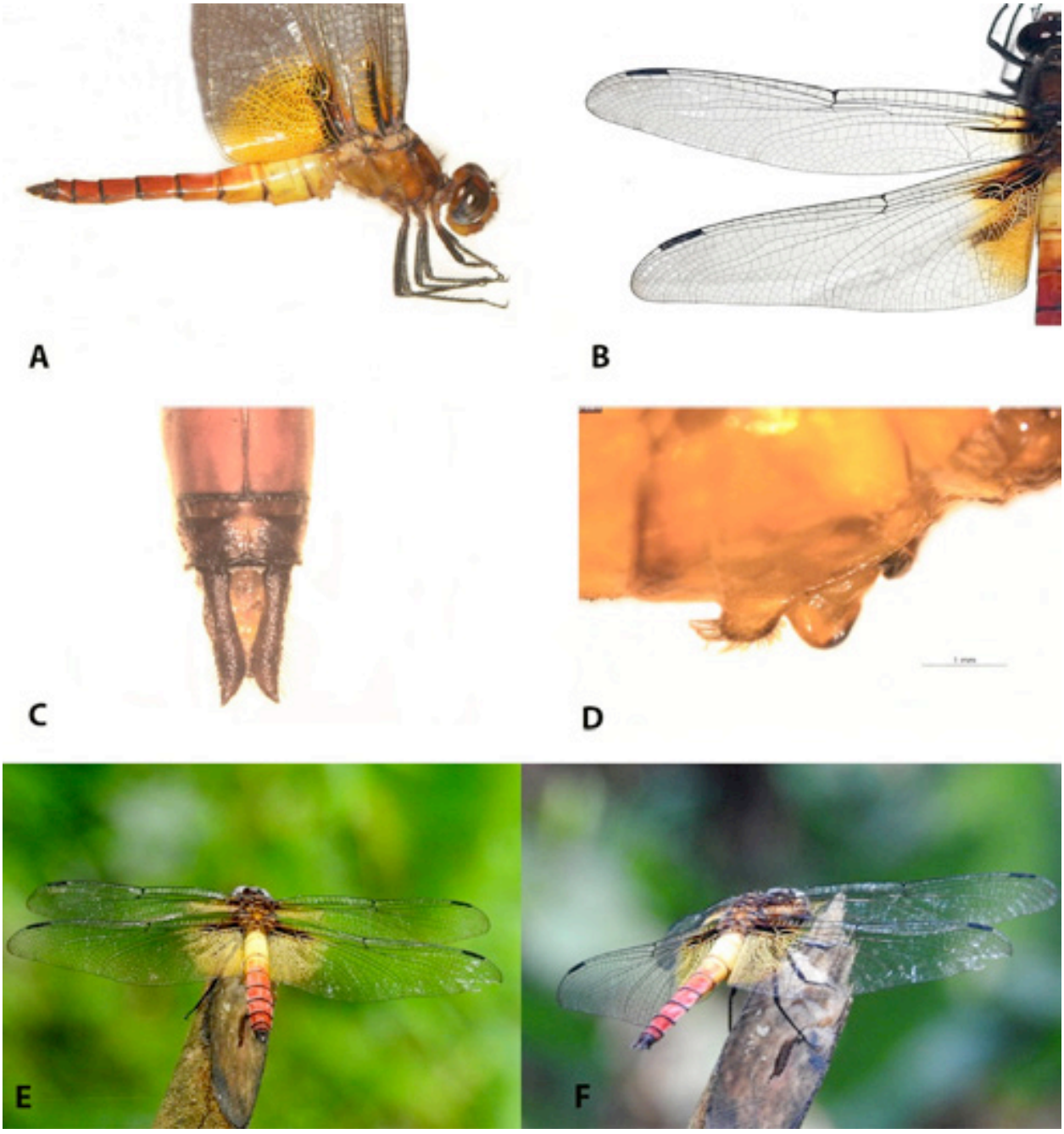

Image 1. *Camacinia harterti* Karsch, 1890: A—Lateral view of male | B—Wing venation | C—Anal appendages in dorsal view | D—Secondary genitalia | E & F—Habitus of male. © Arajush Payra.

orange with hairy apical part black.

Observation and Habitat

On 23 June 2017, during our visit to Deban (Namdapha Tiger Reserve), a single male individual was sighted along the road (Figure 1) about 70m distant from a nearby stream (Noa-Dihing River). It was perched on the tip of a tree branch about 1.5m above the ground. During our first attempt at capture, it flew upwards and away. After 20–30 seconds of flight, it returned to the same perch. The place where the individual was observed was a tropical wet evergreen forest with significant canopy cover (Champion & Seth 1968) (Image 2 A–B).

Discussion

C. harterti was described from Sumatra based on a female collected from Batu Sankahan in Deli Serdang

Table 1. Distribution records of *Camacinia harterti* in southern and southeastern Asian countries.

Country	Localities	Number of Individuals collected/observed, Sex/ life stage and date of collection/observation	Reference
India	Sikkim	One male	Martin (1900)
	Buxa tiger Reserve, West Bengal	One female (31.iii.2018)	Anonymous (2019)
	Namdapha Tiger Reseve, Arunachal Pradesh	One male (23.vi.2017)	Present study
Indonesia	Batu Sankahan of Deliserdang District, Sumatra	One female	Karsch (1889)
	Balimbingan, Deli of northeastern Sumatra	One female	Lieftinck (1954)
Brunei	Lake Merinbum, Brunei Darussalam	One female during the 1990s	Orr (2001)
China	Henglongbei, Nanling National Forest Park, northern Guangdong	One male (28.vi.2000)	Wilson & Dow (2013)
	Xishuangbanna National Nature Reserve, Yunnan Province	One male (May 2016)	Zhang (2017)
Vietnam	Tonkin, northern Vietnam		Martin (1904)
	Tam Dao National Park, Vinh Phuc Province	One male (14.iv.2009); one male (01.vi.2016)	Do (2014); Kompier (2018)
	Xuan Son National Park, Phu Tho Province	One male (31.v.2014)	Kompier (2015)
	Phu Tho Province	Two adults (08.vi.2018); one adult (27.v.2017); one adult (31.vii.2017); one male (29. v.2016); two adults (30.v.2015); one male (18.iv.2015); one male (31.v.2014)	Kompier (2018)
	Quang Binh Province	One male (15.v.2017); two adults (20.v.2016); one adult (30.iv.2016)	Kompier (2018)
	Yen Bai Province	One adult (10.vi.2018)	Kompier (2018)
	Cao Bang Province	One male (03.vi.2016)	Kompier (2018)
Thailand	Chiang Rai	One male individual in 2003 and one male in 2004	Katatani et al. (2004)
Malaysia	Selangor of peninsular Malaysia	One male	Ris (1913)
	Mt. Marapok in Sabah, near the Sarawak border, Borneo	One male and one female	Ris (1913)

District by Karsch (1890). A female was observed ovipositing a phytotelm in the base of a tree root by Raymond Straatman at Balimbingan, Deli in northeastern Sumatra (Lieftinck 1954). In Borneo, this species was recorded by Ris (1913) and Orr (2001). Ris (1913) also reported it from Selangor in peninsular Malaysia. In northern Thailand, *C. harterti* was reported by Katatani et al. (2004). In Vietnam, several individuals were reported mainly from northern Vietnam by Do (2014); Tom (2015) and (Tom 2018) between 2014 and 2018. In China the species was reported by Wilson & Dow (2013) and recently by Zhang (2017) (See Table 1 for global distributional records of *C. harterti*).

In India *C. harterti* was first listed by Fraser (1920) from Sikkim and Bengal, but, later in "The Fauna of British India" series Fraser (1936) excluded *C. harteri* from Indian fauna and stated that the record of *C. harterti* from Sikkim was erroneous. Therefore, *C. harteri* has not generally been included in Indian fauna (Mitra 2004; Subramanian & Babu 2017); however, Wilson (2018), after reviewing all the published literature pertaining to the records of *C. harterti*, validated the synonymy of *C. harmandi* with *C. harterti* as proposed by Ris (1913), and added both Martin's (1900, 1904) records from Sikkim, India and Tonkin, northern Vietnam to the historical distributional range of *C. harterti*. Wilson (2018) also stated that, the record of *C. harterti* by Fraser (1920) from Bengal may be accurate as the northern limits of Bengal are continuous with Sikkim. But due to the lack of evidence regarding the details of involved specimens, Wilson (2018) excluded Bengal, from the historical range of *C. harteri*; however, the recent record of a female *C. harterti* from Buxa Tiger Reserve of West Bengal on 31 March 2018 by Dattaprasad Sawant (Anonymous 2019) supports Fraser's (1920) record from Bengal (see Table 1 for global distributional records of *C. harterti*).

Our present record of *C. harterti* from Namdapha Tiger Reserve of Arunachal Pradesh, India represents

Image 2. The habitat where *C. harterti* was recorded on 23 June 2017 (A & B). © Arajush Payra

its third known locality in the country. The present record also provides new data vital to update the threat status of the species, as the species is currently treated as rare and insufficiently known (Wilson & Dow 2013; Wilson 2018). This discovery also points to the fact that northeastern India is still underexplored with respect to Odonata fauna and extensive surveys are required to document the rich biodiversity of the region.

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SHORT COMMUNICATION

Occurrence of *Fulgoraecia* (= *Epiricania*) *melanoleuca* (Lepidoptera: Epipyropidae) as a parasitoid of sugarcane lophopid planthopper *Pyrilla perpusilla* in Tamil Nadu (India) with brief notes on its life stages

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Abstract: Seasonal incidence of sugarcane planthopper *Pyrilla perpusilla* Walker (Hemiptera: Lophopidae) and its natural enemies was investigated at Cuddalore District, Tamil Nadu during 2018. In this study, *Fulgoraecia melanoleuca*, a parasitoid of sugarcane planthopper *Pyrilla perpusilla* was observed in large numbers in the field. Brief notes on its biology, life stages, and extent of parasitism on the host were studied. Per cent parasitization in nymph and adult was 47.54 and 45.09, respectively, during the month of August. High resolution images of all life stages are provided to help in identification.

Keywords: Biology, *Fulgoraecia melanoleuca,* life stages, natural occurrence, *Pyrilla perpusilla.*

Epipyropidae is a small family of ectoparasitic insects belonging to the order Lepidoptera. Their larvae are parasitic on Auchenorrhyncha, especially Fulgoridae and Membracidae (Pierce 1995). The family comprises 40 species worldwide (Heppner 2008), among which *Fulgoraecia* (= *Epiricania*) *melanoleuca* (Fletcher, 1939) is economically very important as an ectoparasitoid of sugarcane lophopid planthopper *Pyrilla perpusilla*.

Fulgoraecia melanoleuca has been reported from India, Sri Lanka, Pakistan, and Bangladesh (Kumarasinghe & Wratten 1996). It has played a major role in the management of the sugarcane *Pyrilla* epidemics (Gangwar et al. 2008). Although it has been recorded in India in 1939 (Fletcher 1939), its biocontrol potential was recognized only during the *Pyrilla* epidemics in Uttar Pradesh and Bihar (Banerjee 1973). In India, incidence of *Fulgoraecia* has been recorded in Maharashtra (Gholap & Chandele 1985), Gujarat (Pawar et al. 1988), Rajasthan (Joshi & Sharma 1989), Odisha (Patnaik et al. 1990), Haryana (Chhillar & Madan 1992; Ahlawat & Kumar 2015), Uttar Pradesh (Tripathi & Katiyar 1998), Punjab (Sanehdeep et al. 2003), Uttarakhand (Kumar et al. 2008) and Chhattisgarh (Patre 2016). In the southern states, *Fulgoraecia* was recorded in Karnataka (Ansari et al. 1989; Hugar et al. 2002) and Andhra Pradesh (Rajak & Varma 2001). It has been considered as a potential biocontrol agent against *Pyrilla* (Chhillar & Madan 1992; Pawar et al. 2002) and extensively used in management of *Pyrilla* (Pawar et al. 2002; Seneviratne & Kumarasinghe 2002; Rajak 2007; Pandey et al. 2008). *Fulgoraecia melanoleuca* has proved its merit in in situ parasitization

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due to high multiplication rate, comparatively shorter life cycle, survival under varied agro-climatic conditions, and good searching ability of its host by larvae (Rajak 2006, 2007). In this paper, we report the natural occurrence of this parasitoid from Cuddalore District of Tamil Nadu, India.

Materials and Methods

During our regular field surveys for collection of parasitic insects from different ecosystems, *F. melanoleuca* was collected from sugarcane *Saccharum officinarum* at Andipalayam Village of Anna Gramam block (11.77N & 79.55E) of Cuddalore District, Tamil Nadu during July and August 2018. The number of egg masses, nymphs and adults of *P. perpusilla* was recorded and these life stages were collected every week and they were kept separately in polythene bags, with the leaves changed as and when necessary and observations made on parasitoid emergence.

From the egg masses collected, parasitized and unparasitized eggs were segregated by their colour (unparasitized eggs being creamy white and parasitized ones dark brown to black) and per cent parasitism was worked out by using the following formula as described by Mishkat & Khalid (2007). Similarly, per cent parasitism of nymphs and adults was worked out. Parasitized nymph (Image 1B) and adults (Image 1C) were differentiated by presence of white cottony cushion on the back and pleural abdominal region of the host, respectively.

