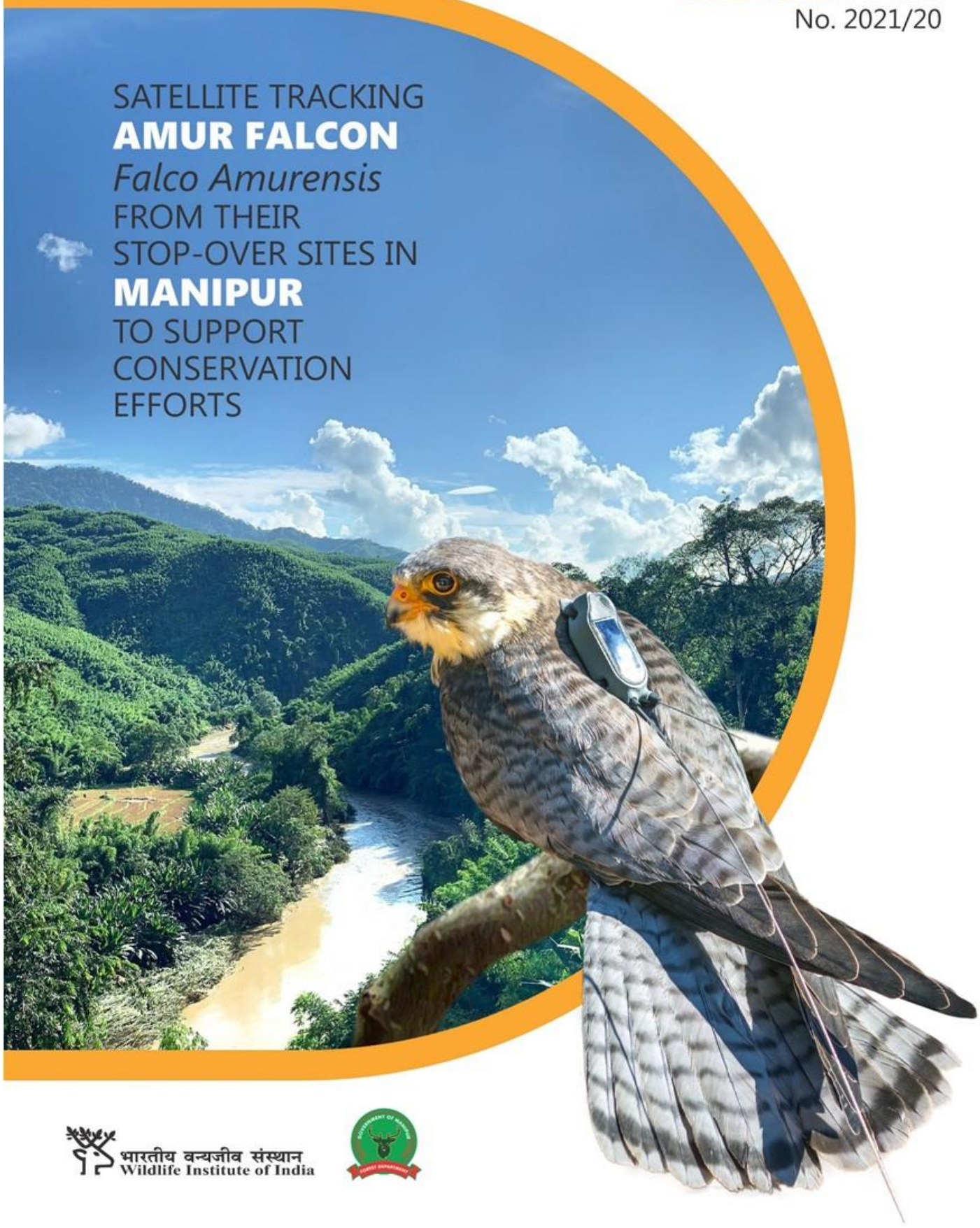
TECHNICAL REPORT
No. 2021/20

SATELLITE TRACKING **AMUR FALCON** *Falco Amurensis* FROM THEIR STOP-OVER SITES IN **MANIPUR** TO SUPPORT CONSERVATION EFFORTS



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

TECHNICAL REPORT
NO. 2021/20

SATELLITE TRACKING AMUR FALCON *Falco amurensis* FROM THEIR STOP-OVER SITES IN MANIPUR TO SUPPORT CONSERVATION EFFORTS

Suggested Citation for the Report:

Kaur, A., Jacob, A and Kumar, R.S. 2022. Satellite tracking Amur falcons *Falco amurensis* from their stop-over sites in Manipur to support conservation efforts. Wildlife Institute of India. Technical Report No. 2021/20. Pg. 83.

Maps preparation and designing: © Amarjeet Kaur

Front cover: Female Amur Falcon © Rajaram Vasudevan
Backdrop picture, Puching stop-over site © Amarjeet Kaur

Contents

Acknowledgements

This project is a collaborative initiative of the Wildlife Institute of India (WII) and Manipur State Forest Department and was undertaken with funding support from the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. This study involved enormous amount of administrative and logistic challenges, and would not have been possible without the support of a number of people. It is particularly important to acknowledge the cooperation and support provided by local people including the village chairman and village council authorities at the Amur Falcon stopover sites in Tamenglong district of Manipur. They welcomed us to their villages and their homes, and many people enthusiastically assisted us during fieldwork, and together pledged to protect falcons and we sincerely thank them all.

A number of forest department officials were instrumental in laying the foundation for the Amur Falcon conservation initiative in Manipur starting from 2015, much before this satellite tracking study was taken up. We would like to acknowledge the Manipur Forest Department, Shri P.N. Prasad, Ex PCCF & HoFF, Shri K. Angami, Ex PCCF & HoFF, Shri D.J.N Anand, Ex CWLW, Shri A.K. Joshi, PCCF & HoFF, CWLW, Shri S. Dhananjoy Singh, Ex CCF- II, Shri Kh. Brojendro Singh, Ex CCF- II, Shri. W. Yaiskul Singh, Ex CCF-II, Smt. Gaithaolu Thaimei, CF, Western Circle, all the people involved in the Project Amur Falcon, Tamenglong Forest Division, and officers of Tamenglong division: Shri Huri Golmei, Ex DFO, Shri Arun RS, Ex DFO, Shri Napolean Ex DFO, Shri Hitler Singh Karibhom, Ex DFO, and Range officers and staff. The District Commissioner, Superintendent of Police, and District Administration of Tamenglong also provided support to the WII team during the study. At WII, Dr. G.S. Rawat, Dr. Dhananjai Mohan IFS former Directors always appreciated our efforts and we thank them for their encouragement and for providing institutional support.

We like to specifically thank Shri Arun RS and Shri Kh. Hitler Singh for their able leadership and they spent several days with us in the field during the capture and tagging of falcons ensuring that we receive all support and making the program a success. Mr. Pormeshwar Angom and Mr. Johnson Khundrakpam Range officers accompanied us throughout from the day one of our arrival in Imphal and it was wonderful knowing them. At Tamenglong, Shri. Nehemiah Panmei and Dr. Chambo Golmei Honorary Wildlife Wardens were important points of contact and a constant source of support. They were a repository of knowledge of local wildlife and the wilderness areas in the district, and their leadership skills were instrumental in influencing local people of many villages there to set aside community forests and protect the precious and unique biodiversity within. Further, members of the Rainforest Club Tamenglong including Mr. Mordecai Panmei assisted us during fieldwork and were great company. During the 2019 season, the chairman of Puching village Shri. R. Gonmei and his family hosted us at their home for close to 25 days and we like to thank them for the lifetime of

wonderful memories. The chairman and authorities of Chiulon and Phalong visited us in Puching village to release the tagged falcons named after their villages
Here again in Manipur our Amur Falcon partners from Hungary Dr. Peter Palatitz, Dr. Peter Fehervari, Dr. Peter Borbath and Ms. Zsofia Sumegi came forward to help us capture and tag Falcons during the 2018 season. Mr. Raja Bhandi, Mr. Hemal Naik, Mr. Vivek H. Sridhar, Mr. Rajaram Vasudevan, Mr. Manish Manick, Mr. Dhiraj Das visited us in Tamenglong and assisted in fieldwork. To help spread awareness on Amur Falcon conservation it would not have been possible without the support of friends in the print & electronic media. We would like to specifically thank the staff of Doordarshan and other television channels for covering the story of the migration of falcons and their return to Manipur every year. Would like to also thank the journalists Mr. Shamungou and Mr. Sobhapati Samom for covering the falcon conservation efforts in the print media. Lastly, thank our family and friends for all their support.

Together it is all these people and many others who we may have inadvertently missed mentioning here that this conservation initiative was successful… the many sacrifices, the untold stories and those covered in the media without doubt has helped spread the word of conservation not only in the remote and beautiful Tamenglong district, but also to the whole of Manipur State and beyond… and will continue on with the journeys of this incredible little raptor - the Amur Falcon known to the Rongmei Naga people as - the Akhoipuina…

Thank you, Amur Falcon Partners…

Summary

As part of the Amur Falcon Conservation Initiative in Manipur this study helped create mass awareness and garner support of local people in conserving the migratory Amur Falcons. To support the conservation efforts satellite tracking of Amur Falcons was initiated in 2018. During the study, eight Amur Falcons were satellite tagged to document their migration, their breeding and non-breeding grounds, stop-over sites and migration strategies. The satellite tracking was undertaken in two stop-over seasons in 2018 and 2019 where a total of 28 Amur Falcons were captured. In 2018, of 5 Amur Falcons that were captured, ringed and released, one male named *Manipur* and one female named *Tamenglong* were fitted with the lightweight PinPoint GPS Argos tags. The Amur Falcon *Manipur* post-tagging and release unfortunately was hunted down by a local hunter at another stop-over site Puching in Tamenglong district. Because of this incident Puching was later revealed to be one of the major stop-over sites in the region. While the female falcon *Tamenglong* tagged successfully crossed the Arabian Sea, however ceased transmission after 40 days of tracking at Zambia on its way to non-breeding grounds.

In 2019, 23 Amur Falcons were captured at Puching stop-over site in Tamenglong district. And of these, two female falcons named *Puching* and *Irang* were tagged and released on 31st October and two males named *Chiulon* and *Phalong* and one female named *Barak* were satellite-tagged and released on 1st November. *Chiulon* and *Irang* were tagged using the Argos microwave PTT tags while the others were fitted with the PinPoint GPS Argos tags. While *Phalong* and *Puching* could not be tracked successfully due to transmitter failure. *Barak* was successfully tracked for its one trip to the non-breeding grounds in southern Africa while *Chiulon* which was tracked for the longest duration of 827 days along with *Irang* were tracked for three trips to the non-breeding grounds and two to the breeding grounds.

A total of 9894 locations from the four-satellite tagged Amur Falcons was collected during their period of tracking of which 39% locations belonged to good location class. At the breeding grounds, the tagged Amur Falcons arrived in May and departed in September-

October, spending on an average of 145 days (range: 137 – 157). When compared with other Amur Falcons which were tracked in Nagaland, *Chiulon* crossed the Khingan Mountains and spent its breeding season farthest north near Hailar city of Inner Mongolia Province. At the non-breeding grounds, the Amur Falcons arrived in December-January and departed in March-April spending on an average of 95 days (range: 57 – 112). The falcons spent their non-breeding season in in the grasslands (veldts) and savannah of southern Africa (Botswana, Mozambique, Zimbabwe, and South Africa). At both their breeding as well non-breeding grounds, Amur Falcons showed high site-fidelity and this was also seen at their stop-over grounds in Northeast India.

Across years, in autumn, Amur Falcons made a stop-over in Manipur, arriving in October-November, spending on an average 13 days. We identified three major Amur Falcon stop-over sites in Tamenglong district of Manipur namely: Chiulon, Phalong and Puching hosting huge congregations of Amur Falcons stopping over in the region in autumn. After spending about two weeks at the stop-over sites in Northeast India the tagged falcons departed on their migration to Africa arriving in Somalia, close to 6000 km covered in an average of 6.5 days. During spring migration just before the crossing of Arabian Sea the tagged Amur Falcons stopped-over in Somalia in April for an average of 14 days. The stop-over in Somalia was primarily to the south-eastern regions at sites near the capital Mogadishu and near Middle Juba.