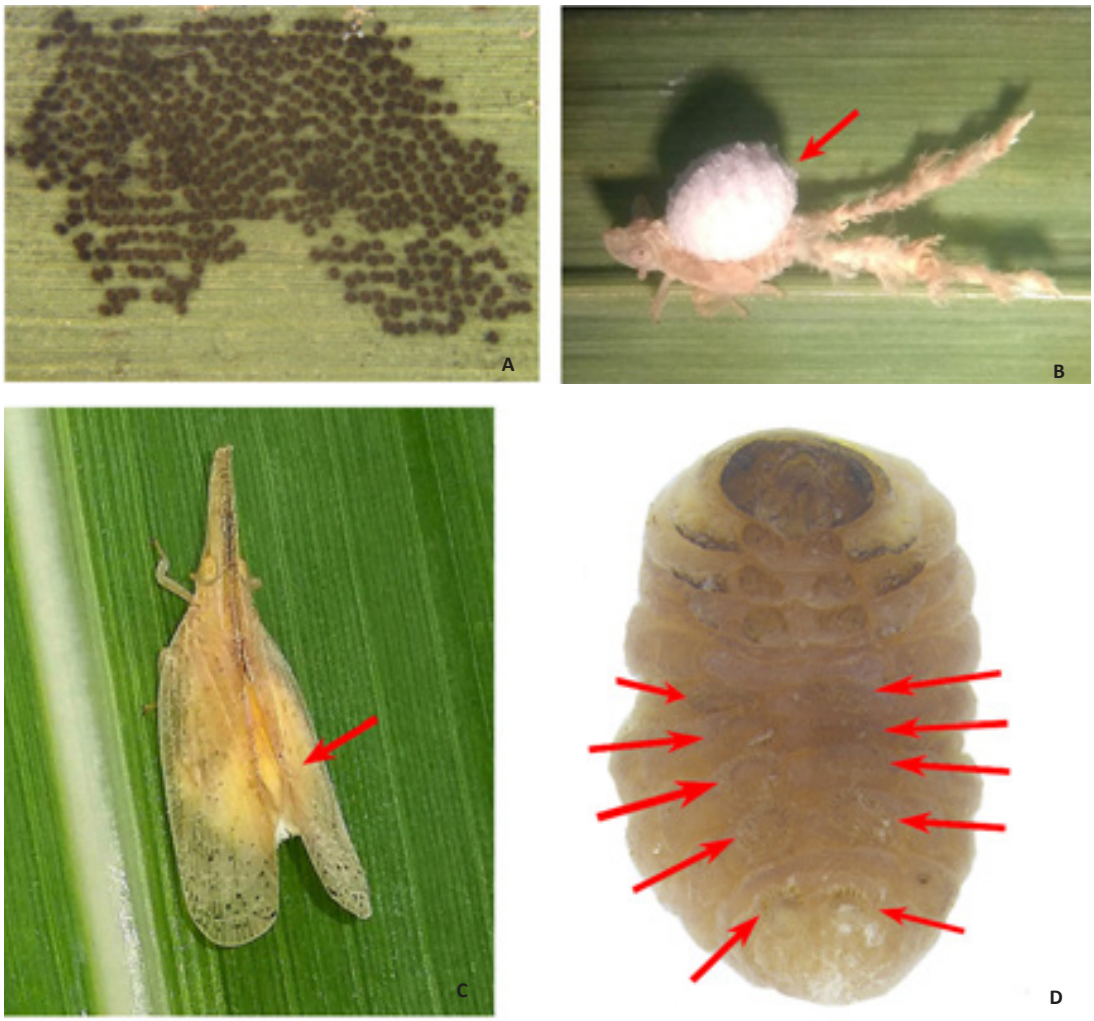

Image 1 A–D. Life stages of *Fulgoraecia melanoleuca*: A—Eggs on the leaves of sugarcane | B—larva developing on *Pyrilla perpusilla* nymph | C—larva developing on adult *Pyrilla perpusilla* | D—Prolegs showing crochets. © H. Sankararaman.

$$\text{Per cent egg/nymph/adult parasitism} = \frac{\text{No. of parasitized eggs/nymphs/adults}}{\text{Total no. of eggs/nymphs/adults}} \times 100$$

The various life stages of *F. melanoleuca* (Images 1 & 2) were also observed.

Results and Discussion

In our observations during July and August, all the three stages of *Pyrilla* recorded higher parasitization during August (34.40%, 47.54%, & 45.09%, respectively, Table 1) compared to July. As per earlier reports by Kumar et al. (2008), the accelerating phase of the *Pyrilla* starts from early July and the population continued to increase at a faster rate from the second fortnight onwards. Accordingly, parasitization also started from July and peaked during August.

Life history of *Fulgoraecia* (*= Epiricania*) *melanoleuca*

Eggs (Image 1A): A trail of dark brown eggs with few silken threads. An adult female lays 240–450 eggs in a batch. The eggs are laid on the abaxial or adaxial surface of the leaf, closer to the midrib. On maturity, the eggs turn pale and larvae hatch out.

Larva (Images 1B, 1C, 1D): Only three instars are observed. Larvae are covered with whitish powdery coating (Image 1B). The first instar is an active wanderer, waits for the host (*P. perpusilla*) to approach and clings to the body of the host (Image 1B). Upon attaching to the abdomen of the host, it starts feeding on its haemolymph, externally (Image 1C). The larvae possess four pairs of abdominal pro-legs with one pair of anal claspers. Abdominal pro-legs have crochets (Image 1D) for helping in adhesion to host. The larva leaves the host before the pupation, and spins a cocoon on the leaf surface.

Pupa (Images 2A, 2B)**:** The cocoons are milky white, elongated, convex anteriorly (Image 2A). Pupa is light brown. Male pupa, short with genital scar in ninth abdominal segment. Female pupa larger (compared to male) with eighth and ninth abdominal segments fused and genital pore is present on the fused segment (Kumar et al. 2015). Anus in tenth abdominal segment of pupa in both the sexes.

Adults (Images 2C, 2D, 2E)**:** Exhibit sexual dimorphism, differences in antennae, hindwing coloration and genitalia. Mouthparts reduced in both the sexes, haustellum absent.

Male: antennae bipectinate, 13-segmented, having long ciliated branches in each segment (Image 2E). Head with grey and thorax with black scales. Fore-wings generally with grey scales entirely, but few specimens with white scales up to discal cell, rest with grey scales. Hind-wings mainly with whitish scales except costal margin with grey scales (Image 2C).

Female: antenna short, bipectinate but with prominently short cilia. Head, thorax and wings unicolorous, covered by grey scales (Image 2D).

All the three stages of *Pyrilla* were parasitized. Eggs were parasitized by undetermined eulophids during July and August up to the tune of 34.40%. No other parasitoid was observed from any life stage of *Pyrilla* during the period of study. Per cent nymphal and adult parasitism by *F. melanoleuca* increased from July to August from 30.88 to 47.54 and 34.04 to 45.09, respectively (Table 1).

The natural parasitization of *Pyrilla* by *F. melanoleuca* has been reported from various states such as Punjab (Sanehdeep et al. 2003), Uttarakhand (Kumar et al. 2008), Haryana (Ahlawat & Kumar 2015), Bihar (Chand et al. 2016), and in southern India from Karnataka (Hugar et al. 2002). Published records of natural occurrence of this parasitoid from the state of Tamil Nadu are scanty but for a mention in the tables of annual reports from Sugarcane Breeding Institute, Coimbatore (Anonymous 2016, 2017). Here we record its natural occurrence from Tamil Nadu with per cent parasitization as stated above, however, the per cent parasitization is reported to the

Table 1. Natural parasitism of *Pyrilla perpusilla* in various life stages by its natural enemies.

Life stages of *P. perpusilla* collected	July 2018			August 2018		
	TC	P	% parasitism	TC	P	% parasitism
Eggs	183	43	23.49	279	96	34.40
Nymph	68	21	30.88	61	29	47.54
Adult	47	16	34.04	51	23	45.09

TC—Total collected | P—Parasitized.

Image 2 A–E. Life stages of *Fulgoraecia melanoleuca*: A—Cocoon on sugarcane leaf | B—cocoon showing pupal exuviae | C—Male | D—Female | E—Male antennae showing long ciliated branches. © H. Sankararaman.

tune of 50.5 to 78.4 from Haryana (Ahlawat & Kumar 2015) and 61.4 from Bihar (Chand et al. 2016). Out of 39 parasitized adults collected in the month of July and August, 31 individuals were females and rest males, from which it is evident that *F. melanoleuca* prefers female *Pyrilla* than males. Similar reports of epipyropids parasitizing more of female hosts have been reported on Lophopidae (Misra & Krishna 1986) and Flatidae (Supeno 2011; Swierczewski et al. 2016), however, the exact sex preferential parasitism of *F. melanoleuca* is not clear and further investigations in this line are required.

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SHORT COMMUNICATION

A preliminary survey of soil nemafauna of Bhagwan Mahaveer Wildlife Sanctuary, Goa, India

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Abstract: Nematological research in India is primarily focussed on major crops and animal parasitic groups, while ignoring free living groups in forest ecosystems. In the present study, soil nemafauna of Bhagwan Mahaveer Wildlife Sanctuary, Goa, India was assessed. A total of 18 genera, 14 families, and five orders were recorded. Among four orders, Dorylaimida was the most dominant one, which consists of 12 genera and nine families. Among the 18 genera *Sicaguttur*, *Qudsinema*, *Microdorylaimus*, *Longidorella*, *Paralongidorus*, *Xiphidorinae*, *Fuscheila* and *Chrysonema* are reported for the first time from the state. More such intensive survey will add more numbers of nematode species.

Keywords: Invertebrate, Nematoda, protected area, underground biota.

Nematodes are one of the important groups of invertebrate in both terrestrial and freshwater ecosystems (Hanel 1999). They are small, worm-like animals (Yeast 1979; Yeast & Bonger 1999), diverse (Ettema 1998), and ubiquitous inhabitants (Bernard 1992; Bloemers et al. 1997; Bonger & Ferris 1999) in nature. A total of 1,000,000 species of nematodes is estimated globally (Hugot et al. 2001); nearly 30,028 species are known. Around 2,900 species of nematodes are identified from India (MoEF 2014) which is 9.66% of the total described species. Nematological research in India predominantly focuses on plant and animal parasitic groups. The parasitic association of nematodes with all the major crops of India has been reported in earlier literature. Little work has been done on the free living groups in forest ecosystems as they do not have a direct connection with agriculture or livestock (Pradhan & Dash 1987; Baniyamuddin et al. 2007; Vaid et al. 2014).

Goa, a small state with an area of 3,702km^2, in the Western Ghats and on the coast of the Arabian Sea, contributes a rich biodiversity (Alvares 2002). Extensive faunal studies, in general, have been done in Goa but the underground biota (Nematoda) has been neglected in most cases. In South Goa District, 52 species of nematodes are reported which is about 0.01% of total species in India (Lizanne & Pai 2014). These sanctuaries are part of the Western Ghats and may incorporate a wide diversity of soil nematodes.

Study Area

Bhagwan Mahaveer Wildlife Sanctuary (Image 1) is a 240km^2 protected area located at 15.319° & 74.288°. It contains several temples and the Dudhsagar Fall. This sanctuary is famous for its snakes particularly the King Cobra. Vegetation is classified as west coast tropical evergreen forests, west coast semi-evergreen forests, and moist deciduous forests (Alvares 2002). The

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Image 1. Bhagawan Mahaveer Wildlife Sanctuary, the study area, in South Goa

predominant species are *Terminalia*, *Lagerstroemia*, *Xylia*, *Strobilanthus*, and *Dalbergia*. The forest canopy is almost closed, pH of soil samples from Bhagwan Mahaveer Sanctuary is slightly acidic (pH6.12) and has high deposits of Phosphorous (88.5 Kg/Ha) and macronutrient viz., Iron (29.908 ppm), Zinc (4.1002ppm), Copper (5.584ppm) and Manganese (29.984ppm) (Soil Testing Laboratory, Ela, Old Goa)

Materials and Methods

Soil collection and processing for nematode extraction and identification was as per Lizanne & Pai (2014) and Vaid et al. (2014). Ten soil samples were collected randomly in a self-sealing plastic bag. Each soil sample comprises 20 sub-samples. These sub-samples were combined to make one composite sample. The soil samples were processed using modified Cobb's sieving and decantation and modified Baermann's funnel techniques for the extraction of nematodes (Ravichandra 2015). A small amount of water suspension from a funnel was drawn into a cavity block through a rubber tubing. The nematodes thus isolated were collected for counting, fixing, and processed for making permanent slides. For counting nematodes, water was added to the extracted nematode suspension to make its volume 25ml. The suspension was stirred thoroughly and then 5ml volume was sucked by a pipette to pour in a Syracuse dish. Counting was done thrice for each sample and finally the mean was calculated. Individuals belonging to a genus were counted separately. Counted nematodes were then killed and fixed in 4% formalin and dehydrated in glycerine-alcohol (Seinhorst 1959). Dehydrated nematodes were mounted in anhydrous glycerine. Permanent slides of the specimens were prepared using paraffin wax ring method and were studied under Olympus BX51 microscope. The identification of nematodes was done consulting relevant literature (Jairajpuri & Ahmad 1992; Lamberti et al. 2002; NEMAPLEX, Nema Species Masterlist).

Results and Discussion

A total of 18 genera, 14 families and five orders of nematodes were reported from Bhagwan Mahaveer Wildlife Sanctuary (Table 1) (provide photographs/ images if available for publication). Among four orders Dorylaimida is the most dominant order (Figure 1) consisting of 13 genera and 10 families followed by Mononchida consisting of two genera and one family. Dominance of order Dorylaimida is due to fewer disturbances in this region. Dorylaims are found in every

Table 1. Soil nematode genera from Bhagwan Mahaveer Wildlife Sanctuary.

Orders	Families	Genera	Feeding type
Dorylaimida	Swangeriinae	*Oxydirus* Thorne, 1939	Plant parasite
	Dorylaimidae	*Dorylaimus* Dujardin, 1845	Omnivore
		Sicaguttar Siddiqi, 1971	-
	Quadsianematidae	*Qudsinema* Jairajpuri, 1965	-
		Microdorylaimus Andrassy, 1986	Omnivore
	Nordiidae	*Longidorella* Thorne, 1939	Omnivore
	Aporcelaimidae	*Aporcelaimium* Loof & Coomans, 1970	Predator
	Actinolaimidae	*Hexactinolaimus* Yeates, 1973	Predator
	Longidoridae	*Longidorus* Micoletzky, 1922	Plant parasite
		Paralongidorus Siddiqi, Hooper & Khan, 1963	Plant parasite
	Xiphinematidae	*Xiphinema*, Cobb, 1913	Plant parasite
	Thornematidae	*Fuscheila* Siddiqi, 1982	-
	Crateronematidae	*Chrysonema* Thorne, 1929	Not known
Tylenchida	Tylenchidae	*Tylenchus* Bastian, 1865	Plant parasite
Alaimida	Alaimidae	*Alaimus* de Man, 1880	Bacterivore
Rhabditida	Rhabditidae	*Mesorhabdtis*	Bacterivore
Mononchida	Monochidae	*Clarkus* Jairajpuri, 1970	Predator
		Monochus Bastian, 1865	Predator

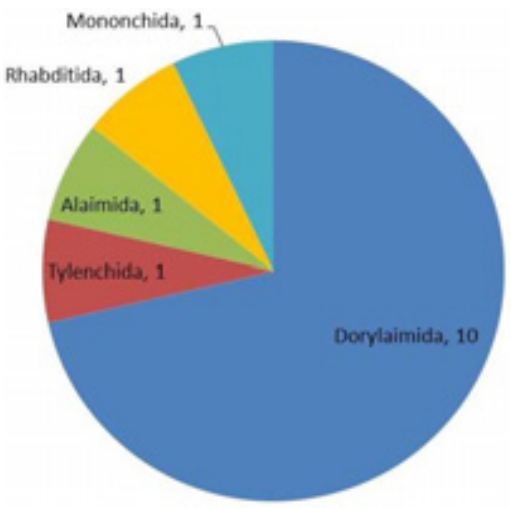

Figure 1. Dominance of orders of soil nematodes

conceived type of habitat and usually dominate both in numbers and in species over all other soil-inhabiting nematodes (Jairajpuri & Ahmad 1992). Dorylaimids and mononchids are more sensitive to disturbance (Forge & Simard 2001), therefore, they are used as indicators of environmental disturbances (Thomas 1978; Sohlenius & Wasilewska 1984). All these 18 genera are reported for the first time from this protected area. Genus *Dorylaimus* Dujardin was the most dominant among all (Figure 2) followed by *Xiphinema* Cobb, *Tylenchus* Bastian, *Longidorus* Micoletzky, and *Longidorella* Thorne. Genera like *Sicaguttur* Siddiqi, *Qudsinema* Jairajpuri, *Microdorylaimus* Andrassy, *Longidorella* Thorne, *Paralongidorus* Siddiqi, *Fuscheila* Siddiqi, and *Chrysonema* Thorne are reported for the first time from the state. Lizanne & Pai (2014) reported 69 species belonging to 48 genera. The addition of these eight genera will take the tally to 56 genera for the state of Goa. On assigning 18 genera to the trophic grouping using secondary data collected (Neher & Weight 2013; Vaid et al. 2014), trophic groups reported were plant parasites, predators, and omnivores (Table 1). Plant parasites were the most dominant (five genera) followed by predators (four genera), omnivore (three genera), and bacterivores (two genera). In terms of number, omnivores dominated the area (Figure 3) followed by predators. According to Vaid et al. (2014), the abundance of predators is uncommon in forest ecosystems and is clearly due to the absence of anthropogenic activities.

Conclusion

This is a preliminary study on this forest, more such intensive survey in the sanctuary will yield more species of nematodes.

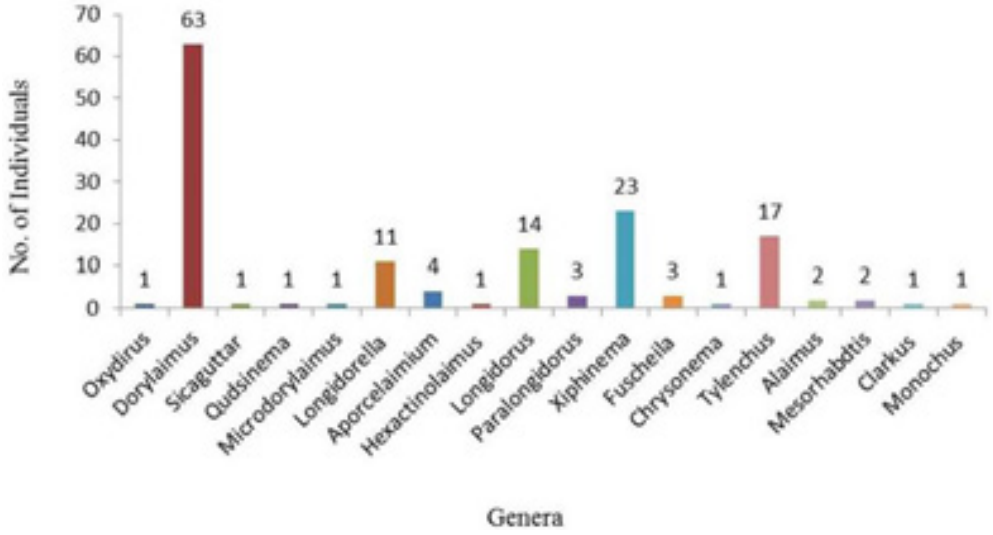

Figure 2. Genera-wise dominance of soil nematodes

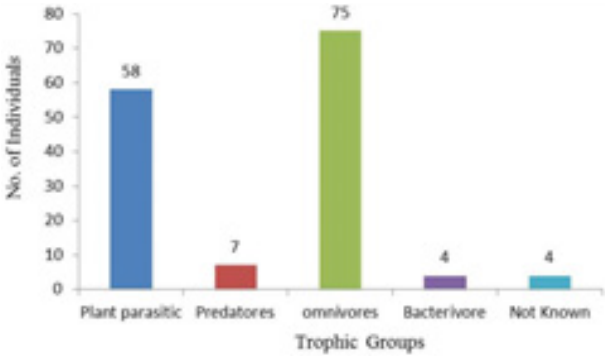

Figure 3. Number of individuals of soil nematodes as per trophic groups

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SHORT COMMUNICATION

Thirty-nine newly documented plant species of Great Nicobar, India

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Abstract: A constituent of the Sundaland Biodiversity Hotspot, Great Nicobar in the Nicobar group of islands, India, is known for rich floristic diversity. As this geographically distinct and southernmost island of India has not been surveyed for plant genetic resources, three survey-cum-exploration trips were undertaken during 2017–2019 to make an inventory of the taxa of importance for food and agriculture, besides their collection for ex situ conservation. These surveys revealed the new distribution of 39 taxa (belonging to 37 genera, 24 families) in this island, including 14 new to the Nicobar group of islands and one to Andaman & Nicobar Islands. Among the 39 taxa, 16 have the importance of being wild relatives of 15 crop species. Fourteen species are classified as naturalized ones (including four globally recognized invasive species); some of them pose potential threat to the ecosystem of this fragile island. Detailed field studies in this remote island will help in better understanding of phytogeography in general and impact of alien species on native plant diversity in particular.

Keywords: Andaman & Nicobar, India, invasive species, new distribution record, Nicobar Islands, plant genetic resources, wild species

Abbreviations: BSI—Botanical Survey of India | PGR—Plant Genetic Resources | ICAR-CIARI—ICAR-Central Island Agricultural Research Institute | ICAR-NBPGR—ICAR-National Bureau of Plant Genetic Resources | ILDIS—International Legume Database and Information Service | NHCP—National Herbarium of Cultivated Plants.

The Great Nicobar Island constitutes the southernmost landmass of India located in the Andaman & Nicobar Archipelago, covering an area of 1,045km^2. It is located at 6.75–7.25 N & 93.61–93.93 E, about 482km south of Port Blair and about 145km north of Sumatra (Indonesia). A constituent of the Sundaland Biodiversity Hotspot, this island experiences humid tropical climate with mean annual temperature of 22–32°C, relative humidity of 82% and rainfall of 3,000–3,800 mm. Rich and unique biodiversity in this island and the need to protect the ethnic tribe (Shompen) made the Ministry of Environment and Forests declare its 85% area as a biosphere reserve in 1989 (Sinha 1999; Gupta et al. 2004). Dense tropical forests, rugged hills, and narrow & flat coastlines are the common features of this island. Major forest types are littoral forests, mangrove forests, lowland swamp forests, mixed evergreen forests (at low altitudes), and evergreen hill forests (high hills, up to 670m at the zenith of Mt Thullier); such a wide range of habitats contributed to the richness of species diversity. By virtue of its location in the tropical Indo-Malayan biotic zone, this island shares phytogeographic affinity with both Malayan and peninsular Indian elements,

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besides exhibiting rare and distinct flora of its own (Palni et al. 2012). According to Sinha (1999), out of a total of 648 plant species occurring on this island, 568 are angiosperms and 13.11% plants are endemic to the island; among the non-endemic plants, 32.25% are not found in mainland India but occur in southeastern Asia. Recently, Jayanthi (2017) reported 729 angiosperm taxa (557 dicots & 172 monocots) belonging to 458 genera and 109 families from the Campbell Bay National Park of Great Nicobar.

K.C. Sahni, the first botanist who explored and collected 180 species from this island since post-independence, aptly commented that "due to high degree of endemism in insular areas, several of the species in the present collection [mentioning about his botanical collection] are likely to be new and there is every reason to believe that future collectors will be amply rewarded by new and interesting types that might be of economic importance" (Sahni 1953). As he rightly predicted, about 729 angiosperm taxa have been reported from this pristine island (Jayanthi 2017), which comprised not less than 25 new taxa and several new distribution records for the flora of Andaman & Nicobar Islands and for the country as well, including species belonging to economically important genera—*Musa*, *Mangifera*, *Calamus*, *Jasminum*, *Dendrobium*, *Aerides*, and *Etlingera*. The Botanical Survey of India, Kolkata conducted several field trips in this biodiversity-rich island from 1960s onwards (Thothathri et al. 1973; Balakrishnan et al. 1989; Sinha 1999; Jayanthi 2017) and brought out several floristic novelties. In the Flora of Great Nicobar, Sinha (1999) mentioned that about 80% area of this island was extensively as well as intensively explored, while the remaining 20% area was inaccessible and unexplored, indicating the need for further systematic exploration. During our expedition aimed at collecting PGR of agri-horticultural importance, we came across many plant species hitherto not reported from this diversity-rich island, which forms the core of this communication.

Materials and methods

As a preparatory phase of the expedition, a preliminary study of herbarium collections of species of PGR value from Great Nicobar was made at the BSI Andaman & Nicobar Regional Centre, Port Blair (PBL). Three survey-cum-exploration trips mainly covering eastern and northern parts (Figure 1), were undertaken during March 2017, January 2018 & 2019, spanning over 45 working days. The first exploration was intended for capturing crop diversity of revenue/private land areas while the second and third trips were meant exclusively for collecting PGR from forest areas. While herbarium vouchers were deposited in the NHCP at ICAR-NBPGR, New Delhi, germplasm collections (of taxa of PGR value) are being conserved in the form of seeds/live plants at ICAR-NBPGR, New Delhi/Thrissur and/or ICAR-CIARI, Port Blair. All the available literature was taken into account to ascertain new distribution status of particular taxa. For establishing their new occurrence in the Nicobar group of islands, literature like Alappatt (2017); ILDIS (2006); WCSP (2019); Pandey & Diwakar (2008) were cross-checked.

Results and Discussion

PGR expedition in Great Nicobar revealed the distribution of 39 plant taxa belonging to 37 genera, 24 families so far not reported from this southernmost island of India (Image 1), including 14 new records to the Nicobar group of islands and one (*Dichondra micrantha* Urb.) to Andaman & Nicobar Islands. Table 1 listed these taxa along with locality/herbarium/germplasm collection details, distribution (India and world), habit, habitats, PGR value and other remarks. Herbs (19) predominate in the list, followed by climbers and shrubs (8 each) and trees (4). Perusal of 24 wild species newly documented from this island (taxa denoted with 'a' in Table 1) indicates their ecogeographic and phytogeographic affinities to Malesian as well as Indian elements.

Out of 39 taxa, 14 are naturalized species including four globally recognized invasive ones posing red alert to the ecosystem of this fragile island. About two-third of such naturalized species is originally native to tropical America. Increasing human activity, besides dispersal through ocean currents, wind, and birds, explains the species movement from adjoining islands and nearby mainlands (Mahanand et al. 2017). The naturalized species, *Hyptis capitata* Jacq., as documented by Sinha (1999) and Jayanthi (2017) has now become invasive. Species like *Canna indica* L., *Ceiba pentandra* (L.) Gaertn., and *Gliricidia sepium* (Jacq.) Walp. have escaped from cultivation, and will soon get naturalized. All these indicate that there is an urgent need for an ecological study on the impact of invasive and naturalized species over native plant diversity. Among the 39 taxa, 16 have importance as wild relatives of 15 crop species, including Black Pepper, Brinjal, Okra, Sugarcane, Kodo Millet, and Jute.