Our study confirms the long-distance trans-equatorial migration of Amur Falcons from their northern hemisphere breeding areas to their southern hemisphere non-breeding areas, following an elliptical or loop migration strategy. The tagged Amur Falcons on their migration either passed through the territory or stopped over in 21 countries including India. The Amur Falcons started their southbound migration from their breeding grounds in mid-September to mid-October and took an average of 63 days to reach south African non-breeding grounds in mid-December to January. And on their return, Amur Falcons started in late March to early April and completed their spring migration in about 49 days which was faster than the autumn migration. We found that during the oceanic crossing, the presence of optimal wind conditions largely facilitated the Amur Falcons' non- stop flights over the Arabian Sea.

Apart from the stop-over sites identified, we carried out modelling for identifying potential stop-over sites elsewhere in the region. The suitability model showed potential Amur Falcon stop-over along the western parts of Manipur next to Imphal valley and also on the borders of eastern Manipur. The highly suitable area for the Amur Falcon to stop-over accounted 0.3% area in Manipur. This study confirms the significance of sites in Manipur as important stop-over sites for Amur Falcons on passage during their autumn migration. Our findings from the suitability model serve as baseline for future management and conservation efforts at select stop-over sites.

Further, we examined the diet of Amur Falcons through regurgitated pellets during their stop-over. We collected 270 pellets from Puching and only found insects (invertebrate) prey in the pellets of the Amur Falcons. This was consistent in the pellets sampled from other stop-over sites during the study. At Puching, the prey remains identified to be of four insect orders and in increasing order of their occurrence: Isoptera (65%), Hemiptera (30%), Coleoptera (4%) and Orthoptera (1%). The predominant occurrence of termite prey in the diet of Amur Falcons while in Northeast India led us to investigate the identity of the termite species, and their swarming behaviour. The morphological examination of the soldier termites resulted in the identity to be of *Odontotermes feae*. We believe that prey availability particularly termite prey likely influences stopover site selection by the Amur Falcons in the Naga and adjoining hills.

Lastly, the satellite tracking initiative proved very effective in producing positive results in conserving Amur Falcons through engagement of local communities in falcon conservation. Along with this, administrative orders banning hunting, media campaign, conservation awareness through the support of the church, and community ownership were also key factors in halting the large-scale harvest of Amur Falcons in the region. Our tracking study on the Amur Falcon has provided deeper insights on the migration of these incredible long-distance migrant and we suggest that the Amur Falcons are an ideal model or subject for understanding climatic influences on migration in birds. However, many important facets about their migration strategy remains unknown which needs to be further explored to better understand the long-distance migration of Amur Falcons.

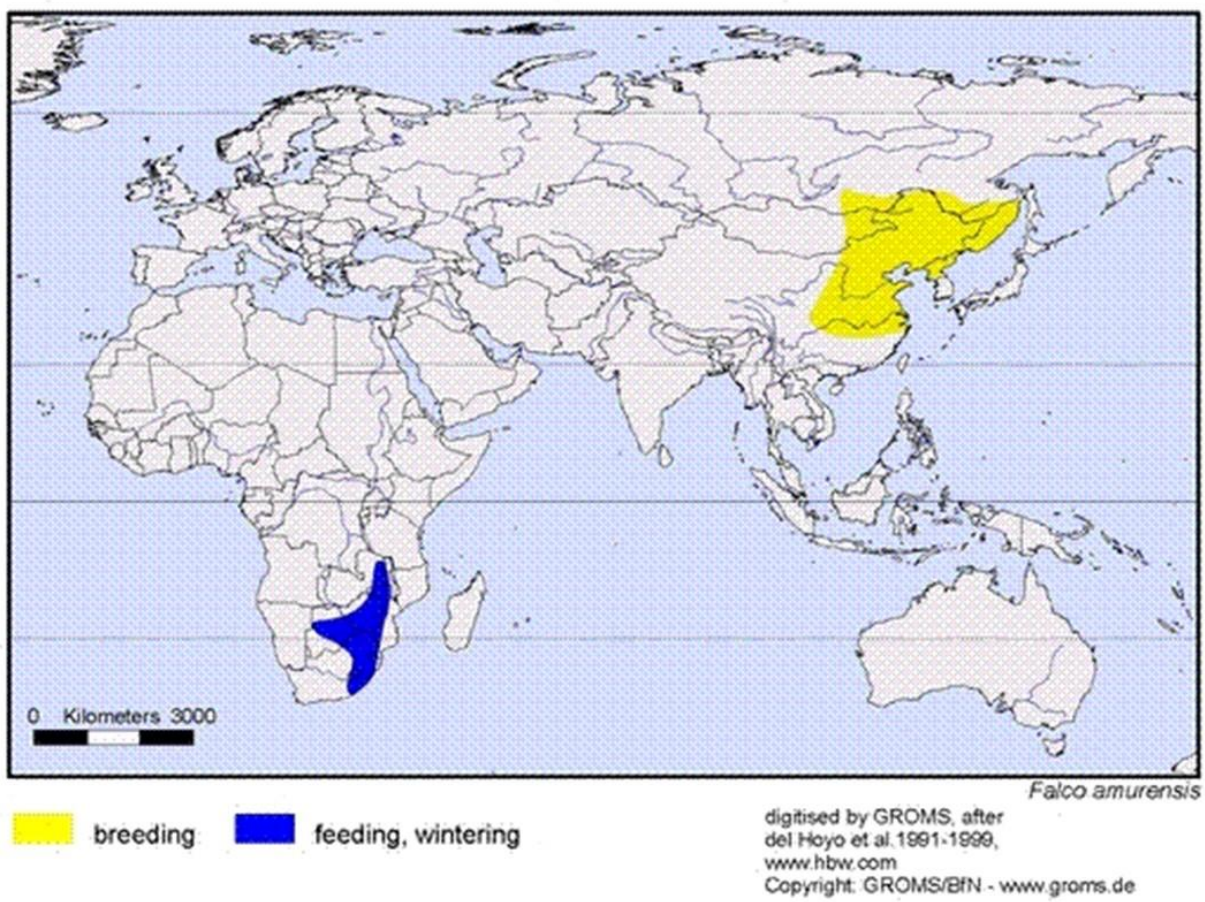

© Rajaram Vasudevan

Akhoipuina

– the long-distance traveller to Manipur

Amur Falcon *Falco amurensis* is a long distance, trans-equatorial migrant (Bildstein 2006). It has one of the longest and most arduous migration routes of any bird, travelling up to 22,000 km in a year, from eastern Asia all the way to Southern Africa and back. Annually, in early autumn, these migrant falcons leave their Asian breeding range and travel to parts of northeast India and Bangladesh that act as staging areas for the overland flights across India (Ali and Ripley 1978). In Nagaland they collect in huge flocks of 100,000+ falcons and remain for about three to four weeks to feed and rest before continuing their journey. Similar such roosting of Amur falcons has also been recorded from Manipur.

Subsequently, they undertake the longest regular overwater passage of any bird of prey, crossing over the Indian Ocean between Western India and tropical East Africa, a journey of more than 4,000 km, which also includes nocturnal flight (Bildstein and Zalles 2005).



Breeding and wintering (non-breeding) distribution of Amur Falcon *Falco amurnesis*

This species is said to be finely attuned to the strong monsoon tailwinds, which results in its late arrival in eastern Africa in autumn (Ash and Atkins 2009). Migrants arrive in their southern African winter range in November-December and depart by early May (Mendelsohn 1997).

This falcon was one of the least talked about species until November 2012 when all that changed following reports by an NGO-Conservation India of a massive large-scale harvest of Amur Falcons at a remote locality in Nagaland. Dalvi et al. (2013) estimated that between 120,000 – 140,000 Amur Falcons were being trapped and killed for human consumption just in that location in Nagaland each year. Hunting of Amur Falcons in Northeast India though is not new and there were reports of considerable number of these birds harvested, specifically in Cachar in Assam (Ali and Ripley 1987, Naoroji 2006). However, the scale of Amur Falcon hunting documented in Nagaland in 2012 with several hundred shipped to local markets daily for commercial sale during the entire stop-over period in 2012 was clearly unsustainable. This led to widespread media outcry asking for an immediate stop to the hunting. Given the species is also protected under the Appendix II of the Convention on the Conservation of Migratory Species (CMS) and that India is a signatory State led to passing administrative orders stating strict ban in hunting of the falcons in the region in Nagaland.

In the following months the Nagaland State Forest Department initiated steps to protect the falcons and one such was the launch of a satellite tracking program in November 2013 to get an understanding of these poorly known falcons and also to support conservation efforts so as to specifically create awareness among local people on the uniqueness of the falcons. This was followed by another detailed study in October-November 2016 involving satellite tagging five more Amur falcons from across stopover sites in Nagaland. The Amur falcons were fitted with the state-of-the-art solar powered satellite transmitters (Microwave Telemetry Inc. USA), weighing only 5 grams in 2013 and 2016. The eight falcons fitted with the tags were named after the local tribe or the name of the village and a few of these were successfully tracked on their round-trip migration. This led to identifying their migratory routes and more importantly locate their stop-over sites while on passage though India. The tracking effort also provided incredible insights into the lives of these small raptors. Particularly, that they undertake a non-stop flight of nearly 6000 km covered

in five and half to six days from Nagaland to Somalia in Africa across the Arabian Sea. The Amur Falcon satellite tracking in Nagaland proved to be a major success in creating mass awareness and garnering support of local Naga people bringing about a change in their attitude towards hunting practices and resulted in hunters turning protectors.

Around the same time when Amur Falcon conservation efforts were being initiated in Nagaland in 2013 similar steps were being taken up in Manipur. With the satellite tracking proving successful in creating positive influence on local people in Nagaland it was only natural that tracking of falcons from stop-over sites in Manipur be initiated. The Tamenglong district in Manipur which adjoins Nagaland was where large congregations of Amur Falcons was reported to occur every October at select sites along the rivers Barak and Irang. Thus, to support the conservation efforts and to gather detailed information on stop-over sites of Amur Falcons within the Manipur State, a satellite tracking study was initiated in October-November 2018. And, this report details the findings of this tracking study, which includes information on the Amur Falcon migration journeys, their breeding and non-breeding grounds, stop-over sites in Manipur and elsewhere, their diet and conservation efforts.

Satellite-tagged female Amur Falcon *Tamenglong*
© Amarjeet Kaur

Tracking the trans-equatorial migration of Amur Falcon *Falco amurensis*

Capture, tagging & release of Amur Falcons

The Amur Falcon tagging in Manipur was undertaken in two phases, first in 2018 and then in 2019 and was scheduled for the first week of November when congregation of falcons is at its peak. In 2018, a team from Hungary including Dr. Peter Palatitz along with Ms. Zsofia Sumegi from BirdLife Hungary, and Dr. Peter Fehervari from Hungarian Museum of Natural History, assisted in the capture and tagging of falcons at the Chiulon village along the Barak River in Tamenglong district. In 2019 season, Amur Falcons were captured at their stopover site in the mountain slopes along the Irang River near Puching (Khebuching) village in Tamenglong.

Amur Falcons at their stop-over sites in Manipur were captured between 16:00 to 20:00 hr using canopy mist-nets. A series of mist-nets (45 x 45 mm) spanning 12 meters in length and 5 meters in height held on bamboo poles were hoisted on average 20 to 25 feet up almost in line with canopy height of trees or bamboo in the area. Upon capture the falcons were placed in separate cardboard boxes and brought to the camp nearby. The following morning, the falcons were age-sexed and assessed for their body condition by examining the flight muscle mass, and then weighed. A set of morphometric measurements were also recorded. The feather condition in the falcons along with stage of moult was also examined. Based on the above a select number of Amur Falcons were identified for satellite tagging and these were fitted with the lightweight and a ~6 g Lotek PinPoint Solar GPS tag and 5 g Solar-Powered Microwave PTT like a backpack using a teflon harness. The tags were programmed to a duty cycle of 10 hours on followed by 24 hours off. The captured falcons were ringed on the left with a metal ring of the Bombay Natural History Society and a colour coded plastic ring on the right. Following this, the falcons were released at or near the site of capture.

Amur Falcons were trapped using mist nets hoisted 20 to 25 ft up in the canopy, here a local person from the village Chiulon assisting in hoisting up the mist-net.

Lotek

Lotek PinPoint Solar GPS tag ~6 g

Microwave Telemetry, Inc.

PTT-100 5 gram Solar PTT

The light-weight tags were fitted like a backpack using a specially made Teflon harness on the captured Amur Falcons.

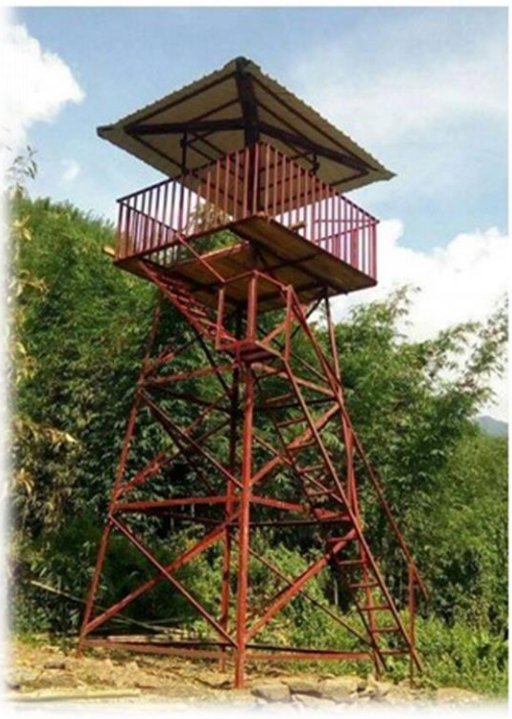
Processing and fitting of tags on the captured Amur Falcons by the Hungarian team: Dr. Peter Palatitz (right), Dr. Peter Fehervari (middle) and Ms. Zsofia Sumegi (left).

Release of the female Amur Falcon *Tamenglong* in 2018

Release of the male Amur Falcon *Manipur* in 2018

Hon'ble Minister, Forest & Environment, Shri Th. Shyamkumar at the 4th Amur Falcon Festival

Celebration of 4th Amur Falcon Festival at Bhalok village



Inauguration of two Watch Towers at Bhalok village along with others at Sonpram, Azuram and Bamgaijang villages.

The tagged Amur Falcons

In all 28 Amur Falcons were captured during this study: 5 of these were captured on 4th November 2018 at the Chiulon stop-over site in Tamenglong district that included three males, one female and one juvenile. Two of these: a male named *Manipur* after the name of the State, and one female named *Tamenglong* after the name of the district were tagged and released. The male falcon *Manipur* and the female *Tamenglong* were released on the 5th of November near the banks of Barak River at Chiulon stop-over site in the presence of Sri Kh Hitler Singh of Tamenglong Forest Division and the village Chairman. Post-release the tagging of Amur Falcons in Manipur was then celebrated at the "4th Amur Falcon festival" held at Unity Stadium Tamenglong chaired by Hon'ble Minister, Forest & Environment, Shri Th. Shyamkumar as Chief Guest. Parallelly, the 4th Amur Falcon Festival 2018 was also held at Bhalok (Phalong) village which was later declared as Amur Falcon Village.

In 2019, over a period of three days (29th October, 31st October, and 1st November), 23 Amur Falcons were captured at the Puching stop-over site in Tamenglong district. On 29th October 2019, a juvenile falcon was captured and was ringed and released. On 31st October, four falcons including three females and one juvenile were captured and of these, two female falcons, one named *Puching* after the name of the village and one *Irang* after the name of the Irang River were tagged and released. Another 18 falcons (6 males, 6 females and 6 juveniles) were captured on 1st November 2019, and of these two males and a female were satellite- tagged and released. The males were named *Chiulon* and *Phalong* after the name of the villages hosting large Amur Falcon congregations in Tamenglong while the female was named *Barak* after the name of the Barak River flowing along the Chiulon site. The tagging was followed by the celebration of 6th Amur Falcon festival at the Unity Stadium, Tamenglong.

Release of five satellite-tagged Amur Falcon at Puching village in 2019

Hon'ble Minister, Forest & Environment, Shri Th. Shyamkumar, President Shri K. Angami PCCF & HoFF, Shri Armstrong Pame IAS, Shri Arun RS DFO, Tamenglong gracing the 5th Amur Falcon Festival

Local communities attending the 5th Amur Falcon Festival

The conservation awareness along with the tracking of Amur Falcons have led to the annual celebration of the return of the Amur Falcon as Amur Falcon Festival


ARUNACHAL PRADESH
North Lakhimpur
Itanagar
Sibsagar
Jorhat
Tezpur
ASSAM
Mokokchung
NAGALAND
Lumding
Phalong ♂
Chiulon ♂
2835 m
Tamenglong
Chiulon
Puching
Manipur ♂
INDIA
Imphal
MANIPUR
Silchar
MANIPUR
Irang ♀
Tamenglong ♀
1697 m
Aizawl
MIZORAM
MIZO HILLS
Barak ♀
MYANMAR
Puching ♀
Lunglei
Haka
Mxd assembled by Corey LaMar, Sources: Esri, MapmyIndia, DeLorme, METI/NASA, Esri, HERE, Garmin, FAO, NOAA, USGS

Tracking data

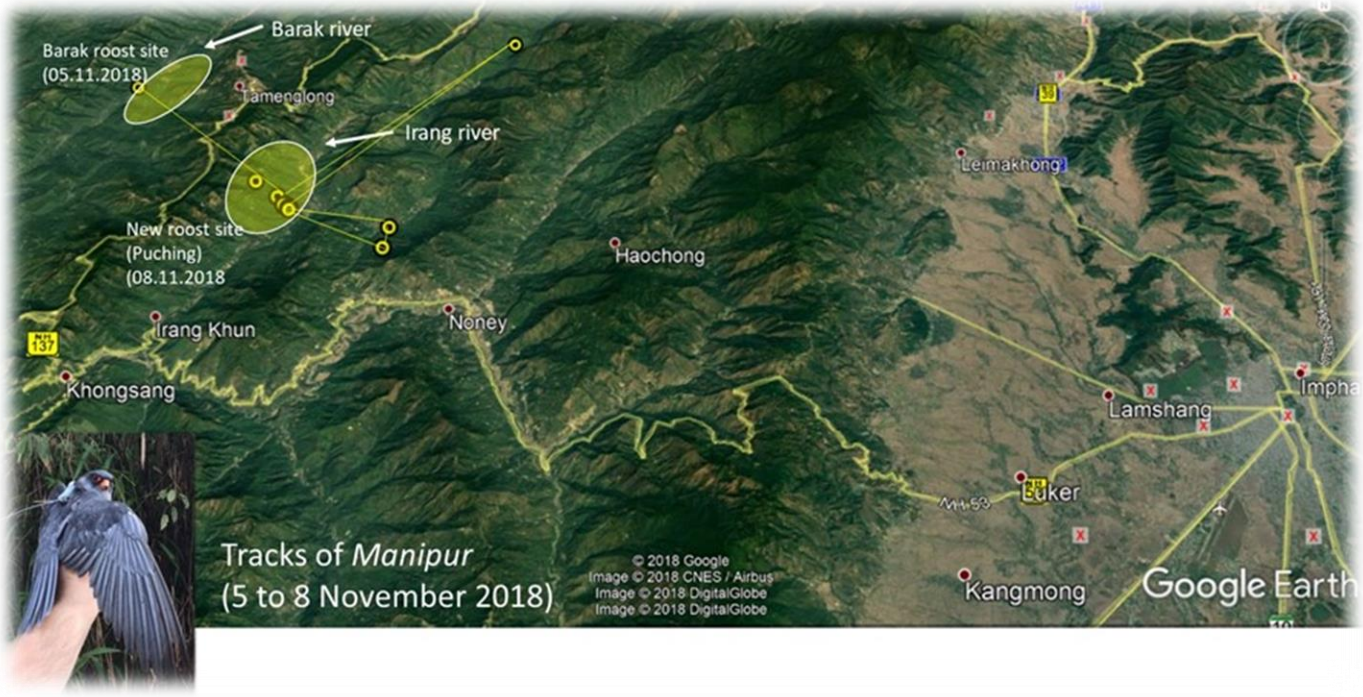
For each of the tagged falcons, we downloaded the movement data from the Argos website. The Argos satellite telemetry system estimates the location as per their accuracy in different classes in decreasing order: 3, 2, 1, 0, A, B and Z. In addition to the Kalman filtering automatically applied to the data by the Argos (Lowther et al. 2015), we also attempted to distinguish genuine movements by removing outliers by plotting the points in ArcGIS. The location data were archived on Movebank data repository. The location class 0, A, and B were excluded for all analysis except for depicting Amur Falcon tracks. From the location data we identified Amur Falcon stop-over sites during their migration as well as in the breeding and wintering grounds.

A total of 9894 locations from the four-satellite tagged Amur Falcons was collected during their period of tracking. And, of which 3878 (39%) locations belonged to good location class; 3, 2, and 1 (Table 1). The Amur Falcon *Manipur* post-tagging and release was hunted down by a local hunter at another stop-over site Puching in Tamenglong district. Analysis of the tracking data showed that immediately after release *Manipur* moved to a site 3 km southeast of Punglam village along the Irang river where it roosted. Thereafter, the next two days Manipur foraged in around the Irang river between Punglam Kabui Khullen - Nagaching – Bhalok and returned to roost along the Irang river. On 9th November evening DFO, Tamenglong received information about a falcon with a satellite tag attached having been hunted at Puching (Kebuching) village. The tag was handed over to the forest department personnel in Noney and it was confirmed to be the same one deployed on the falcon Manipur. From the data gathered this bird was killed on 8th morning at the Irang river roost site (Puching) which was later revealed to be one of the major stop-over sites in the region. During the three days of tracking, *Manipur* transmitted 14 GPS and 5 Argos locations.

Even though one of the tagged Amur Falcon was killed, it did help identify other roost sites and that the problem of hunting persists. Tamenglong district administration immediately issued an order strictly prohibiting use of air guns along Irang river near Gwan gram,

Puching, Rangkhung and Taobam villages. The Forest Department with support of District Administration and Police along with village leaders had also stepped-up monitoring and protection of the Amur falcons at all the roost sites there. It was found that Amur falcons roost at several other sites in Tamenglong and adjoining districts and this incident called for spreading conservation awareness activities in all villages in the region.

While the female falcon *Tamenglong* tagged at the same time crossed the Arabian Sea and ceased transmission after 40 days of tracking at Zambia on its way to non-breeding grounds. *Barak* made one trip to its non-breeding grounds in southern Africa and on its way to breeding grounds ceased transmission in Northeast India. *Phalong* and *Puching* could not be tracked successfully due to transmitter failure. Chiulon and Irang made three successful trips to the non-breeding grounds and two to the breeding grounds and both ceased transmission at their non-breeding grounds. The tracks of all the tagged falcons are shown in Figure 1 along with the individual falcon tracks are shown with their tracking duration (Figure 2 to 5) and their migration is described in detail in later sections.



EastMojo
Nov 10, 2018 at 18:31 •

#**Manipur**: The migratory bird was recently satellite-tagged and named 'Manipur'; found killed by unknown miscreants at Kebuching bordering Tamenglong district
#**EastStory** #**NortheastIndia**

EASTMOJO.COM
Manipur govt mulling ban on hunting guns over amur falcon killing

Following the killing of Amur Falcon *Manipur*, conservation efforts in several remote villages were strengthened. Here the Chairman of Puching village is seen with the deposited airguns of the local people in 2019.