Dagar & Singh (1999) in their enumeration of plant wealth of the Andaman & Nicobar Islands did not specifically mention the occurrence of *Amaranthus spinosus* L., *Barleria prionitis* L., *Crotalaria pallida* Aiton,

Figure 1. Areas surveyed (in yellow spots) in Great Nicobar

Flemingia strobiliifera (L.) R.Br. ex W.T.Aiton, *Hyptis suaveolens* (L.) Poit., *Senna occidentalis* (L.) Link, *S. tora* (L.) Roxb., *Sida rhombifolia* L., and *Solanum nigrum* L. in Great Nicobar Island, which have now been collected. The contemporary floristic literature (Sinha 1999) and subsequent work (Jayanthi 2017), however, didn't mention the same.

Twenty years back, Sinha (1999) reported a rare occurrence of *Rhopaloblaste augusta* (Kurz) H.E.Moore, *Macaranga nicobarica* N.P.Balakr. & Chakrab., *Dioscorea glabra* Roxb., and *Garcinia nervosa* Miq., but we found good populations of these species, the former two towards Galathea riverside and the latter two throughout. Further, he mentioned that *Mangifera nicobarica* Kosterm. had not been collected after its type (specimen) collection. We, however, found about 50 trees, especially along Galathea riverside and towards Mt Thullier. Our observation corroborates with Kothamsi et al. (1995), who mentioned a plant community of *Mangifera nicobarica-Terminalia bialata* at Galathea part. We confirm the occurrence of *Piper clypeatum* Wall., mentioned by Sinha (1999) as species of doubtful existence. Though observed (through photographic records), we refrain from reporting distribution of

Table 1. Angiosperm taxa recorded newly on Great Nicobar Island.

	Family	Taxon name	Locality & herbarium/ germplasm collection details	Distribution (India; World)	Habit	Habitat	PGR value & other remarks
1	Amaranthaceae	*Amaranthus hybridus* L.[b]†	Campbell Bay 2762 (NHCP23123), 26.i.2018, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Himalaya and southern Indian hills; native to Mexico and North America, now naturalized worldwide	Annual herb	Rare along roadsides	Wild relative of grain amaranth crops
2	Asteraceae	*Parthenium hysterophorus* L.[c]	Sastry Nagar to Galathea, Campbell Bay 2827, 14.i.2019, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Throughout; native to tropical America, now pantropic	Annual herb	Rare weed as of now along roadsides	---
3	Boraginaceae	*Cordia dichotoma* G.Forst[b]	Campbell Bay, Joginder Nagar 2828, 14.i.2019, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Throughout; tropical Asia, Australia and Pacific Islands	Small tree	Man-made roadside plantation; also self-sown	Minor fruit
4	Boraginaceae	*Ehretia microphylla* Lam.[a]	Campbell Bay, Sastry Nagar 2816, 14.i.2019, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Peninsular India, Andaman Islands; Eastern & southeastern Asia and Australia	Shrub	Escaped from cultivation	Used as hedge; ornamental
5	Campanulaceae	*Hippobroma longiflora* (L.) G.Don[b]	Campbell Bay, Kamal Basti 2801, 16.i.2019, Kamal Basti, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Andaman & Nicobar Islands; a native of Caribbean Islands, established as weed elsewhere	Herb	Roadside weed	Ornamental value
6	Clusiaceae	*Garcinia speciosa* Wall.[a]†	Afra Bay AJJPN/19-169 (live collection), 21.i.2019, Afra Bay.	Andaman & Nicobar Islands; Myanmar and Thailand	Large tree	Rare in littoral forests	Preferred edible fruit species, related to mangosteen
7	Convolvulaceae	*Dichondra micrantha* Urb.[b]	Campbell Bay 2795, 16.i.2019, Campbell Bay, Coll. K. Pradheep & K. Joseph John.	Tropical areas; North & South America, Pacific Islands, naturalized elsewhere	Prostrate herb	Lawn weed	New to Andaman & Nicobar Islands
8	Convolvulaceae	*Stictocardia tiliifolia* (Desr.) Hallier f.[a]* (Image 1A)	Galathea 2802, 12.i.2019, Galathea, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Almost throughout; southern & southeastern Asia, Tropical America, Pacific Islands	Perennial climber	Seashore thickets and forests	Ornamental value
9	Cucurbitaceae	*Trichosanthes pilosa* Lour. (syn. *T. ovigera* Blume)[a]†	Sastry Nagar to Galathea, Afra Bay 2757 (NHCP23118), 19.i.2018, 14 Km from Campbell Bay to Kopenheat E-W road, Coll. K. Pradheep, K. Joseph John & I. Jaisankar; 2759 (NHCP23120), 17.i.2018, Galathea point, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Andaman & Nicobar Islands, northeastern region, West Bengal and Andhra Pradesh; southern, eastern & southeastern Asia	Perennial climber	Occasional in thickets along with *Trichosanthes tricuspidata*	Young twigs are white-hairy
10	Cucurbitaceae	*Trichosanthes tricuspidata* Lour.[a]	Magar nullah, Chingwan, Sastry Nagar to Galathea 2755 (NHCP23116), 17.i.2018, Galathea (mouth point), Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Andaman & Nicobar Islands; southeastern Asia	Perennial climber	Rare along forest openings	---

	Family	Taxon name	Locality & herbarium/ germplasm collection details	Distribution (India; World)	Habit	Habitat	PGR value & other remarks
11	Dioscoreaceae	*Dioscorea bulbifera* L.[a]*†	Navy Dera, 12–17 km on East-West Road, Govind Nagar, Galathea JP/17-23 (live collection), 05.iii.2017, Govind Nagar; JP/17-34 (live collection), 06.iii.2017, Vijay Nagar; JPJ/18-108 (live collection), 27.i.2018, 18 km from Campbell Bay to Kopenheat on E-W road.	Almost throughout; tropical and subtropical Asia & Africa	Climber	Occasional in inland as well as coastal areas	Cultivated elsewhere; wild form
12	Ebenaceae	*Diospyros undulata* Wall. ex G.Don[a] (Image 1B)	Chingwan 2794 (AJJPN/19-190), 25.i.2019, Chingwan, Coll. K. Pradheep, K. Joseph John.	Andaman & Nicobar Islands; Indo-China to peninsular Malaysia	Shrub	Rare in littoral forests	Edible fruit
13	Euphorbiaceae	*Ricinus communis* L.[b]†	Campbell Bay JP/17-06 (live collection), 04.iii.2017, Campbell Bay.	Throughout India; native to northeastern tropical Africa, naturalized elsewhere	Small shrub	Common in (human) disturbed areas	Oilseed value; weedy form
14	Fabaceae	*Calopogonium mucunoides* Desv.[b]*	Gandhi Nagar, Sastry Nagar 2488 (NHCP23110), 04.iii.2017, Joginder Nagar, Coll. K. Pradheep & K. Joseph John.	Kerala, Tamil Nadu, Karnataka, Odisha, Andaman Islands; native to tropical America, naturalized elsewhere	Twining or procumbent climber	Spreading fast in disturbed areas	Cover crop elsewhere
15	Fabaceae	*Crotalaria retusa* L.[a]*	Campbell Bay 2482 (NHCP23014), 08.iii.2017, Campbell Bay, Coll. K. Pradheep & K. Joseph John.	Throughout; tropical Asia, naturalized elsewhere	Erect herb	Rare on roadsides	---
16	Fabaceae	*Indigofera tinctoria* L.[a]	Joginder Nagar, Sastry Nagar JP/17-39 (IC623181; live collection; NHCP23001), 06.iii.2017, Sastry Nagar.	Throughout; tropical Asia & Africa	Highly branched subshrub	Rare on roadsides	Medicinal-cum-dye-yielding plant
17	Fabaceae	*Mimosa diplotricha* C.Wright[c]*	Joginder Nagar, Laxmi Nagar 2813, 12.i.2019, Laxmi Nagar, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Karnataka, Kerala, Tamil Nadu; native to tropical America, naturalized elsewhere	Scandent herb	Occasional in thickets and field boundaries	---
18	Fabaceae	*Prosopis juliflora* (Sw.) DC.[c]	Campbell Bay, Joginder Nagar 2808, 16.i.2019, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Almost throughout; native to Mexico and tropical America, naturalized elsewhere	Tree	Rare; now located only in two places	---
19	Fabaceae	*Pueraria phaseoloides* (Roxb.) Benth. var. *javanica* (Benth.) Baker[b]*	Almost all motorable areas 2485 (NHCP23016), 08.iii.2017, Sastry Nagar, Coll. K. Pradheep & K. Joseph John.	Kerala, Tamil Nadu, Uttar Pradesh, Andaman Islands; southeastern Asia	Climber	Very common along thickets	Introduced cover crop
20	Fabaceae	*Senna hirsuta* (L.) H.S.Irwin & Barneby[b]*	Campbell Bay 2823, 14.i.2019, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Throughout; native to tropical America, naturalized elsewhere	Erect subshrub	Rare in disturbed areas	---
21	Fabaceae	*Smithia sensitiva* Aiton[a]	Gandhi Nagar 2788, 12.1.2019, Gandhi Nagar, Coll. K. Pradheep & K. Joseph John.	Throughout India; southern & southeastern Asia	Annual herb	Common in coastal plains	Forage value

	Family	Taxon name	Locality & herbarium/ germplasm collection details	Distribution (India; World)	Habit	Habitat	PGR value & other remarks
22	Fabaceae	*Vigna adenantha* (G.Mey.) Marechal et al.[a]*† (Image 1C)	Campbell Bay, Vijay Nagar 2494 (NHCP23020; JP/17-56), 04.iii.2017, Vijay Nagar, Coll. K. Pradheep & K. Joseph John; 2774 (NHCP23135), 28.i.2018, Campbell Bay beach, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Almost throughout; tropical Asia & Africa	Perennial climber	Rare in estuaries, lagoons	Wild relative of *Vigna* crops; plants with violet flower
23	Lamiaceae	*Mentha spicata* L.[b]†	Campbell Bay, Govind Nagar, Rajiv Nagar 2480 (NHCP23012), 08.iii.2017, Campbell Bay, Coll. K. Pradheep & K. Joseph John.	Western Himalaya; a native of Europe to China, naturalized elsewhere	Procumbent herb	Common in moist/ marshy places	Cultivated elsewhere as vegetable-cum-aromatic crop
24	Malvaceae	*Abelmoschus moschatus* Medik.[a]*† (Image 1D)	Vijay Nagar, Joginder Nagar 2448 (NHCP23004; JP/17-35), 06.iii.2017, Vijay Nagar, Coll. K. Pradheep & K. Joseph John; 2493 (NHCP23019; JP/17-13), 04.iii.2017, Joginder Nagar, Coll. K. Pradheep & K. Joseph John.	Tropical area; southern & southeastern Asia	Herb	Rare along roadsides and sides of backwaters	Wild relative of okra; leaves characteristically deeply lobed
25	Oleaceae	*Jasminum elongatum* (P.J.Bergius) Willd.[a] (Image 1E)	Chingwan, Sastry Nagar, 17–18 km on East-West Road, Govind Nagar 2492 (NHCP23139), 06.iii.2017, Sastry Nagar, Coll. K. Pradheep & K. Joseph John; JPJ/18-106 (live collection), 27.i.2018, 19 Km from Campbell Bay to Kopenheat E-W Road.	Northeastern India, Andaman & Nicobar Islands; southern & southeastern Asia, Australia and Pacific Islands	Scandent climbing shrub	Occasional in mixed evergreen forests	Wild ornamental with fragrant white flowers
26	Phyllanthaceae	*Breynia lanceolata* (Hook.f.) Welzen & Pruesapan[a] (syn. *Sauropus rhamnoides* Blume)	Kamal Basti, Chingwan, Galathea, Campbell Bay 2461 (NHCP23010), 07.iii.2017, Campbell Bay, Coll. K. Pradheep & K. Joseph John; 2752 (NHCP23113), 28.i.2018, B-Quarry beach, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar	Andaman & Nicobar Islands; southeastern Asia	Small tree	Rare in open forest areas	---
27	Piperaceae	*Peperomia pellucida* (L.) Kunth[b]	Campbell Bay 2760 (NHCP23121), 19.i.2018, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Assam, Kerala, Karnataka, Maharashtra, Meghalaya, Uttarakhand, Andaman & Nicobar Islands; native to tropical America, naturalized elsewhere	Small herb	Common in disturbed areas and moist field bunds	---
28	Piperaceae	*Piper clypeatum* Wall.[a]† (Image 1F)	Sastry Nagar to Galathea, Afra Bay 2756 (NHCP23117; JPJ/18-34), 18.i.2018, 3 Km from Sastry Nagar to Galathea, Coll. K. Pradheep, K. Joseph John & I. Jaisankar; JPJ/18-85 (live collection), 23.i.2018, Afra Bay; AJJPN/19-99 (live collection), 13.I.2019, Way to Indira Point.	Nicobar Islands; Malaysia and Indonesia	Creeper	Rare in mixed evergreen forests	Distant wild relative of black pepper; potential as new foliage ornamental for humid tropics

	Family	Taxon name	Locality & herbarium/ germplasm collection details	Distribution (India; World)	Habit	Habitat	PGR value & other remarks
29	Poaceae	*Paspalum sumatrense* Roth[a†]	Vijay Nagar 2495 (NHCP23161), 04.iii.2017, Vijay Nagar, Coll. K. Pradheep & K. Joseph John.	Tropical and subtropical areas; tropical & subtropical Asia, Australia and Pacific Islands	Herb	Occasional along roadsides	Wild relative of kodo millet
30	Poaceae	*Saccharum spontaneum* L.[a†]	Joginder Nagar, Sastri Nagar to Galathea 2496 (NHCP23021; JP/17-12), 04.iii.2017, Joginder Nagar, Coll. K. Pradheep & K. Joseph John.	Almost throughout; Africa, Asia, and Australia	Perennial herb	Rare in forest edges and roadsides	Wild relative of sugarcane; thin-culmed type
31	Pontederiaceae	*Monochoria vaginalis* (Burm.f.) C.Presl[a*]	Campbell Bay 2767 (NHCP23128), 29.i.2018, Campbell Bay, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Almost throughout; tropical & subtropical Asia, and Australia	Aquatic herb	Occasional in ditches and sewage lines	---
32	Rhamnaceae	*Ziziphus oenopolia* (L.) Mill.[a*†]	Afra Bay, Campbell bay 2797, 15.i.2019, Near Army area, Campbell Bay, Coll. K. Pradheep & K. Joseph John; 2463 (NHCP23108), 10.iii.2017, Campbell Bay, Coll. K. Pradheep & K. Joseph John.	Tropical and subtropical areas; southern & southeastern Asia and Australia	Scandent shrub	Rare in open areas and low-land swampy areas	Wild relative of 'ber'; also found in Little Nicobar
33	Scrophulariaceae	*Bacopa monnieri* (L.) Pennell[a*] (Image 1G)	Campbell Bay, Sastry Nagar to Galathea, Rajiv Nagar 2481 (NHCP23013; JP/17-69), 08.iii.2017, Campbell Bay, Coll. K. Pradheep & K. Joseph John.	Throughout; Africa, Asia, Australia, and North & South America	Procumbent herb	Wetland weed	Medicinal plant cultivated in mainland India; wild/ weedy form
34	Solanaceae	*Solanum sisymbriifolium* Lam.[c†]	Sastry Nagar to Galathea 2754 (NHCP23115), 17.i.2018, Sastry Nagar, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Odisha, West Bengal, Tamil Nadu, Meghalaya, Andaman Islands; native to South America, naturalized in Africa, Asia, and Australia	Thorny annual herb	Occasional along roadsides, especially in sunny sites	Wild relative of brinjal
35	Solanaceae	*Solanum virginianum* L.[a†]	Sastry Nagar to Galathea, Campbell Bay 2444 (NHCP23002), 05.iii.2017, Campbell Bay beach, Coll. K. Pradheep & K. Joseph John.	Almost throughout; Asia	Spiny prostrate herb	Rare weed	Wild relative of brinjal
36	Tiliaceae	*Corchorus aestuans* L.[a*†]	Campbell Bay, Sastry Nagar JP/17-05 (live collection), 04.iii.2017, Campbell Bay; AJJPN/19-184 (IC631166; live collection), Sastry Nagar.	Throughout; pantropical	Annual herb	Occasional in wet areas	Wild relative of jute
37	Verbenaceae	*Vitex trifolia* L.[a*]	Campbell Bay 2449 (NHCP23005), 07.iii.2017, Campbell Bay, Coll. K. Pradheep & K. Joseph John.	Almost throughout; Africa, Asia, Australia, and Pacific Islands	Tall shrub	Hedge plant; also self-sown	---
38	Zingiberaceae	*Curcuma mangga* Valeton & Zijp[a†]	Campbell Bay, Govind Nagar, Rajiv Nagar JP/17-24 (live collection), 05.iii.2017, Rajiv Nagar; JP/17-44 (live collection), 07.iii.2017, Campbell Bay.	Andaman & Nicobar Islands; southeastern Asia (Indonesia)	Herbaceous perennial	Common in disturbed areas	Wild relative of mango-ginger

	Family	Taxon name	Locality & herbarium/ germplasm collection details	Distribution (India; World)	Habit	Habitat	PGR value & other remarks
39	Zingiberaceae	*Hedychium coronarium* J.Koenig[b]	East-West Road, Gandhi Nagar, Sastry Nagar 2811, 14.i.2019, Sastry Nagar, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Throughout India; southern Asia and Indo-China	Herbaceous perennial	Common in disturbed areas	Ornamental value

[a]— wild species | [b]— naturalized species | [c]— invasive species (as per Invasive Species Specialist Group of the IUCN Species Survival Commission) | *—new to Nicobar group of islands also |†—of importance as wild relative of crops.

Image 1. Some new additions to the flora of Great Nicobar. A—*Stictocardia tiliifolia* | B—*Diospyros undulata* | C—*Vigna adenantha* (inset: inflorescence with immature pod) | D— *Abelmoschus moschatus* | E—*Jasminum elongatum* | F—*Piper clypeatum* | G—*Bacopa monnieri*. © K Pradheep.

Zanthoxylum rhetse DC., (in Galathea) and *Panicum repens* L. (in East-West Road) from this island, which needs further confirmation.

Further exploration would warrant many more distribution records to the study area and new yet-to-be described native species, which will help in better understanding of phytogeography as well as ecosystem of this part of Sundaland Biodiversity Hotspot.

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NOTE

An observation of homosexual fellatio in the Indian Flying Fox *Pteropus medius* (Temminck, 1825) (Mammalia: Chiroptera: Pteropodidae)

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Apart from a small number of primate species, bats appear to be unique in the animal world in practising oral sex. These acts include fellatio (Tan et al. 2009; Sugita 2016) and cunnilingus (Maruthupandian & Marimuthu 2013) with observations suggesting that such behaviours are usually carried out between heterosexual pairs to help improve fertilization. In addition to oral sex, bats are unusual in engaging in homosexual acts, the utility of which appear to have generated considerable discussion with no understanding yet as to why bats might engage in such sexual behaviour (Kunz & Hosken 2009). Homosexual behaviour included mounting and jousting, and observations indicate that genital licking was limited to pairs of subordinate males (Riccucci 2011). Homosexual fellatio has been observed in bats but appears to be rare and has been observed only in one species, the Bonin Flying Fox *Pteropus pselaphon* (Sugita 2016). In Indian bats, oral sex has been observed in heterosexual pairs (Maruthupandian & Marimuthu 2013), and homosexual behaviour with males mounting other males has been observed in captivity (see references in Riccucci 2011). Sexual behaviours are poorly documented in Indian bats owing to the difficulty of observing bats that roost in dark spaces making direct observations challenging. In this note, we describe an observation of homosexual fellatio in the Indian Flying Fox *Pteropus medius* (formerly *P. giganteus*).

On 17 March 2020, we visited Nagawli lake beside the village of Nagawli in Chittaurgarh District of southern Rajasthan. A roosting colony of Indian Flying Foxes used large mango trees that bordered the lake and numbered ~ 300 individuals. One pair of bats roosted away from other bats and attracted our attention by their regular jousting. This included beating each other with their patagium, wrestling with the patagium wrapped around each other, and snapping at each other's faces. Between sessions of jousting, one male bat performed repeated acts of fellatio on the second bat (recipient). This included licking the recipient on the scrotum (Image 1a), licking the shaft and tip of the penis (Image 1b), and twice taking the penis into his mouth between episodes of licking the tip (Image 1c). Both bats also licked their own penises intermittently (Image 1d), and the recipient never performed fellatio on the other male bat. The bat performing the fellatio appeared to get aroused starting with a flaccid penis at the beginning of the interaction (Image 1a) and gained a prominent erection within a few seconds (Image 1d). The recipient had an erect penis when interactions began (not photographed) and a flaccid penis after fellatio began (Image 1), however, the recipient did not do anything to stop the fellatio, instead it kept closing its eyes briefly (Image 1b). The two bats also groomed themselves and each other during the interaction that lasted about three minutes (0959 to 1002 h). Observations were disturbed

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Image 1. Series of photographs showing homosexual fellatio performed by a male Indian Flying Fox in Chittaurgarh District, Rajasthan, India. © K.S. Gopi Sundar.

by human activity near the tree that resulted in all the bats taking flight.

Homosexual fellatio has not previously been described in the Indian Flying Fox though a number of published studies are available on the copulatory and other sexual behaviours of this species (Koilraj et al. 2001; Maruthupandian & Marimuthu 2013; Kumar et al. 2017). Male-male fellatio has been observed and described in the closely related Bonin Flying Fox, where males licked scrota and the erect penis of other males in the colony (Sugita 2016). Our observation had a few novel features in that only one of the bats performed the fellatio and also gained an erection during the act. Taking the penis into the mouth was also exceedingly unusual and has probably not been observed before in bats. Female-male fellatio appears to be correlated to copulation length signifying a clear function (Tan et al. 2009). Homosexual fellatio, on the other hand, is rare and is suspected to help males resolve aggressive relationships within colonies (Sugita 2016). We echo past assertions that many more behavioural studies are needed on Indian and other bats and will be crucial in enhancing the growing number of suspicions regarding bat socio-biology.

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NOTE

Diurnal observation of a Malayan Krait *Bungarus candidus* (Reptilia: Elapidae) feeding inside a building in Thailand

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In altered habitats, species must face challenges resulting from interactions with humans in a complex landscape mosaic, particularly in agricultural and urban areas (Knoot & Best 2011). Remnant forest fragments, gardens, and other "green spaces" can play a vital role in maintaining species in human-dominated landscapes (McKinney 2006; Hughes 2017). Some fauna capitalize on proximity to humans (Vanderduys & Kutt 2013) by exploiting abundant resources (namely food) among human-modified habitats (Prange et al. 2004). Fauna capable of tolerating human presence are also often involved in human-wildlife interactions, which can lead to injury or death of wildlife or humans (Woodroffe et al. 2005). Here we describe an instance of a potentially dangerous snake, the Malayan Krait *Bungarus candidus*, coming into contact with humans during the pursuit of prey in the early morning inside a building located on a large university campus in Nakhon Ratchasima, Thailand.

Kraits are among the most medically significant snakes throughout their range owing to their behavior and potent venom (World Health Organization 2016). A substantial proportion of human victims are bitten while indoors at night, presumably by kraits which enter habitations in search of prey (Kularatne 2002; Tongpoo et al. 2018). The Malayan Krait *Bungarus candidus* (Linnaeus, 1758) is distributed throughout southeastern Asia. As nocturnal foragers, *B. candidus* feed on a variety of prey including snakes (Kuch 2004), lizards (Slowinski 1994; Siow & Figueroa 2016), amphibians (Grossmann & Schäfer 2000), and small mammals (Kuch 2001). In Thailand, *B. candidus* frequently occurs in human-modified habitats such as agricultural land and rural settlements (Chanhome et al. 2011; Crane et al. 2016; Knierim et al. 2018).

The observation took place on Suranaree University of Technology (SUT) campus in Nakhon Ratchasima, Thailand (Image 1). The campus is ideal for supporting snakes in many green refugia, with 26 forest fragments on the SUT property ranging from 0.45–1.5 ha making it a good study area for assessing human-snake interactions. The university grounds are comprised of a variety of human-modified lands interspersed with degraded secondary dipterocarp forest fragments. Many of the larger buildings at the university contain open-roofed

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Image 1. Satellite imagery of central SUT campus in Nakhon Ratchasima, Thailand. The yellow circle indicates the location where the observation occurred inside a university building (Satellite imagery is from Bing [2019]).

garden areas at the center of their structures. These "green" atriums only measure about 200m^2, however, they typically contain an assortment of flora as well as small, semi-permanent water features, thus providing suitable habitat for a variety of fauna.

In conjunction with an ongoing investigation of *B. candidus* movement at SUT, we offer a free snake-removal and relocation service for "nuisance snakes" found in campus households. As a result, each year since our project began in late 2017 we have been notified about approximately 100 snakes that residents have encountered among their homes, gardens, or university buildings. We have documented a total of 17 snake species which came into contact with humans within our study site through these notifications. Those most frequently removed from buildings include the harmless *Chrysopelea ornata*, *Oligodon fasciolatus*, *Ptyas mucosa*, *Ptyas korros*, *Lycodon capucinus*, *Coelognathus radiata*, and *Python bivittatus*, and the highly venomous *Naja siamensis*, and *Bungarus candidus*. Non-target species are relocated to the nearest suitable habitat upon capture, while *B. candidus* are taken to the laboratory for morphometric data collection, including measuring the weight, snout-vent length (SVL), and tail length (TL), before being released. All rescued snakes are typically released within 100m from the capture location (well within the home range of most species).

At 07.05h on 08 January 2019, campus security contacted our team after a custodian staff member discovered two snakes interacting inside a large laboratory building. We arrived on scene at 07.15h to observe an adult female *B. candidus* (mass = 216.7g, SVL = 91.2cm, TL = 12.7cm) swallowing a small Golden Tree Snake *Chrysopelea ornata* (Shaw, 1802), in the hallway adjacent to the building's garden atrium (14.877°, 102.018°; Image 2). We documented the event from a distance of approximately 10m to avoid disrupting the animal's behavior. At the initial time of discovery the *B. candidus* had just begun to swallow the *C. ornata* head-first. By the time we arrived, the *B. candidus* had nearly completed ingestion of the *C. ornata*, which was unresponsive. The *B. candidus* pulled the prey item further down its esophagus with a series of corresponding side-to-side head and jaw movements,

Image 2. An adult *Bungarus candidus* preying on a *Chrysopelea ornata* in the hallway of a laboratory building on a large university campus in northeastern Thailand.

as is typical feeding behavior in snakes. The prey item was no longer visible at 07.20h, approximately 40min after sunrise. Thereafter, we captured the snake and housed it within a plastic box so it could digest the prey item prior to taking morphological measurements and adding the individual to our ongoing *B. candidus* spatial ecology study. The *B. candidus* regurgitated the partially digested *C. ornata* approximately 24 hours post-ingestion (TL = 22cm).