Table 1 Satellite telemetry data of the seven tagged Amur Falcons during the period of tagging (2018 and 2019) including their duration of tracking along with the number of locations of each Amur Falcon per Argos location class data

S. No	Falcon	Weight (g) of falcon at the time of tagging	First Date of Tracking	Last Date of Tracking	Tracking Duration (Days)	Argos Location Class Data						Total Locations
						3	2	1	0	A	B	
1	*Manipur* ♂	149	05-11-2018	08-11-2018	4*	-	-	-	-	-	-	-
2	*Tamenglong* ♀	164	05-11-2018	14-12-2018	40	15	16	17	04	-	3	55
3	*Puching* ♀	160	31-10-2019	-	-*	-	-	-	-	-	-	-
4	*Irang* ♀*	155	31-10-2019	18-12-2021	780	537	477	676	664	389	917	3660
5	*Chiulon* ♂*	150	01-11-2019	04-02-2022	827	539	542	874	1147	835	2132	6069
6	*Phalong* ♂	169	01-11-2019	-	-*	-	-	-	-	-	-	-
7	*Barak* ♀	185	01-11-2019	29-05-2020	211	130	88	127	88	22	46	501
					Total	**1179**	**1076**	**1623**	**1835**	**1198**	**2983**	**9894**

*The marked falcons were fitted with the solar-powered microwave PTT while the others were tagged using the PinPoint GPS tags. *Post-release, the falcon *Manipur* was killed by the local hunter & the tag was retrieved. *Two falcons could not be tracked due to tag failure.

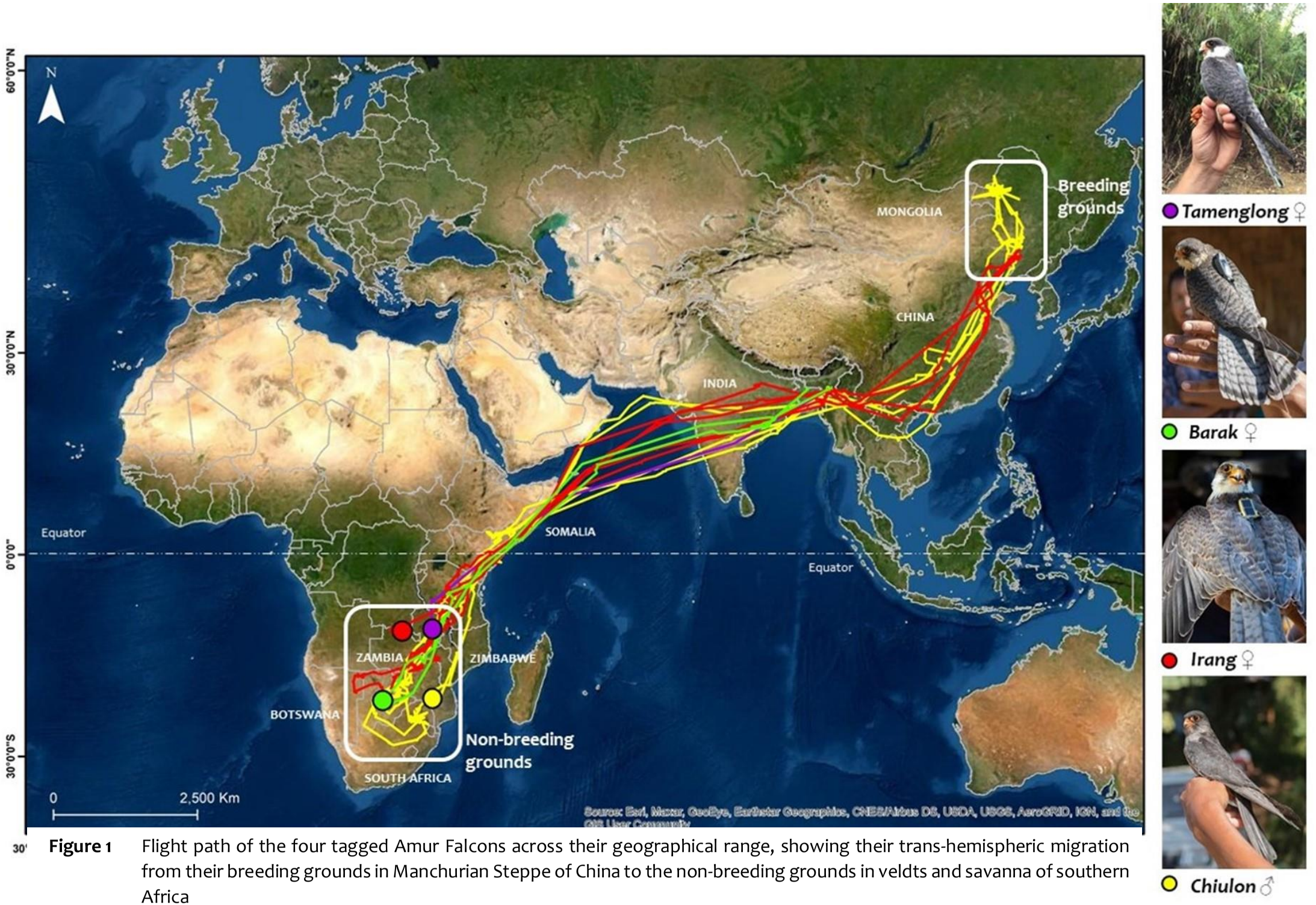


Figure 1 Flight path of the four tagged Amur Falcons across their geographical range, showing their trans-hemispheric migration from their breeding grounds in Manchurian Steppe of China to the non-breeding grounds in veldts and savanna of southern Africa

Figure 2 Track of satellite-tagged Amur Falcon Tamenglong tagged on 5th November 2018 in Chiulon village in Tamenglong district. Tamenglong last location was from North Luangwa National Park in northeast Zambia on 14th November 2018.

Figure 3 Track of satellite-tagged Amur Falcon *Irang* tagged and released on 31st October 2019 in Puching village in Tamenglong district. *Irang* is currently active and is at its non-breeding grounds in Southern Africa.

Figure 4 Track of satellite-tagged Amur Falcon Chiulon tagged and released on 1st November 2019 in Puching village in Tamenglong district. Chiulon is currently active and is at its non-breeding grounds in Southern Africa.

Figure 5 Track of satellite-tagged Amur Falcon Barak tagged and released on 1st November 2019 in Puching village in Tamenglong district. Barak is currently inactive and after completing its one trip to non-breeding grounds, it stopped transmitting during its spring migration at Bangladesh-Assam border.

Breeding Sites

Two Amur Falcons *Irang* and *Chiulon* could be tracked to their breeding grounds in northeast China. Across two years of tracking, both *Irang* and *Chiulon* arrived at the breeding grounds in the month of May. Interestingly, the dates of arrival of both the falcons were same in 2020 and 2021. On an average *Irang* and *Chiulon* spent 145 days (range: 137 – 157) at the breeding grounds in China (Table 2) and showed fidelity to their breeding sites returning to the same site in the following year (Figure 6). When compared with other Amur Falcons which were tracked in Nagaland, *Chiulon* went furthest towards the northwest China at Inner Mongolia Province where it spent two breeding seasons near to Hailar city. Unlike other tagged falcons, Irang went to the eastern China border where in consecutive two years where it spent the breeding seasons near Shenyang city of northeast Liaoning Province.

Table 2 Number of days spent by the satellite – tagged Amur Falcons across years along with the breeding sites across their breeding range in China. (* represents more than one breeding site in a season)

Falcon	Year	Arrival	Departure	Duration	Breeding Site	Province	Country
Irang	2020	25.05.2020	19.10.2020	148 (125,13) *	Shenyang	Liaoning	China
					Luoma Lake	Jiangsu	China
Chiulon	2020	14.05.2020	17.10.2020	157 (119,11,18) *	Hailar	Inner Mongolia Province	China
					Zhanjiang	Guangdong	China
					Zaozhuang	Shangdong	China
Irang	2021	25.05.2021	19.10.2021	137	Shenyang	Liaoning	China
Chiulon	2021	14.05.2021	28.09.2021	138 (111,14,10) *	Hailar	Inner Mongolia Province	China
					Tuquan	Inner Mongolia	China
					Zhanjiang	Guangdong	China

Figure 6 Amur Falcon breeding sites identified from the satellite tracking data (Kernel density) depicted along with their breeding range as reported in the Birdlife International 2021 (red dashed polygon) in the northern Steppe of China.

Non- breeding Sites

The Amur Falcons arrived at their non-breeding grounds in the months of December-January across years of tracking. The tagged falcons spent their austral summer in the grasslands (veldts) and savannah region of southern Africa (Botswana, Mozambique, Zimbabwe, and South Africa) spending on an average 95 days (range: 57 – 112) before departing in March-April (Table 3, Figure 7). Barak was tracked only for a one trip to its non-breeding grounds where it spent maximum days at Central Kalahari Game Reserve in Botswana while *Chiulon* and *Irang* were tracked for three non-breeding seasons. Both *Irang* and *Chiulon* showed high site fidelity to the sites where they spent their non – breeding season in consecutive years. Across years at the non-breeding grounds *Chiulon* and *Irang* moved between different sites spending maximum duration at sites in Zimbabwe, Botswana, and South Africa.

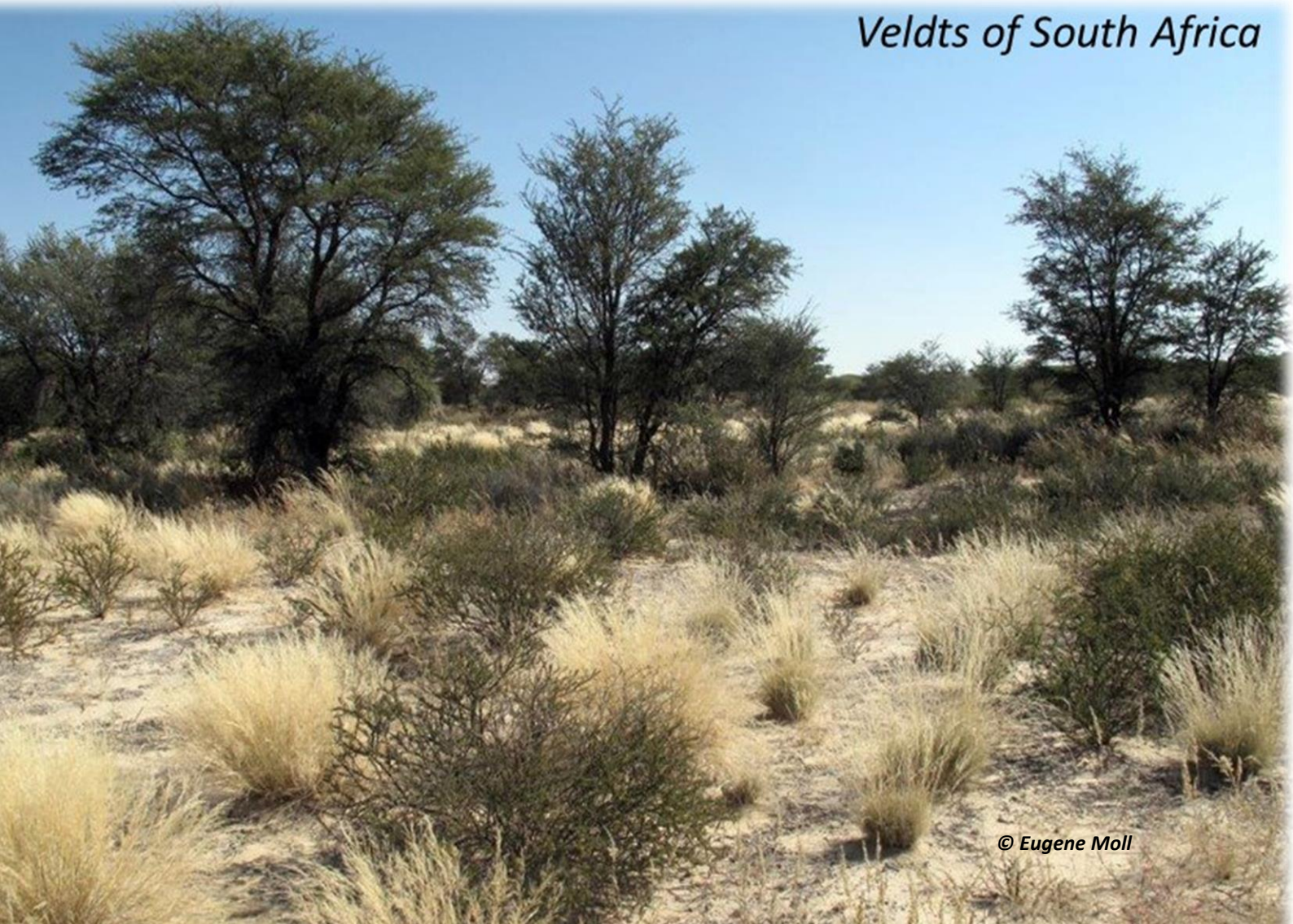


Table 3 Number of days spent by the satellite-tagged Amur Falcons across years along with the non-breeding sites across their non-breeding range in Southern Africa, (* represents more than one site in a single season, # represents last tracking location).

Falcon	Year	Arrival	Departure	Duration	Non-breeding Site	Province	Country
Barak	2019 – 2020	27.01.2020	24.03.2020	57 (5,52) *	Hwange National Park	Hwange District	Zimbabwe
					Central Kalahari Game Reserve	Central Botswana	Botswana
Irang	2019 – 2020	03.01.2020	03.04.2020	92 (19,9,60) *	Cahora Bassa	Tete Province	Mozambique
					Matusadona National Park	Northern Zimbabwe	Zimbabwe
					Lake Kariba	Central Africa	Zimbabwe
Chiulon	2019 – 2020	08.12.2019	24.03.2020	107 (5,8,4,86) *	Hwange National Park	Hwange District	Zimbabwe
					Letlhakane	Central District	Botswana
					Central Kalahari Game Reserve, Kgalagadi Transfrontier Park	Central Botswana	Botswana
Irang	2020 – 2021	05.12.2020	27.03.2021	112 (11,32,69) *	Hwange National Park	Hwange District	Zimbabwe
					Khaudum Game Reserve	Kalahari Desert	Namibia
					Lake Kariba	Central Africa	Zimbabwe
Chiulon	2020 – 2021	05.12.2020	21.03.2021	106 (27,79) *	Hwange National Park	Hwange District	Zimbabwe
					Marble hall	Limpopo	South Africa
Chiulon	2021 – 2022	03.12.2021	04.02.2020	63#	Marble hall	Limpopo	South Africa
Irang	2021 – 2022	18.12.2021 #	-	-	Lake Kariba	Central Africa	Zimbabwe

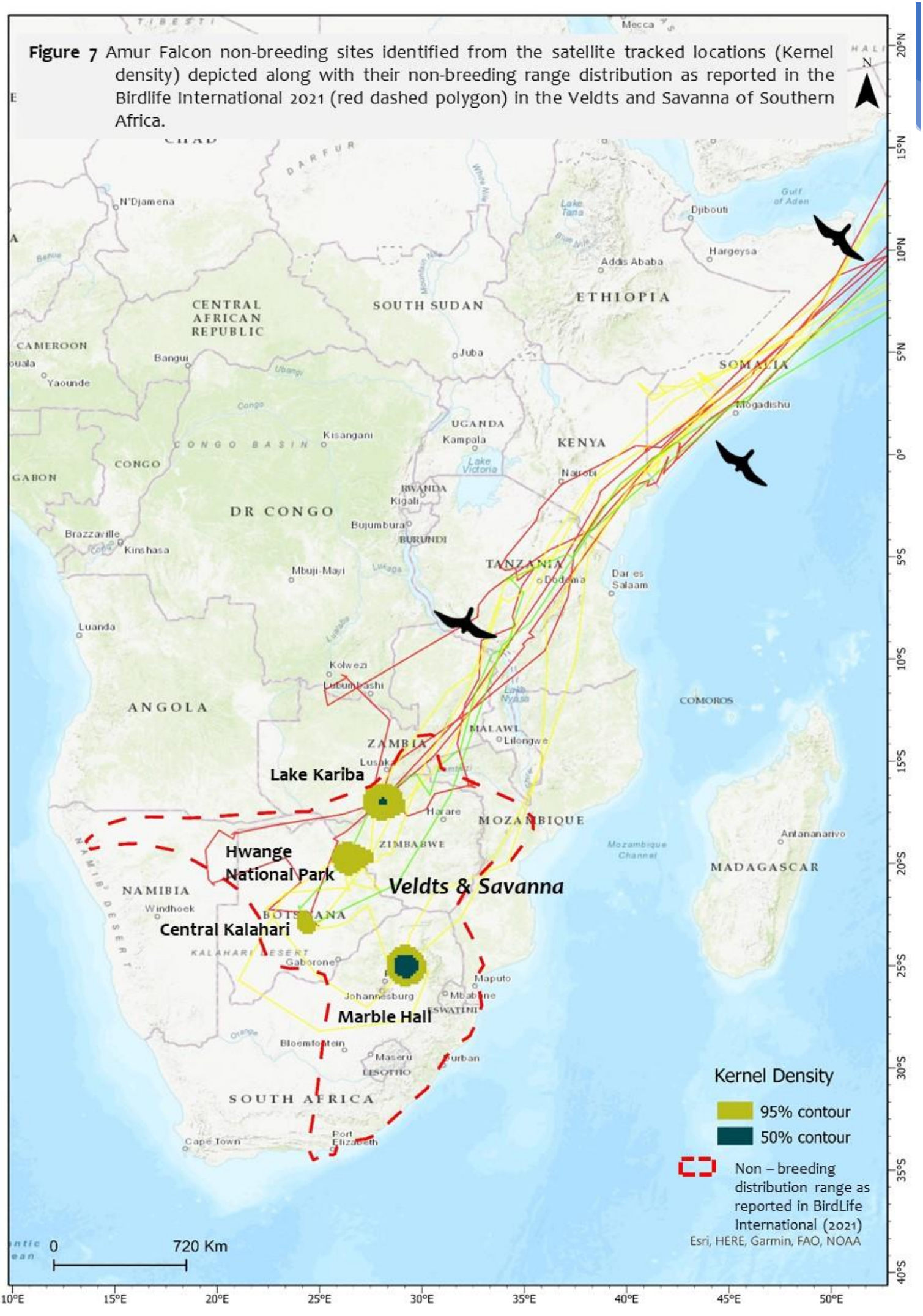


Figure 7 Amur Falcon non-breeding sites identified from the satellite tracked locations (Kernel density) depicted along with their non-breeding range distribution as reported in the Birdlife International 2021 (red dashed polygon) in the Veldts and Savanna of Southern Africa.

We divided the autumn and spring migration into three phases each to understand the migration of falcons. For autumn, first phase of migration depicts flight between breeding grounds to the first major stop-over in Northeast India, second phase depicts flight from Northeast India to Somalia which involves the Arabian Sea crossing, and third phase from Somalia to the non-breeding grounds in Southern Africa. Similarly, the three phases of spring migration are first from Southern Africa to spring stop-over in Somalia, second phase from Somalia to India and third from India to the breeding grounds in China.

The tagged Amur Falcons on their migration either passed through the territory or stopped over in **21** countries including India. This included China, Mongolia, Vietnam, Laos, Thailand, Myanmar, Bangladesh, Pakistan, Oman, Somalia, Ethiopia, Kenya, Tanzania, Malawi, Zambia, Zimbabwe, Mozambique, Botswana, Namibia, and South Africa.

Autumn Migration

The tagged Amur Falcons *Irang* and *Chiulon* departed on their southbound migration from their breeding grounds in China in mid-September to mid-October. The first phase of migration took an average of 22 days (range: 9 – 49 days) to reach their stop-over sites in Northeast India where *Irang* in 2021 took longer (49 days) to reach Northeast India. After spending about two weeks at the stop-over sites in Northeast India the tagged falcons departed on their migration to Africa arriving in Somalia, close to 6000 km covered in an average of 6.5 days. This journey involved two oceanic crossings, at first about 700 km stretch over the Bay of Bengal to enter Deccan region in India and thereafter around 3000 km over the Arabian Sea to reach Somalia in Africa. In some years, few of the tagged birds, however, avoided Bay of Bengal crossing and opted a land route from Northeast India to western coast of India.

From Somalia, the Amur Falcons on an average took 24days (range: 10 – 53 days) to reach their non-breeding grounds in southern Africa. Of the four Amur Falcons which could be tracked for at least one migratory journey to the southern Africa, Tamenglong ceased transmission before reaching its non-breeding grounds in North Luangwa National Park, Zimbabwe on 14th December 2018. The three falcons, *Barak, Chiulon* and *Irang* reached the non-breeding grounds in their first year of tracking between December-January. In 2020 and 2021, *Irang* and *Chiulon* arrived at the non-breeding grounds in the first week of December, except in 2021 where *Irang* reached the southern African region in mid-December. The tagged falcons arrived at the non-breeding grounds between mid-December to early January and stayed on till March and early April. To complete the entire autumn migration, starting from the breeding grounds to the non-breeding grounds, the Amur Falcons took on an average 63 days (range: 47 – 91) (Table 5).

Spring Migration

The tagged Amur Falcons started on their spring migration from the non-breeding grounds in late March to early April. For the first phase of spring migration, the tagged Amur Falcons first flew northwards to reach Somalia, where all the falcons flew over the land in African continent and took on an average of 15 days (range: 8 – 24 days). During spring migration, the tagged falcons took a halt in Somalia where they spent an average of 14 days before commencing their non-stop flights over the Arabian Sea to reach the Indian landmass. During spring migration, while crossing the Arabian Sea, the Amur Falcons took a northerly flight route which was different from their autumn flight paths. Upon leaving Somalia, all the tagged falcons, flew near the Socotra Island, covered a distance of about 2500 km over the Arabian Sea and entered western coasts of India near Gujarat and Mumbai in western coasts of India. On an average, Amur Falcons took five days from Somalia to reach Northeast India and covered an average distance of 6,000 km.

For the third phase of spring migration Amur Falcon took a shorter number of days than that of autumn migration, an average of 16 days (range: 9 – 20 days) to reach their breeding grounds from northeast Indian region. The tagged falcons completed their spring

migration from non-breeding to breeding grounds in about 49 days (range: 39 – 54) which was faster than the autumn migration (Table 5).

Table 5 Number of days the tagged Amur Falcons took on their spring migration (back from non-breeding grounds to the breeding grounds) and on autumn migration (from the breeding grounds to reach their non-breeding grounds)

Falcon	Year	Autumn Migration (From breeding to non-breeding grounds)			Spring Migration (From non-breeding to breeding grounds)		
		Departure	Arrival	Duration (No. of days)	Departure	Arrival	Duration (No. of days)
Irang	2020	19-10-2020	05-12-2020	47	03-04-2020	25-05-2020	52
Chiulon	2020	17-10-2020	05-12-2020	49	24-03-2020	14-05-2020	51
Irang	2021	18-09-2021	18-12-2021	91	27-03-2021	05-05-2021	39
Chiulon	2021	28-09-2021	03-12-2021	66	21-03-2021	14-05-2021	54

Cyclone *Amphan* and *Barak*

The northbound migration of the satellite tagged Amur Falcon *Barak* towards its breeding grounds in China was faced by the Tropical Cyclone *Amphan* over the Bay of Bengal. The Cyclone formed on May 16, 2020 in the Northern Indian Ocean and became the most powerful cyclone to form in the Bay of Bengal to date. Making the landfall near the India-Bangladesh border along the northern edge of the Bay of Bengal on May 20, 2020 with winds measuring 165 km per hour (NASA 2020) (Figure 8).