This observation confirms that *B. candidus* forages for prey around and within buildings. The prey species, *C. ornata*, is known to commonly venture inside human habitations to feed on geckos which congregate there (Pauwels et al. 2003). Likewise, *B. candidus* may also be attracted to human settlements in order to take advantage of potential prey. This possibly increases the potential for snake-human encounters with the risk of life-threatening snakebites, and intentional and unintentional killings of snakes by humans (Ahsan & Rahman 2017; Knierim et al. 2017; Meek 2012). We suggest further investigation into the kraits' use of human settlements, including habitat selection, movement ecology, and human responses to snakes.

We provide evidence that *B. candidus* will occasionally remain active shortly after sunrise when engaged in feeding behavior, as this individual did not begin ingestion of the *C. ornata* until approximately 25min after sunrise. As characteristically nocturnal and highly cryptic snakes, kraits are generally at less risk of being detected by humans than are diurnal snake species (Viravan et al. 1992). As a consequence, diurnal activity in *B. candidus* may lead to more pronounced conflict with humans. Kraits that forage among anthropogenic settlements during the daylight are likely at greater risk of being killed by humans. Similarly, humans are likely to be at greater risk of being bitten by *B. candidus* that are active during daylight. Our finding may help support the statistics of how nearly 27% of 78 reported bites by *B. candidus* in Thailand occurred during daylight hours (Tongpoo et al. 2018).

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NOTE

An additional record of the Tamdil Leaf-litter Frog *Leptobrachella tamdil* (Sengupta et al., 2010) (Amphibia: Megophryidae) from Dampa Tiger Reserve, Mizoram, India

Vanlalsiammawii [1], Remruatpuii [2], V.L. Malsawmhriatzuali [3], Lalmuansanga [4], Gospel Zothanmawia Hmar [5], Saisangpuia Sailo [6], Ht. Decemson [7], Lal Biakzuala [8] & H.T. Lalremsanga [9]

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Among anurans, family Megophryidae consists of 251 species with two subfamilies, of which the subfamily Leptobrachiinae is the largest with 154 species under four genera. The Tamdil Leaf-litter Frog belongs to the genus *Leptobrachella* Smith, 1925, which includes 75 species known to be distributed from southern China, northeastern India, Myanmar through Thailand, Vietnam to Malaya, Borneo, and Natuna Island (Frost 2020). *Leptobrachella tamdil* was described by Sengupta et al. (2010) as Leptolalax tamdil on the basis of two specimens collected from Tamdil National Wetland, Mizoram, northeastern India on the 19 April 2007. After its description, many herpetological surveys did not yield additional specimens from the type locality and its surrounding habitats (Lalremsanga et al. 2015; Lalropeki 2018; Lalbiakzuala & Lalremsanga 2019). The species remains known only from its type locality for more than a decade. This paper presents a third specimen of *L. tamdil* which was rediscovered from Dampa Tiger Reserve, Mamit District, Mizoram.

Dampa Tiger Reserve, the largest protected area in Mizoram is located in Mamit District along the international border with Bangladesh. It covers an area of ca. 500km^2 (23.387–23.705 ^{0}N & 92.273–92.431 ^{0}E) and lies in the western part of Mizoram. It has remained one of the least explored areas of northeastern India and till date, very few studies have been taken up to record its faunal richness. During herpetological collections for an inventory 14 February 2020, an individual, adult male frog was collected from Tuilut Stream (23.697^{0}N & 92.371^{0}E, 449m) at around 19.15h ca. 59km west of the type locality. The collected specimen (MZMU–1631) is preserved in 70% ethanol and catalogued in the Departmental Museum of Zoology, Mizoram University, Aizawl, Mizoram, India. Careful observation of the specimen revealed it to be the Tamdil Leaf-litter Frog *Leptobrachella tamdil* (Sengupta et al. 2010). The morphometric measurements were taken with Mitutoyo (505-730 D15TX) dial callipers and are given to the nearest 0.1mm. The sex was determined through

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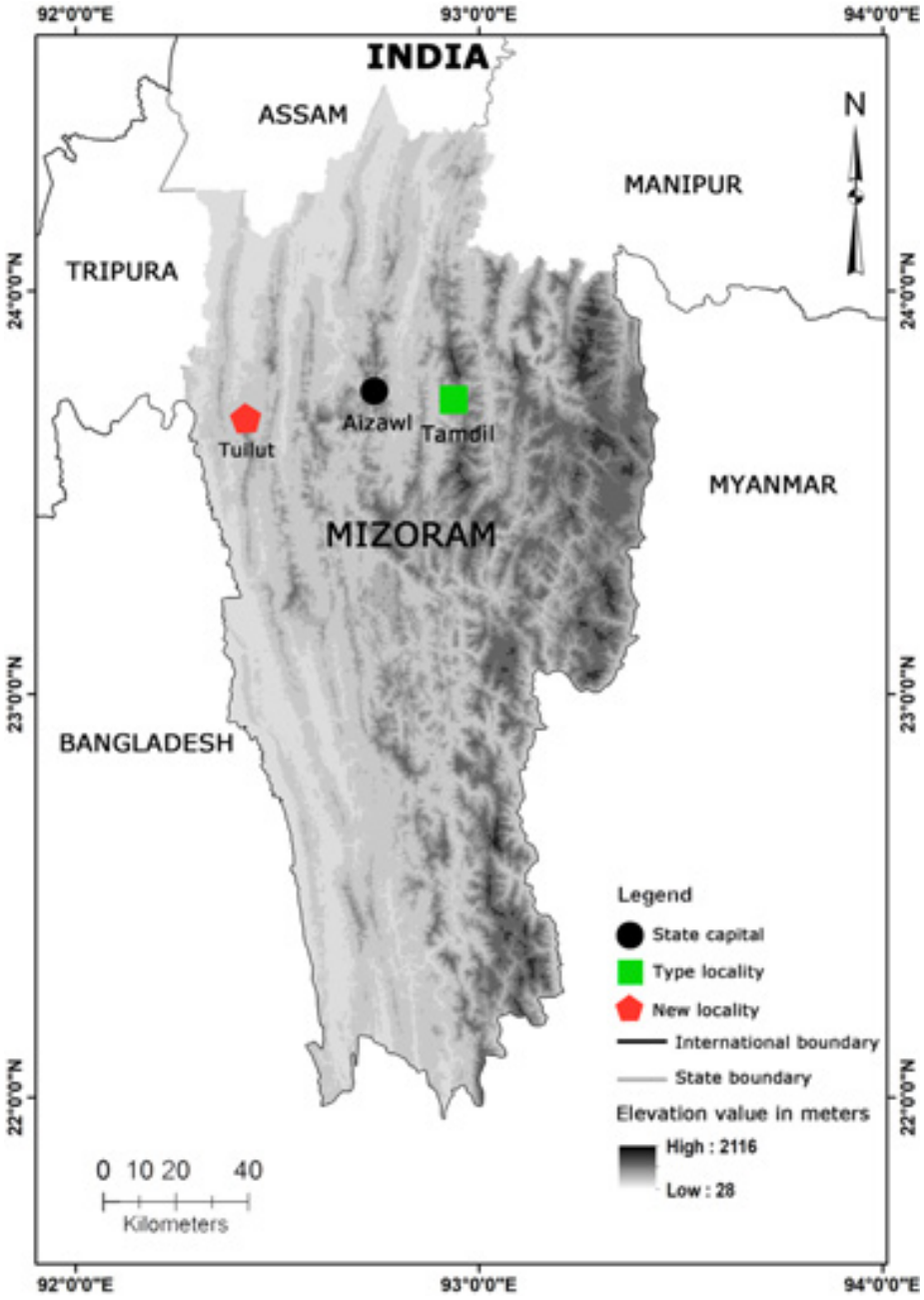

Figure 1. Mizoram State showing the type locality (in green square) and new locality (in red polygon) of *Leptobrachella tamdil*.

dissection.

We used the following abbreviations for measurements and morphometry: SVL – snout to vent length (from tip of snout to vent); IN – internarial distance (distance between nostrils); HL – head length (distance between angle of jaws and snout-tip); HW - head width (measured at angle of jaws); HD – head depth (greatest transverse depth of head, taken posterior of the orbital region); ED – eye diameter (horizontal diameter of the eyes); E-S – eye to snout distance (distance between anterior-most point of eyes and tip of snout); E-N – eye to nostril distance (distance between anterior-most point of eyes and nostrils); E-T – eye to tympanum distance (distance between posterior corner of orbit and anterior corner of tympanum); UE - upper eyelid width (greatest width of upper eyelid); IO – interorbital distance (least distance between upper eyelids); HTD – horizontal tympanum diameter (greatest diameter of tympanum along horizontal plane); VTD – vertical tympanum diameter (greatest diameter of tympanum along vertical plane); FL – forelimb length (distance between elbow and base of outer tubercle); F1 – first

Image 1. A male *Leptobrachella tamdil* collected from Tuilut Stream in Dampa Tiger Reserve, Mizoram, northeastern India.

Table 1. Morphometric measurements of *Leptobrachella tamdil* including holotype (ZSI A10962), paratype (ZSI A10963) and present specimen (MZMU 1631, collected from Dampa Tiger Reserve, Mamit District, Mizoram).

	ZSI A10962 (Holotype)	ZSI A10963 (Paratype)	MZMU 1631
Sex	Adult male	Adult female	Adult male
Morphometric (in mm)			
SVL	32.3	31.8	31.3
IN	3.2	3.1	3.2
HL	8.7	8.8	9.2
HW	12.0	12.0	10.5
HD	5.2	4.8	4.4
ED	4.5	4.6	4.3
IO	5.1	5.8	4.8
E-S	4.7	4.7	4.6
E-N	2.8	2.7	2.5
E-T	1.1	1.4	1.3
UE	3.4	3.5	3.1
HTD	2.9	3.1	2.5
VTD	2.3	2.2	2.1
FL	4.3	3.5	4.1
TBL	16.0	15.7	14.2
IMT	1.9	1.8	1.8
IPT	2.2	1.8	2.1
A-G	13.8	13.8	13.7
BW	9.7	11.9	9.8

finger length; F2 – second finger length; F3 – third finger length; F4 – Fourth finger length; TBL – tibia length (distance between surface of knee and surface of heel, with both tibia and tarsus flexed); IMT – length of inner metatarsal tubercle (greatest length of inner metatarsal tubercle); IPT - length of inner palmar tubercle (greatest length of inner palmar tubercle); T1 – first toe length; T2 – second toe length; T3 – third toe length; T4 – fourth toe length; T5 – fifth toe length; A–G – axilla to groin distance (distance between posterior edge of forelimb at its insertion to body to anterior edge of hind limb at its insertion to body) and BW – body width (greatest width of body).

The specimen is mid-sized (SVL 31.3mm smaller than 32.3mm in the male holotype) (Image 1; Table 1), allocated to *Leptobrachella tamdil* (Sengupta et al. 2010) showing the following combination of characters: head wider than long (HW/HL ratio 1.14); vocal sac indistinct; snout obtusely pointed when viewed dorsally and laterally; projecting slightly beyond mandible; nostrils dorso-laterally positioned, nearer to tip of snout than to eye (E-N/E-S ratio 0.52); canthus rostralis obtuse; internarial distance greater than distance from anterior margin of eye to nostril (IN/E-N ratio 1.28); eye large (ED/HL ratio 0.47; ED/E-N ratio 1.72); pupil elliptical; interorbital space flattened, interorbital width greater than upper eyelid width (IO/UE ratio 1.55); vomerine teeth absent; choanae located at anterior of palate; tongue subtriangular, bifid; snout smooth; dorsum tuberculate; tuberculated eyelids; tympanum & supratympanic fold distinct; supratympanic fold extending to posterior edge of tympanum; macroglands (preaxillary, pectorals, femoral and ventrolateral glands) present; under surfaces of forelimbs, shanks & thighs smooth. Fore limbs short (FL/SVL ratio 0.29); nuptial pads absent; indistinct subarticular tubercles; relative length of fingers: F3 > F2 > F1 > F4 (7.3mm > 4.5mm > 4.4mm > 4.2mm); fingers lacking webbing, tips rounded, not disk-like; inner and outer metacarpals present. Hind limbs relatively long and slender (TBL/SVL ratio 0.49), with heels overlapping when limbs are held perpendicular to body; outer metatarsal tubercle absent; toe webbing basal, tips not dilated apically, bearing dermal fringes; relative length of toes: T4 > T3 > T5 > T2 > T1 (12.4 mm > 9.3mm > 8.6mm > 6.3mm > 3.8mm); subarticular tubercles indistinct. The morphometric data is provided in Table 1.

In life, forehead and dorsum mid-grey, with irregular dark grey blotches; flanks with large dark blotches; that partially encircle pale tubercles; eyes with bright orange iris pigmentation mostly restricted to upper orbit;

Image 2. Habitat in which *Leptobrachella tamdil* was found at Tuilut stream, Dampa Tiger Reserve, Mizoram, northeastern India.

blackish dark vertical ellipsoid pupil; dark tympanic mask present; venter pale pinkish grey; dark greyish-black labial bars present and limbs with dark cross-bars; fingers and toes with faint dark transverse stripes; macroglands pale pink.