This was during the time of *Barak* traveling across the Indian landscapes near the coast of Bay of Bengal. In order to avoid the strong winds developing due to the Cyclone, Barak appeared to have taken a detour on its northbound route and travelled back to Chhattisgarh. And just after the Cyclone *Amphan* made the landfall on May 20, 2020 Barak again started its travel northwards on May 21, 2020 taking benefits from the Cyclone tailwinds to reach Bangladesh – Meghalaya border where it last stopped transmission (Figure 9). This was also observed by Kumar (2021) where the Amur Falcon named Longleng tagged in Nagaland was also seen following the tailwinds of Cyclone *Fani* developed over the Bay of Bengal in 2019.

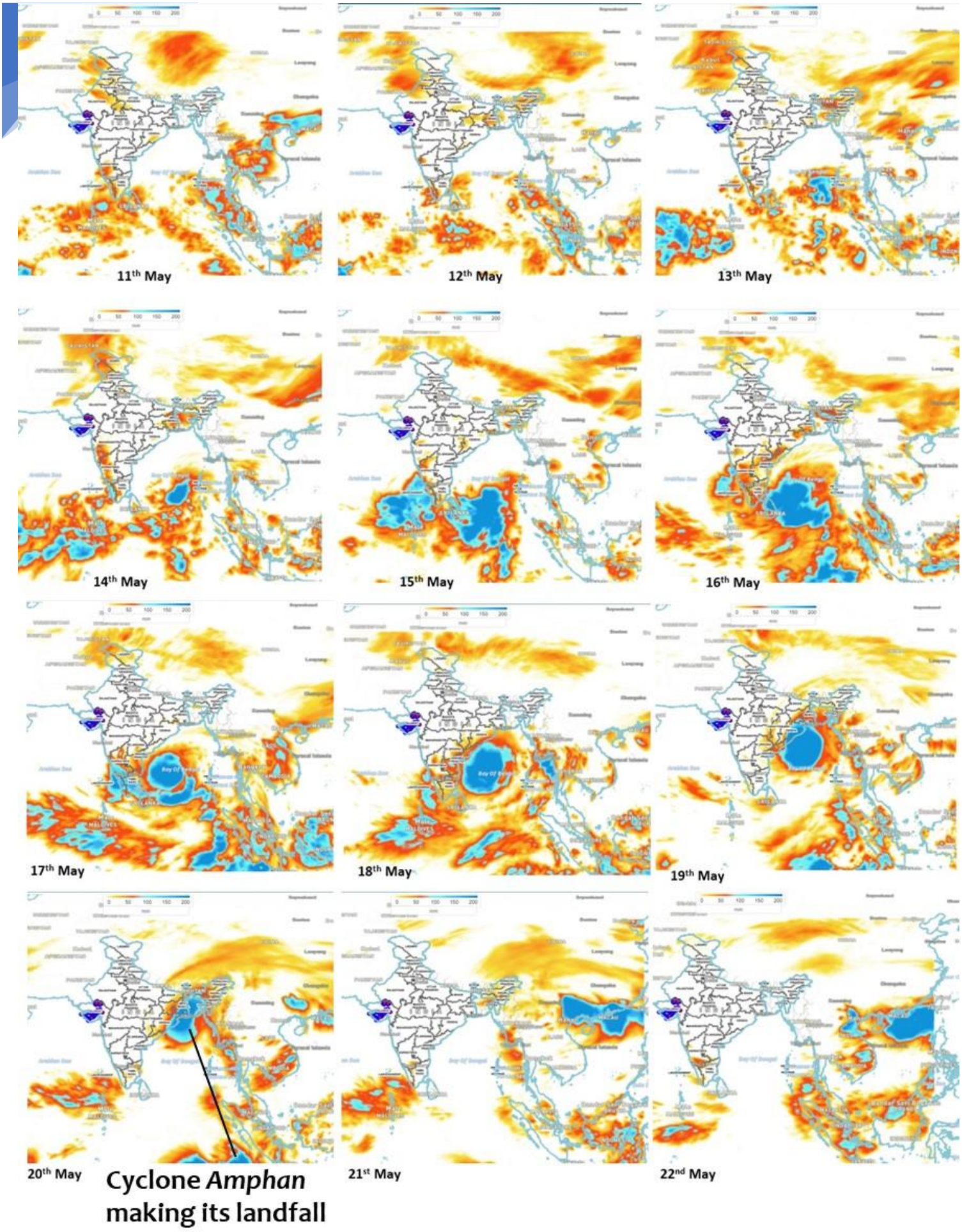


Figure 8 Development of Cyclone *Amphan* at the Bay of Bengal from 11th of May 2020 to 22nd May 2020. This was the time of Amur Falcon *Barak* crossing across the Indian landscape over Chhattisgarh and Odisha (Source: VEDAS 2022).

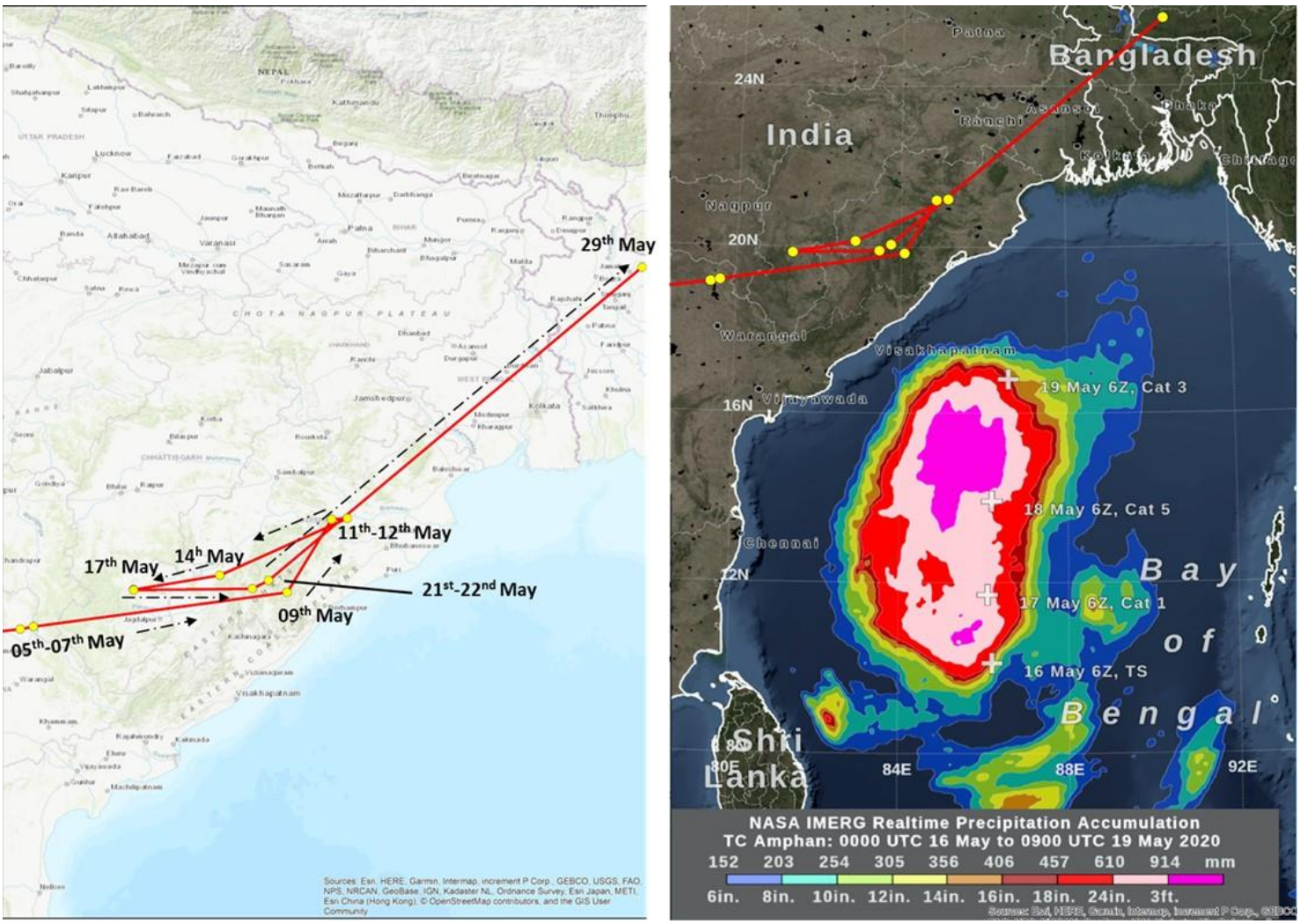


Figure 9 Flight path of Amur Falcon *Barak* crossing across the Indian landscape over Chhattisgarh and then to Odisha (5th May to 12th May), with the development of *Amphan* cyclone, Barak was seen traveling back to halt at sites in Chhattisgarh (12th May to 17th May) and waited for better weather conditions to start its travel back to Odisha and thereafter north and where it stopped transmitting near Meghalaya – Bangladesh border (29th May) (Left). Track of Barak along with the Cyclone *Amphan* over the Bay of Bengal (Image Credit: Owen Kelly, NASA GSFC).

The Imphal Valley Gateway

During the southbound migration, the tagged Amur Falcons flew southwards towards southeast Asia and after crossing Thailand instead of taking straight line course to the Arakan Mountains in Myanmar, took a route appeared to be a detour in the northwest direction towards Northeast India. This gave an interesting insight on how the falcons are using the gap in the region full of high mountains as they funnelled through the narrow Imphal valley gap in Manipur (Figure 10 A). On their return migration, all the tagged falcons again crossed the Northeast India from Imphal valley, however, few others also flew in different directions, depicting no sign of funnelling in the region. However, these paths seemed to be the result of overall flight orientation of falcons during their overland journey over India (Figure 10 B).

It is interesting to see the elevation profile (Figure 10 C) of the region depicting the significance of the Imphal river valley gap in the funnelling in of Amur Falcons in autumn. As this gap is located right in the middle of Naga hills to the north and Chin hills to the south is of considerably lower elevation, allowing the Amur Falcons to pass through without facing any barrier of crossing high mountains. All of the tagged falcons upon entering into Manipur, headed first to Tamenglong district. Here the falcons which were tagged in Manipur, namely *Chiulon* and *Irang* moved locally to their stop-over sites in Tamenglong while those tagged in Nagaland took a northward route to finally enter the Naga hills in Nagaland to stop-over. This flight path clearly suggests that the Amur Falcons avoid crossing high Naga hills to directly reach their stop-over sites in Nagaland.

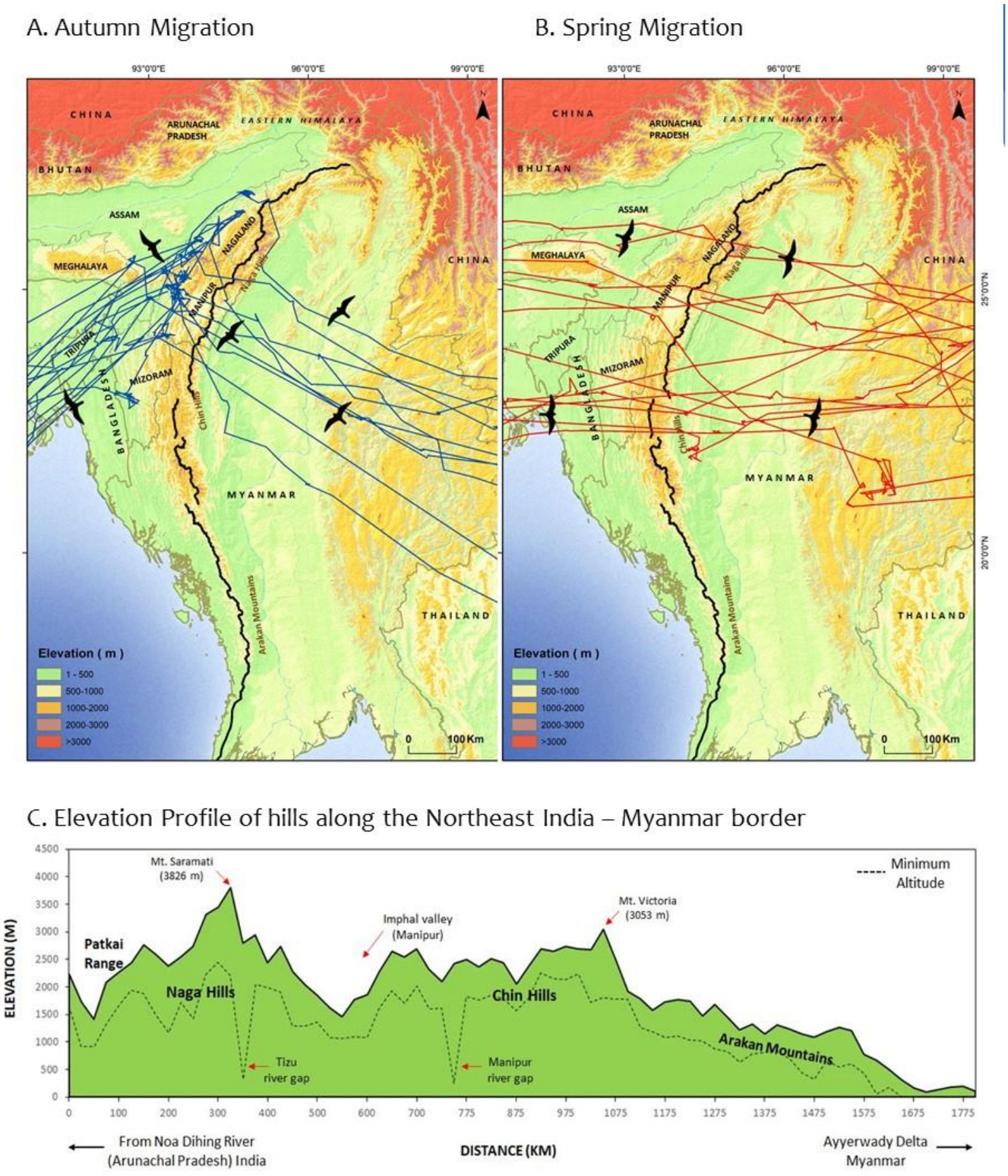


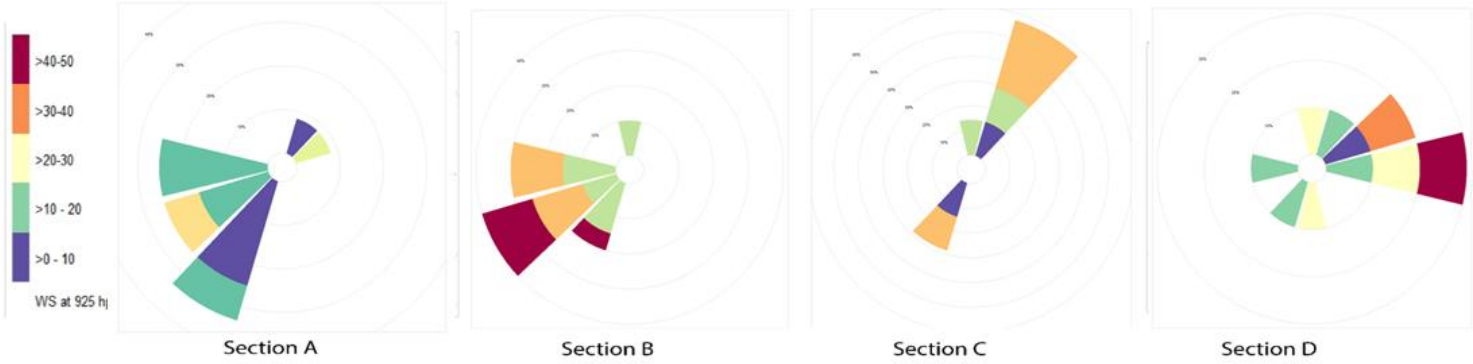
Figure 10 Amur Falcon (tagged in Manipur and Nagaland) flight paths during their southbound/autumn migration (A) and during their northbound/spring migration (B), along with the elevation profile of major hills in the region (C) that the falcons encounter during their passage. It was observed that the falcons during their southbound migration diverted their course of flight on approaching Myanmar and flew northwards converging into the Imphal valley of lower elevation and then flew northwards to reach stop-over sites in the Naga hills. While during spring migration, no convergence of Amur Falcons was observed undertaking different flight paths.

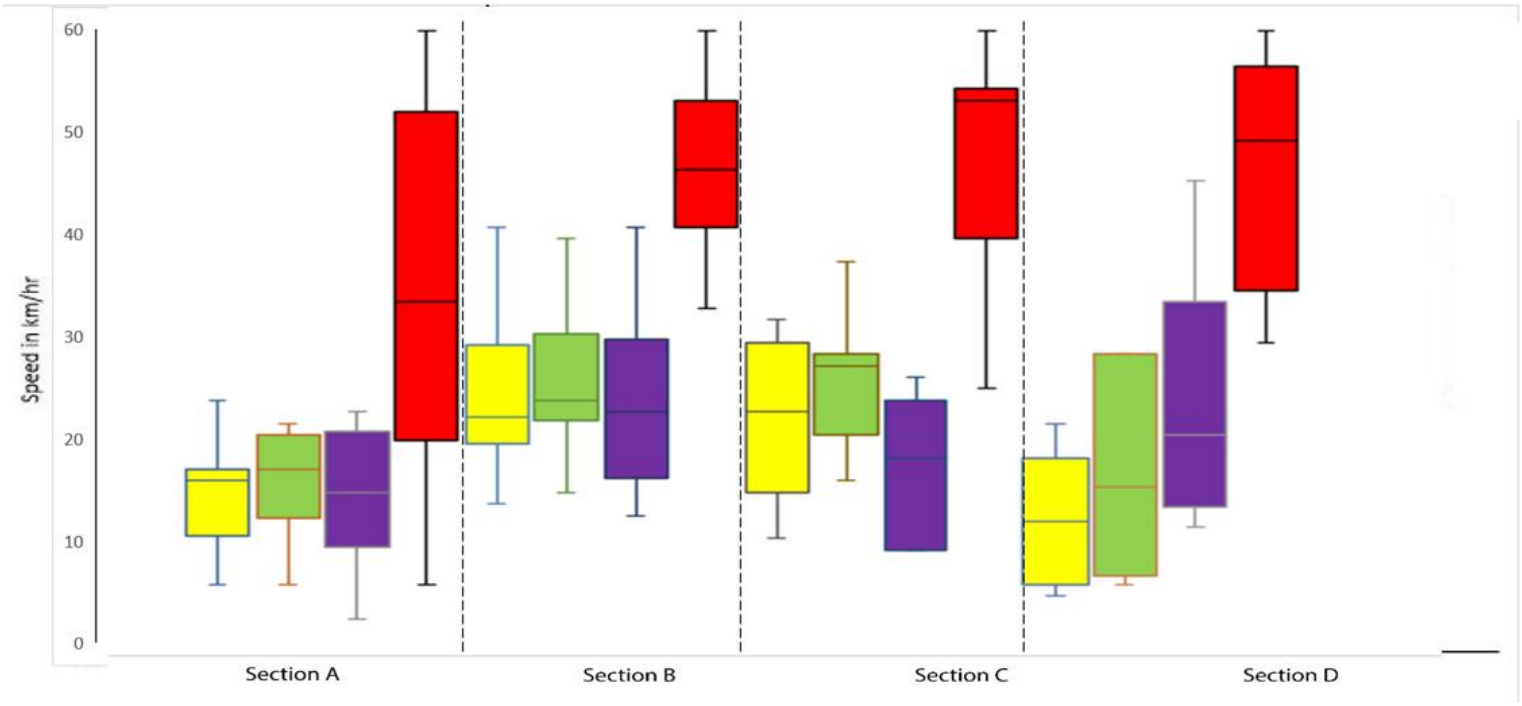
Across the four sections of autumn (A – from Northeast India to south-west coast of India, B - from south-west coast of India to Somalia) and spring migration (C – from Somalia to western coast of India, D – from western coast of India to Northeast India) during the crossing of Indian Subcontinent and the Arabian Sea, the speed of Amur Falcons was found to be not significantly different (*Kruskal Wallis Test*: p- value = 0.08 > 0.05). However, the average speed of Amur Falcons differed at each of the four sections where in all the speed while crossing the ocean (39 km/hr for section B and 40 km/hr for section C) was greater than that of land (29 km/hr for section A and 40 km/hr for section D) (Figure 11).

Further, along the Amur Falcon flight paths, the speed of the prevalent winds at height 850 hPa during autumn (average 17.1 km/h) and spring migration (17.6 km/h) was found to be not significantly different (*Kruskal Wallis test*: p-value = 0.09 > 0.05) and similar was the case at height 925 hPa (*Kruskal Wallis test*: p-value = 0.008 > 0.05) during autumn (19.4 km/h) and spring migration (18.5 km/h). At what heights the Amur Falcons fly during their migration specially while crossing the Arabian Sea, whether at 850 hpa or 925 hpa could not be discerned. The wind direction, on the other hand, at both 925 and 850 hPa was predominantly oriented southeast to west during autumn migration and northeast to east during spring migration, appearing to facilitate the Amur Falcons flights (Figure 11).

© Zuthunglo Patton

Figure 11 Amur Falcon migration divided into four sections over land and ocean during their autumn migration (arrows A & B), and spring migration (arrows C & D) (top). The wind-rose diagrams shown in the middle depict the wind speed and direction during migration at each of the four sections at 850 hpa (Amur Falcon flight altitude). The boxplot at the bottom shows the Amur Falcon speed (in red) across four sections along with the wind speed at three flight altitudes (1000 hpa in yellow, 925 hpa in green and 850 hpa in purple).






© Amarjeet Kaur

Stop-over Sites

We identified three major Amur Falcon stop-over sites in Tamenglong district of Manipur namely: Chiulon, Phalong and Puching hosting huge congregations of Amur Falcons stopping over in the region in autumn. The stop-over site in Puching village was identified after the incident of hunting down of the falcon Manipur which was satellite tagged in 2018. The stop-over sites were located predominantly between 180-800 m elevation and on North-east to Southwest aspects with moderate to steep slopes. The sites were further found in the vicinity of rivers that originate in the Naga hills and drain north-westwards into the river Brahmaputra. The Chiulon stop-over site was found to be located on a mountain slope facing the major river flowing in the region, the Barak River. While Puching stop-over site was found to be facing Irang River which is the major river in the region. Across the stop-over sites the vegetation type was primarily bamboo brakes and secondary forests, a result of past slash and burn agriculture in the region. Few sites Amur Falcon stop-over sites were found to be plantations of Teak *Tectona grandis* and Beech wood *Gmelina arborea*, and primary forests.