The habitat where the specimen was found is located in the core area of the western part of Dampa Tiger Reserve. The natural vegetation in the reserve is tropical evergreen to semi-evergreen, corresponding to the Cachar Tropical Evergreen 1B/C3 and semi-evergreen 2B/C2 forest (Champion & Seth 1968). The forest in the moist valleys is lofty and evergreen, while the steeper slopes on the west aspect have more deciduous elements, often with sympodial bamboos in the understory. Tuilut, the slow-flowing stream where sampling took place (Image 2; Fig. 1), is surrounded by tropical evergreen and moist deciduous forest dominated by *Oroxylum indicum*, *Trema orientalis*, *Ziziphus ncurve*, *Calamus erectus*, *Tinospora cordifolia*, *Acacia pennata*, *Calamus acanthospathus*, *Ulmus lancifolia*, *Macropanax dispermus*, *Pandanas fascicularis*, *Pterospermuma cerifolium*, *Ficus fistulosa*, and *Meloccana baccifera*. The specimen was collected from the exposed pebbles in the vicinity of a slow-flowing stream. Atmospheric temperature and relative humidity during the collection period were 14.7˚C and 81.9 %, respectively. Other frogs found in sympatry include *Amnirana* cf. *nicobariensis*, *Amolops* sp., *Microhyla berdmorei*, and *Odorrana chloronota*.

At present, as only three individuals are recorded so far, there is still very little information on the natural history and distribution range of *L. tamdil*. In fact, the conservation status for the species remains ambiguous till recently, where Deuti (2013) categorized this species as data deficient but later changed the status into not assessed by Dinesh et al. (2019), however, we suggested that the species is very rare, solitary and secretive with nocturnal behavior, and in need of a proper assessment on its conservation status. The macrohabitat of *L. tamdil* appears to consist primarily of slow-flowing stream mixed with rocky terrain within tropical semi-evergreen forest. By updating our knowledge of the distribution, *L. tamdil* remains endemic to Mizoram, India. Other aspects of the natural history of *L. tamdil* remain largely unknown and considerable work remains in order to fill gaps in its known range and determine whether its distribution extends further outside the state of Mizoram.

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NOTE

Records of dragonflies and damselflies (Insecta: Odonata) of Dipang Lake, with two new records to Nepal

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Odonata is an order of insects that comprises dragonflies (Anisoptera) and damselflies (Zygoptera). They are carnivorous in nature. They can be taken as an excellent biological indicator of environmental conditions (Corbet 1993) and also play an important role in the ecology of wetlands (Chovanec & Waringer 2005). Many species of Odonata inhabiting agro-ecosystems play a crucial role in controlling pest populations (Tiple et al. 2008). Since they are primarily aquatic, their life history is closely linked to specific aquatic habitats (Andrew et al. 2009). Worldwide, 6,324 species of Odonata are known (World Odonata List 2020). Nepal, being rich in water resources, serves as an excellent habitat for Odonata. The earliest record of dragonflies was carried out by Selys (1854) in Nepal. Since then, there have been various other researchers who had carried out studies, including Vick (1989) who listed out 172 species with altitudinal distribution for the first time in Nepal. In recent times, Thapa (2015) enlisted 195 species from 87 genera belonging to 18 families while Conniff (2020) states that 183 different species of Odonates are recorded from Nepal till date in accordance with the modern classification.

Dipang Lake is one of the eight lakes in Pokhara Metropolitan Municipality located in Lekhnath covering a total catchment area of 2.39km^2 and total water body area of 0.14km^2 (MoFE 2018). Most of its area is covered by swampland and the lake itself, while the tributaries too serve as an excellent abode for Odonata. Khatre and Kusunde rivers are its major sources with Kahur, Kaure and Deurali rivers as other tributary streams (MoFE 2018). The lake, however, seems to have passed its glory days because of its drying water sources. Human encroachment though seems low and constant, siltation is medium and constant, pollution is medium but increasing and the number of invasive species like water hyacinth, parthenium, morning glory, *Lantana camara*, etc. is high and increasing (MoFE 2018). Conservation efforts though, have been undergone by NGOs like CODEFUND.

Not many studies on Odonata have been performed from this lake, however, Karen Conniff, who has been working extensively on the Odonata of Nepal, has been recording several of them in Pokhara on her blog "Nepal Odonata". This study was conducted to explore the Odonata species exclusively from Dipang Lake.

The research was carried under the biodiversity project of the Conservation Development Foundation (CODEFUND), Koteshwor, Kathmandu, Nepal. The surveys were carried out during April and May of 2019

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in the locality of Dipang Lake, Lekhnath, Kaski (28.180^{0}N & 84.066^{0}E, 670–700 m) (Figure 1). Different areas of the lake including the swampland, inlet, outlet and the peripheries were extensively explored. The sightings were recorded capturing photos in the Sony Cyber-Shot DSC-HX90V 18.2MP camera. The GPS details of the locations and the dates were recorded on the photos themselves. The number of individuals seen was recorded in a notebook to analyze their local status. During this study, no species of Odonata were harmed. The records were photographed from a proper distance and were identified from the photographs using Karen Conniff's blog "Nepal Odonata", "Odonata of India" website and Andrew et al. (2009). Moreover, some species were identified by Karen Conniff herself.

Local status of Odonata species are categorized as; rare—only one individual recorded, uncommon—only two individuals recorded, less common—only 3–5 individuals recorded, rather common—individuals recorded 6–10 in number, common—individuals recorded 11–50 in number, and quite common—individuals recorded more than 50 in number.

A total of 28 species of Odonates including 17 species of Anisoptera (Dragonflies) and 11 species of Zygoptera (damselflies) were recorded (Table 1). Libellulidae with 16 species was the most dominant family among the Anisoptera followed by Gomphidae (one sp.). Among Zygoptera, eight species recorded belong to the family Coenagrionidae, one species to Platycnemididae, one species to Calopterygidae, and one species to Chlorocyphidae (Figure 2). Among Anisoptera, *Neurothemis tullia* was found to be the commonest of all while *Pantala flavescens*, *Rhyothemis variegata*, and *Tramea virginia* were found to be rare. Similarly, among Zygoptera, *Ceriagrion coromandelianum* was the most dominant species encountered. Likewise, *Aciagrion approximans* (Selys, 1876) also known as The Indian Violet Dartlet and *Ceriagrion cerinorubellum* (Brauer, 1865) also known as the Orange-tailed Marsh Dart had not been reported from Nepal before this research and is, thus, taken as species new to Nepal. This particular record for *Aciagrion approximans*, however, also appears

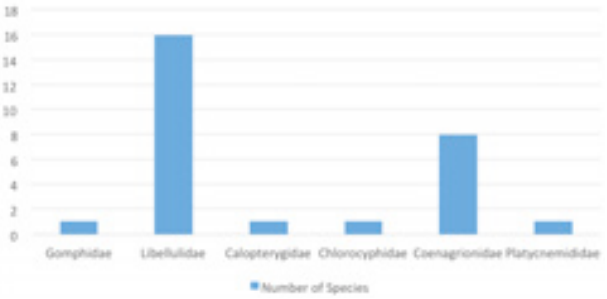

Figure 2. Family-wise composition of the observed species.

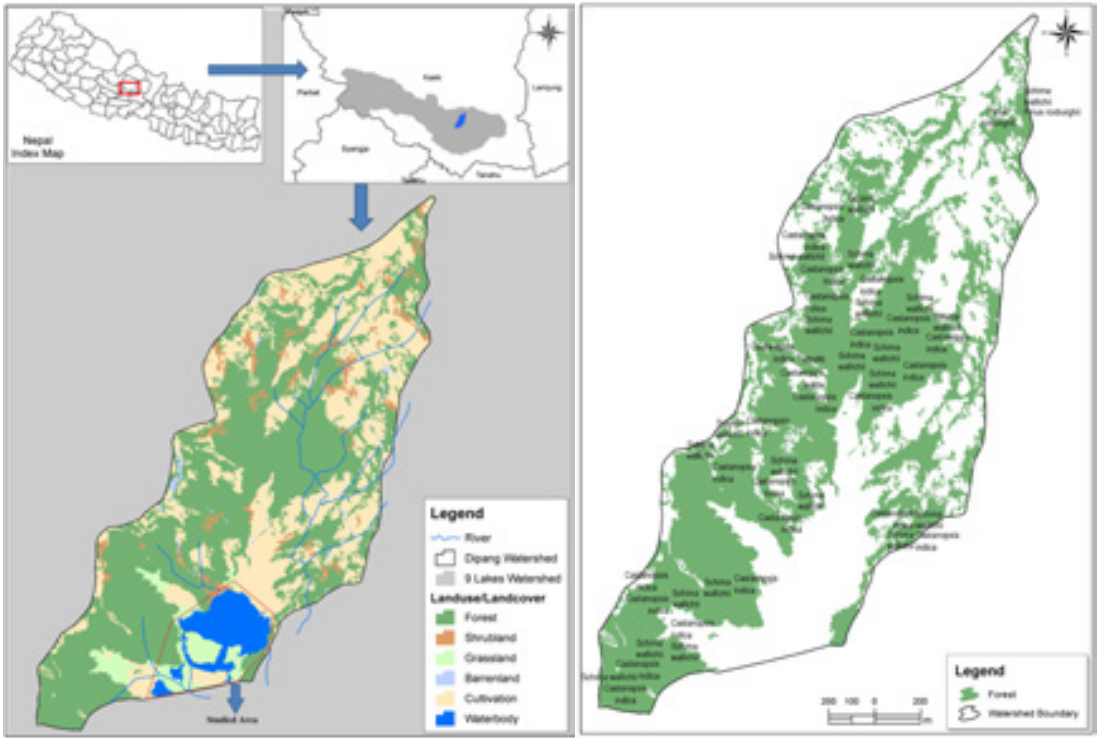

Figure 1. Study area - locality of Dipang Lake, Lekhnath, Kaski, Nepal.

Table 1. List of the observed species and their local and IUCN Red List status.

	Common name	Scientific name	Author	Local status	IUCN Red List status
Family: Gomphidae					
1.	Common Clubtail	*Ictinogomphus rapax*	(Rambur, 1842)	Rather Common (6)	Least Concern
Family: Libellulidae					
2.	Trumpet Tail	*Acisoma panorpoides*	Rambur, 1842	Common (10+)	Least Concern
3.	Little Blue Marsh Hawk	*Brachydiplax sobrina*	(Rambur, 1842)	Less Common (3)	Least Concern
4.	Ditch Jewel	*Brachythemis contaminata*	(Fabricius, 1793)	Common (10+)	Least Concern
5.	Scarlet Skimmer	*Crocothemis servilia*	(Drury, 1770)	Common (10+)	Least Concern
6.	Fulvous Forest Skimmer	*Neurothemis fulvia*	(Drury, 1773)	Common (10+)	Least Concern
7.	Paddyfield Parasol	*Neurothemis intermedia*	(Rambur, 1842)	Common (10+)	Least Concern
8.	Pied Paddy Skimmer	*Neurothemis tullia*	(Drury, 1773)	Quite Common (50+)	Least Concern
9.	Tricolored Marsh Hawk	*Orthetrum luzonicum*	(Brauer, 1868)	Common (10+)	Least Concern
10.	Crimson-tailed Marsh Hawk	*Orthetrum pruinosum*	(Burmeister, 1839)	Common (10+)	Least Concern
11.	Green Marsh Hawk	*Orthetrum sabina*	(Drury, 1770)	Common (10+)	Least Concern
12.	Blue-tailed Yellow Skimmer	*Palpopleura sexmaculata*	(Fabricius, 1787)	Less Common (3)	Least Concern
13.	Wandering Glider	*Pantala flavescens*	(Fabricius, 1798)	Rare (1)	Least Concern
14.	Lesser Blue Wing	*Rhyothemis triangularis*	Kirby, 1889	Uncommon (2)	Least Concern
15.	Common Picturewing	*Rhyothemis variegata*	(Linnaeus, 1763)	Rare (1)	Least Concern
16.	Saddlebag Glider	*Tramea virginia*	(Rambur, 1842)	Rare (1)	Least Concern
17.	Black Stream Glider	*Trithemis festiva*	(Rambur, 1842)	Uncommon (2)	Least Concern
Family: Calopterygidae					
18.	Clear-winged Forest Glory	*Vestalis gracilis*	Rambur, 1842	Rather Common (8)	Least Concern
Family: Chlorocyphidae					
19.	River Heliodore	*Libellago lineata*	(Burmeister, 1839)	Rare (1)	Least Concern
Family: Coenagrionidae					
20.	Indian Violet Dartlet	*Aciagrion approximans**	(Selys, 1876)	Rather Common (6)	Least Concern
21	NA	*Agriocnemis clauseni*	Fraser, 1922	Rare (1)	Least Concern
22.	Pygmy Dartlet	*Agriocnemis pygmaea*	(Rambur, 1842)	Rather Common (7)	Least Concern
23.	Orange-tailed Marsh Dart	*Ceriagrion cerinorubellum**	(Brauer, 1865)	Rather Common (6)	Least Concern
24.	Coromandel Marsh Dart	*Ceriagrion coromandelianum*	(Fabricius, 1798)	Common (10+)	Least Concern
25.	Western Golden Dartlet	*Ischnura rubilio*	Selys, 1876	Less Common (4)	Least Concern
26.	Ruby Dartlet	*Ischnura rufostigma*	Selys, 1876	Less Common (5)	Least Concern
27.	Three-lined Dart	*Pseudagrion decorum*	(Rambur, 1842)	Less Common (3)	Least Concern
Family: Platycnemididae					
28.	Black Marsh Dart	*Onychargia atrocyana*	Selys, 1865	Less Common (4)	Least Concern

* Species new to Nepal

in the additions made to the checklist of Odonata of Nepal (Conniff et al. 2020).

These records and the local status, however, is representative to the studied months only, i.e., April and May. Several other species could show up during other seasons and the local status of the species recorded during the study period could change year-round.

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Image 1. *Ictinogomphus rapax* (Rambur, 1842)

Image 2. *Acisoma panorpoides* Rambur, 1842 ♂

Image 3. *Acisoma panorpoides* Rambur, 1842 ♀

Image 4. *Brachydiplax sobrina* (Rambur, 1842)

Image 5. *Brachythemis contaminata* (Fabricius, 1793) ♂

Image 6. *Brachythemis contaminata* (Fabricius, 1793) ♀

Image 7. *Crocothemis servilia* (Drury, 1770) ♂

Image 8. *Neurothemis fulvia* (Drury, 1773) ♂

Image 9. *Neurothemis intermedia* (Rambur, 1842)

Image 10. *Neurothemis tullia* (Drury, 1773)♂

Image 11. *Neurothemis tullia* (Drury, 1773) ♀

Image 12. *Orthetrum luzonicum* (Brauer, 1868)♂

Image 13. *Orthetrum luzonicum* (Brauer, 1868) ♀

Image 14. *Orthetrum pruinosum* (Burmeister, 1839) ♂

Image 15. *Orthetrum pruinosum* (Burmeister, 1839) ♀

Image 16. *Orthetrum sabina* (Drury, 1770)

Image 17. *Palpopleura sexmaculata* (Fabricius, 1787) ♂

Image 18. *Palpopleura sexmaculata* (Fabricius, 1787) ♀

Image 19. *Pantala flavescens* (Fabricius, 1798)

Image 20. *Rhyothemis triangularis* Kirby, 1889

Image 21. *Rhyothemis variegata* (Linnaeus, 1763) ♂

Image 22. *Tramea virginia* (Rambur, 1842)

Image 23. *Trithemis festiva* (Rambur, 1842)

Image 24. *Vestalis gracilis* Rambur, 1842

Image 25. *Libellago lineata* (Burmeister, 1839)

Image 26. *Aciagrion approximans* (Selys, 1876)

Image 27. *Agriocnemis clauseni* Fraser, 1922 ♀

Image 28. *Agriocnemis pygmaea* (Rambur, 1842)

Image 29. *Agriocnemis pygmaea* (Rambur, 1842)

Image 30. *Ceriagrion cerinorubellum* (Brauer, 1865)

Image 31. *Ceriagrion coromandelianum* (Fabricius, 1798)

Image 32. *Ischnura rubilio* Selys, 1876

Image 33. *Ischnura rufostigma* Selys, 1876

Image 34. *Pseudagrion decorum* (Rambur, 1842)

Image 36. *Onychargia atrocyana* Selys, 1865

Image 37. *Orthetrum sabina* (Drury, 1770) feeding on one of the Sapphire (*Heliophorus* sp.) butterflies.

Image 35. A dragonfly naiad taken out of the water

Image 38. *Ceriagrion cerinorubellum* (Brauer, 1865), a damselfly new to Nepal, feeding on a Leafhopper (*Atkinsoniella* sp.).

Image 39. Top to bottom: *Crocothemis servilia* (Drury, 1770) ♂, *Neurothemis fulvia* (Drury, 1773) ♂ and *Orthetrum pruinosum* (Burmeister, 1839) ♂ on a same perch.

Image 40. Glimpses of the lake. © K.C. Sajan.

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NOTE

Henry's Rattan *Calamus henryanus* Becc. (Arecaceae), a new record to India

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The genus *Calamus* L. is the largest group of Arecaceae, represented by 520 species and distributed in OW tropics especially Malesia (Mabberley 2017). Out of 48 species of *Calamus* in India, 47 were reported by Renuka et al. (2010) and one more species by Mandal et al. (2019). While exploring the Barak valley of Assam, an interesting species of *Calamus* viz., *Calamus henryanus* Becc. was collected from Bhuban Hill of Cachar District located in the southern part of Assam (Figure 1). This species is a new record to the flora of India as it has not been reported in any of the works on rattans in India (Basu 1992; Biswas & Dayal 1995; Renuka 1999; Rahman 2007; Barooah & Ahmed 2014). This species is known to occur in China, Thailand, Laos & Vietnam (Evans et al. 2002), and Myanmar (Henderson et al. 2018).

Standard method (Jain & Rao 1977; Dransfield 1986) for collection of specimens and herbarium preparation was followed and preliminary identification of the specimen was done on the basis of careful taxonomic analysis and survey of literature (Beccari 1908; Henderson 2009; Peters & Henderson 2014). The identity of the species was confirmed through online herbaria Kew Herbarium Catalogue (K) and New York Botanical Garden (NYBG). The website Palm Web was also consulted. The specimens have been deposited in the departmental herbaria of Cotton University (Image 2) and a duplicate was submitted in ASSAM (Accession No. 95113, 95114). Taxonomic description along with photographs (Image 1 & 2), habitat, examined specimens and a note is provided to facilitate its easy identification.

Calamus henryanus Becc., Rec. Bot. Surv. India 2:199.1902.

Clustered climbing rattan, 6–8 m tall; stem 10–12 mm across including sheath and 8–9 mm excluding sheath, leaf sheath of young stem is covered by brown indumentum, mature stem green; spines triangular, brown, 0.3–2.5 cm long, comparatively more dense and longer below the knee. Internodes 10–12 cm. Knees 2.5–3×0.6–0.7 cm, armed or unarmed, light green to yellow, surface smooth or with brown indumentums. Ocrea inconspicuous, 1–2 mm long, unarmed. Flagella 1.3–1.5 m, base c. 5×3 mm, armed by 2–3 mm spines. Leaf ecirriate, 1–1.1 m long, abaxially armed by 2–3 mm spines, adaxially rachis unarmed. Petiole 28–30 cm with triangular adaxial spines 4–5 mm. Leaflets 30–46 per side, regular, alternate and opposite, in equidistant, linear to

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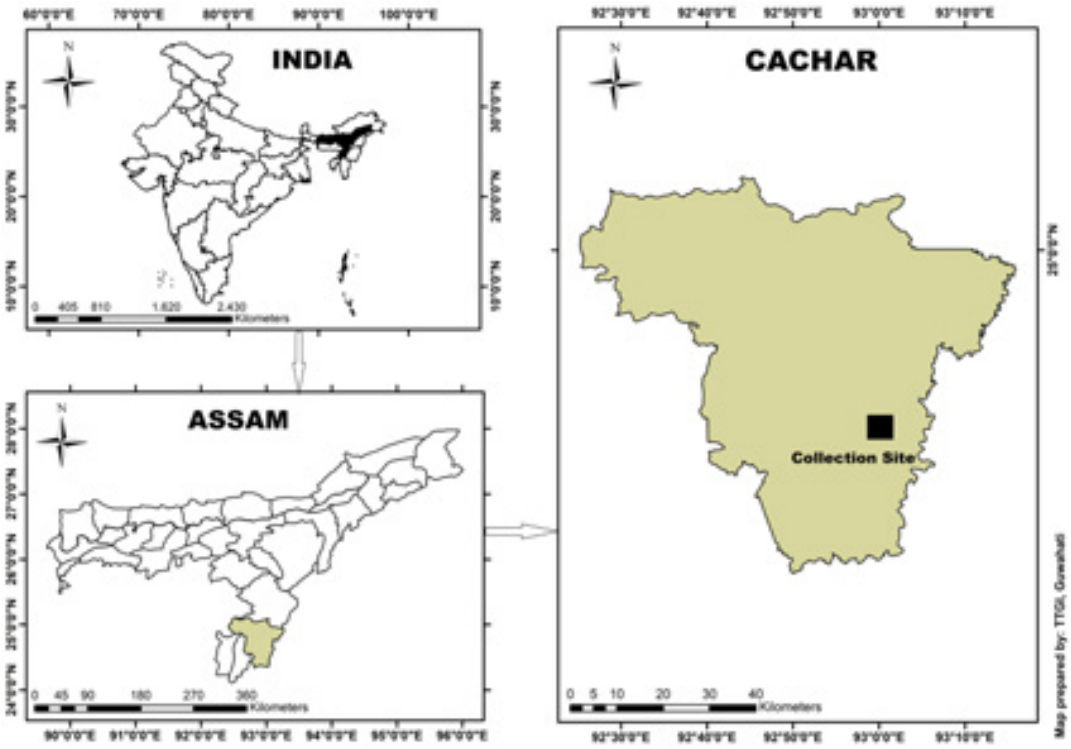

Figure 1. Study area showing collection site.

ensiform, basal longest leaflets 30–33×2 cm, mid region leaflets 26–28×1.3 cm, terminally free 14–16×0.5–0.6 cm, 5–nerved, acute to long acuminate at apex; bristles 2mm long, brown, crowded abaxially, few and restricted to the vein adaxially. Inflorescence flagellate, prophyll 18–20 cm long, tubular; partial inflorescence with splitting, dry or tattering bract; long one at base; terminal rachilla is two to three times longer than others. Staminate inflorescence 3–3.5 m long with 5–7 nos. partial inflorescences 7–23 cm long; flagella 25–30 cm long, armed. Rachillae 2–4 cm long, alternate, slightly bent or straight. Staminate flower ovate c. 3×2 mm; calyx c. 2mm long, connate, green; corolla c. 3mm long, free, ovate; six stamens, c. 3mm long; filaments linear, 2mm long, anthers bi–lobed, 2mm long, fertile, yellow; pistillode c. 1mm long, trifid. Pistillate inflorescence 1.5–1.8 m long, partial inflorescences 2–4 nos. 4–23 cm long; flagella 80 cm long, densely armed. Rachillae 1–4 cm long; dyad alternately arranged. Pistillate flower c. 3×1 mm, ovate; calyx connate, tip villose; corolla free c. 2×1.5 mm long, ovate, light green; six staminodes, c.1mm long, staminodal ring c. 2mm long with six tips; gynoecium c. 2mm long; ovary tri-carpellary; style short; three stigmas. Neuter flower oblique or ovate, c. 2mm long; pedicel c. 0.5mm long; perianth same as pistillate flower; five staminodes, c. 1mm; filaments linear, free, c. 0.5mm long; pistillode bifid, c. 1mm long. Immature fruit ovoid 5×3 mm.

Flowering: November–January; **Fruiting**: February onwards.

Habitat: The species was found in association with *Alpinia* spp. *Bambusa* spp., *Bauhinia acuminata* L., *Mesua ferea* L., *Mikania micrantha* Kunth, *Calamus erectus* Roxb., *Saraca asoka* (Roxb.) de Wilde., and *Licuala peltata* Roxb. ex Buch-Ham. at an elevation up to 704m on slopes and shady areas.

Specimen examined: #69 (Image 2A), 10.xi.2018, India, Assam: Bhuban Hill, Cachar District, 24.644^{0}N; 93.144^{0}E, 704m, coll. S. Mehmud; #116 (Image 2B), 23.iii.2019, 24.648^{0}N; 93.007^{0}E, 112m, coll. S. Mehmud (Department of Botany, Cotton University; ASSAM); NQD 2023, Vietnam, Ha Giang Province, Quang Binh District, Vinh Hao State Forestry Company, Compartment 9, Block 301, Coordinates 482386 & 2470188, 134m, 16.x.2019, Nguyen Quoc Dung and Le Manh Tuan (NYBG barcode 01204787!); #1967, 22.xi.2003, Myanmar, Mon State, Kyaikto, Mt. Kyaikhtiyo, 17.479^{0}N, 97.093^{0}E, 900m, D.R. Hodel (NYBG barcode 02390385!).

Note: The leaf of the specimens examined was found with regular leaflets while the presence of both regular and interrupted leaflets are known to occur in the species (Evans et al. 2002). The collection site located

Image 1. *Calamus henryanus*: A—habit | B–C—staminate inflorescence | D—pistillate inflorescence | E—rachilla with pistillate and neuter flower | F—neuter flower | G—stamens of staminate flower | H—pistillodes of staminate flower | I—calyx tip of pistillate and neuter flower | J–K—staminode of pistillate and neuter flower respectively | L—pistillode of neuter flower | M—immature fruit. © Selim Mehmud.

Image 2. Herbarium of *Calamus henryanus*: A—with staminate inflorescence | B—with pistillate inflorescence.

in the Bhuban Hill is 44–50 km away from the district headquarters at Silchar. Occurrence of the species was noted in a few spots and was within a range of around 7–9 km. A total of five populations with around 17 individuals were observed in the study area. Three populations out of five were observed near roadsides. The cane was found to be utilized by local people for preparation of furniture and domestic uses, which probably shrinks its occurrence in the study area. As the study area shares a border with Manipur, Mizoram, and Tripura, therefore, there are chances of occurrence of the species in these states of northeastern India.

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1) Abstract—Page 13531, Line no 7 “16 Trail cameras” should be stated as “10 Trail cameras”
2) Material and method section under the title “Trail camera placements”(Column 3) page 13534, Line No—12 “Sixteen trail cameras” should be stated as “Ten trail cameras”.
3) Abstract—Page 13531, Line no 8 “The total sampling effort was 180 trap-nights” could be stated as “The total sampling effort was 180 trap-nights for each study habitat”

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