Chiulon Stop-over site located on the banks of Barak River

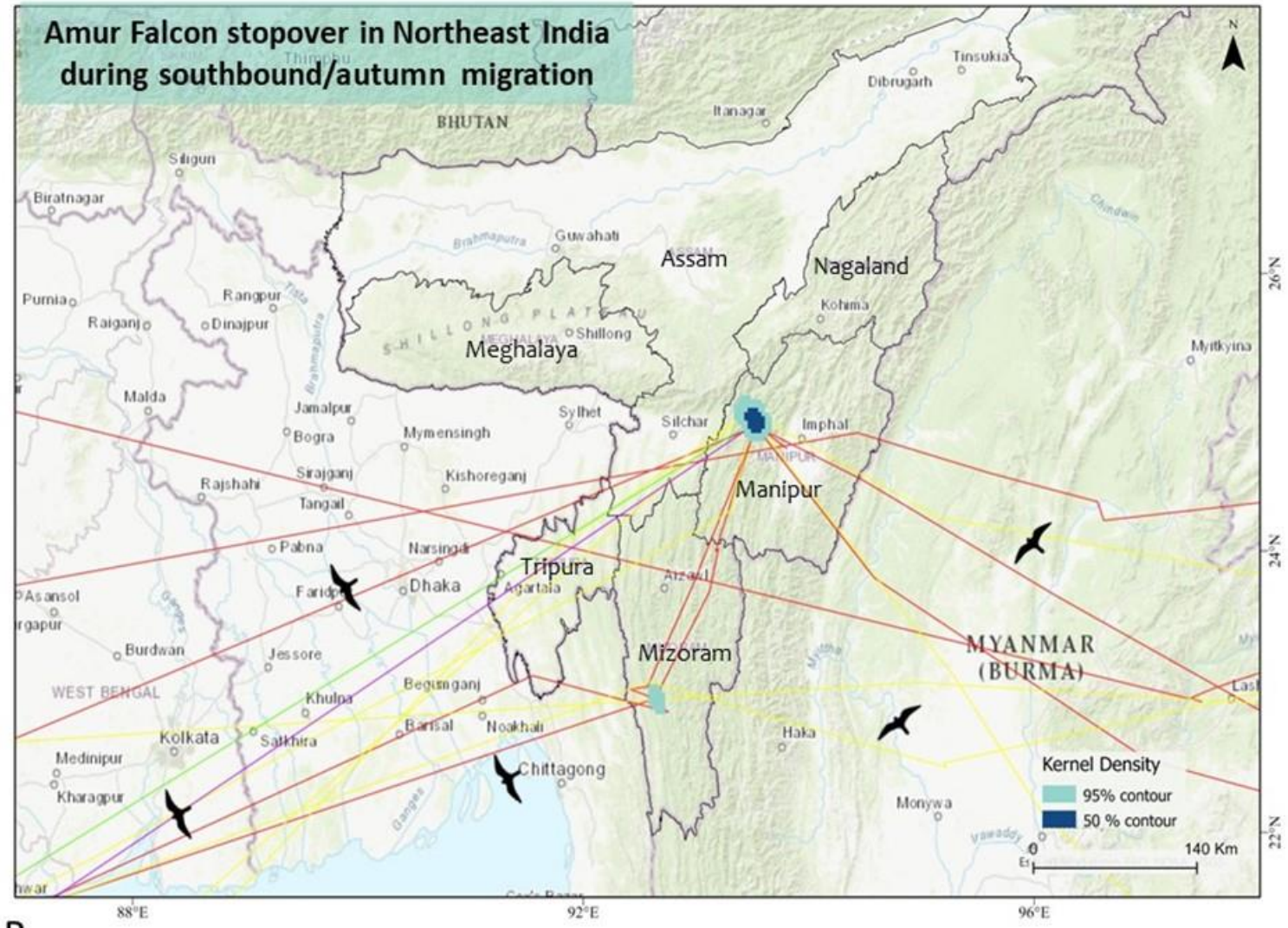
Puching Stop-over site located on the banks of Irang River

Stop-over Sites during Autumn Migration

From the tracking data it was seen that the falcons tagged in Manipur spent the consecutive stop-over at sites in Manipur itself, showing high-site and regional fidelity. *Irang* which was captured, tagged and release at the Puching stop-over site, returned back to the site in the next two years of tracking where it spent the entire stop-over duration. However, in 2019 and 2020, after departing from the stop-over, *Irang* moved to another site near Mizo hills, Lunglei near to Phairang River tributary of Lunglei River in Mizoram where it spent few days in 2019 and 2020 before starting its southbound migration to the non-breeding grounds. While in 2019 *Chiulon* post-tagging and release moved from Puching stop-over site to another site north of Tamenglong town, Chiulon on the banks of Barak River where it spent the rest of the stop-over period before undertaking the southbound migration. In 2020 and 2021, *Chiulon* also showed high- site affinity as it returned to select stop-over sites first to Puching and then to Chiulon (Figure 12 a).

The data from the tagged Amur Falcons showed that their arrival and stop-over duration in Manipur during autumn migration was highly variable across individuals and across years (Figure 12 b). In 2020, *Irang* returned to the stop-over sites in the region towards the end of October while in 2021 it reached the stop-over grounds almost in the second week of November. While Chiulon in 2020 timed its arrival to the stop-over site almost at the same time with Irang, however, in 2021, it arrived early in the third week of October. Across the two years of tracking *Irang* and *Chiulon* stopped over for an average of 13 days (range: 7-17 days). The timing of departure from the stop-over sites was observed to be similar as *Irang* in both the years departed in the second week of November while *Chiulon* in the first week of November (Figure 12 b). During spring migration, Amur Falcons passed through the region without making a stop to their breeding sites.

A



B

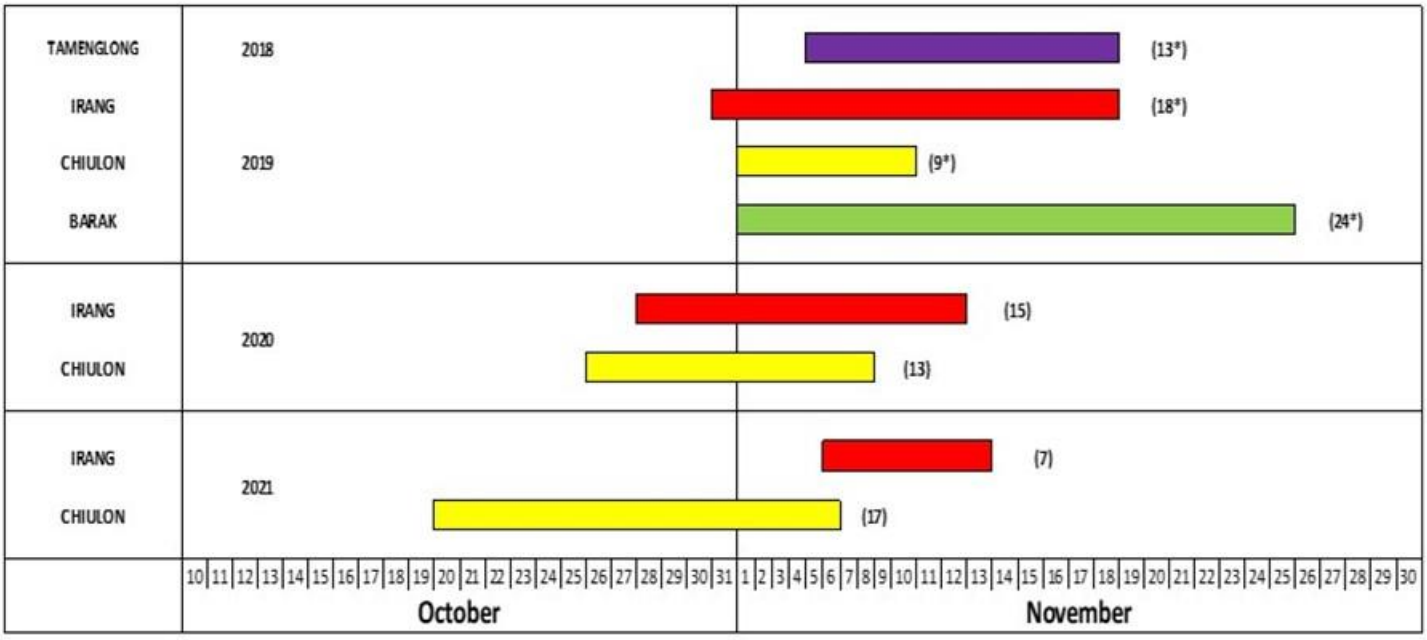
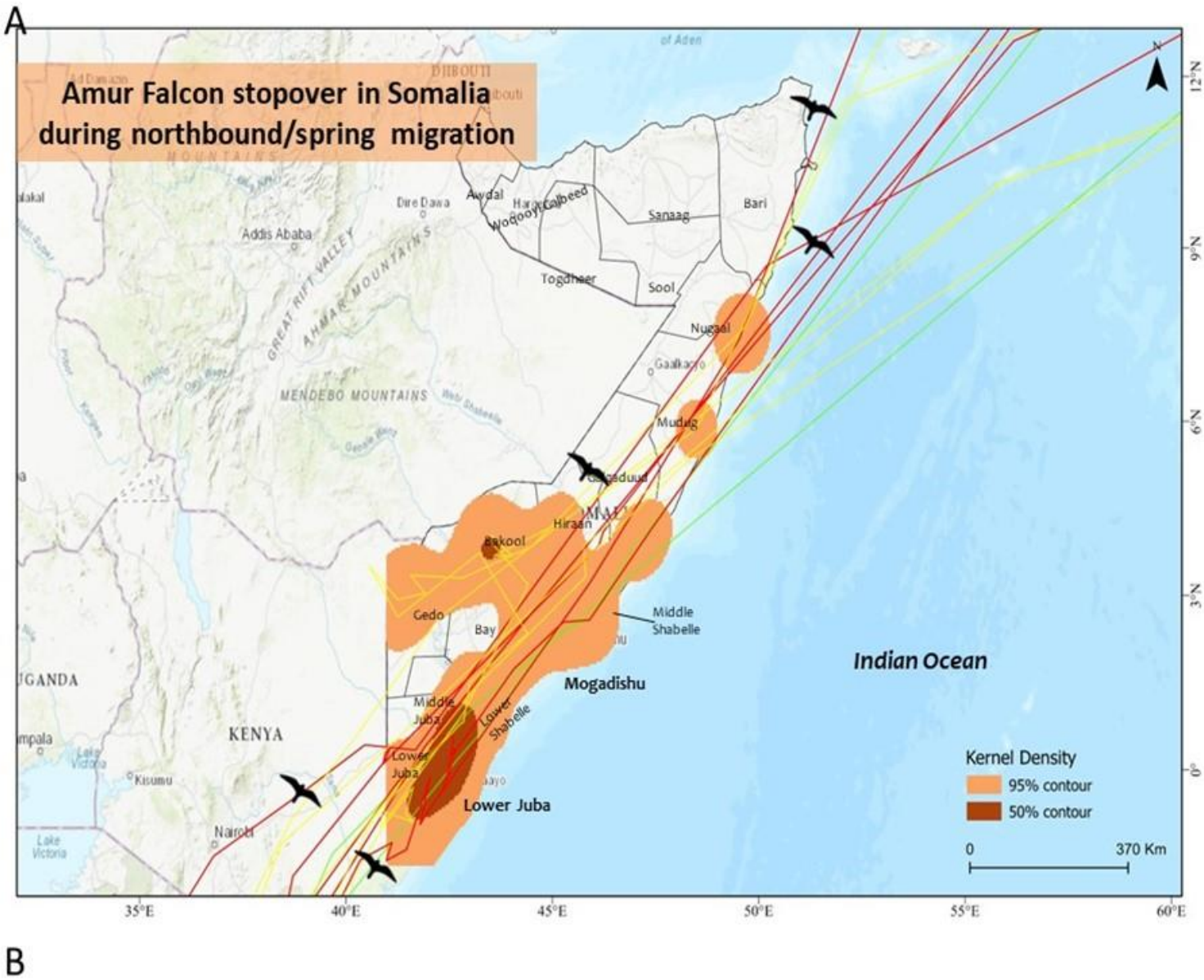


Figure 12 Amur Falcons stop-over in Manipur during their southbound migration (October-November). A: shows the stop-over range using Kernel Density of tagged falcons in the region, B: shows the residency period where the color of the bars corresponds to the color of the tracks shown above (A). Note that the stop-over duration of Amur Falcons during their first year of tracking is shown with * as total days does not include the days before deployment of tag.


© Kh. Hitler SIngh

Stop-over Sites during Spring Migration

During the spring migration, the tagged Amur Falcons after departing from the non-breeding grounds in southern Africa, spent the stop-over in Somalia. Across years, the Amur Falcons reached Somalia in the month of April. In Somalia, the falcons stopped over for an average of 14 days (range: 10 – 19 days). The stop-over in Somalia was primarily to the south-eastern regions at sites near the capital Mogadishu and near Middle Juba (Figure 13). All the tagged falcons departed from Somalia towards the end of April, before undertaking their non-stop flights over the Arabian Sea. The stop-over in Somalia was identified as the only major stop-over ground for the Amur Falcons during their spring migration as the falcons did not stop-over anywhere else for such long duration.



B

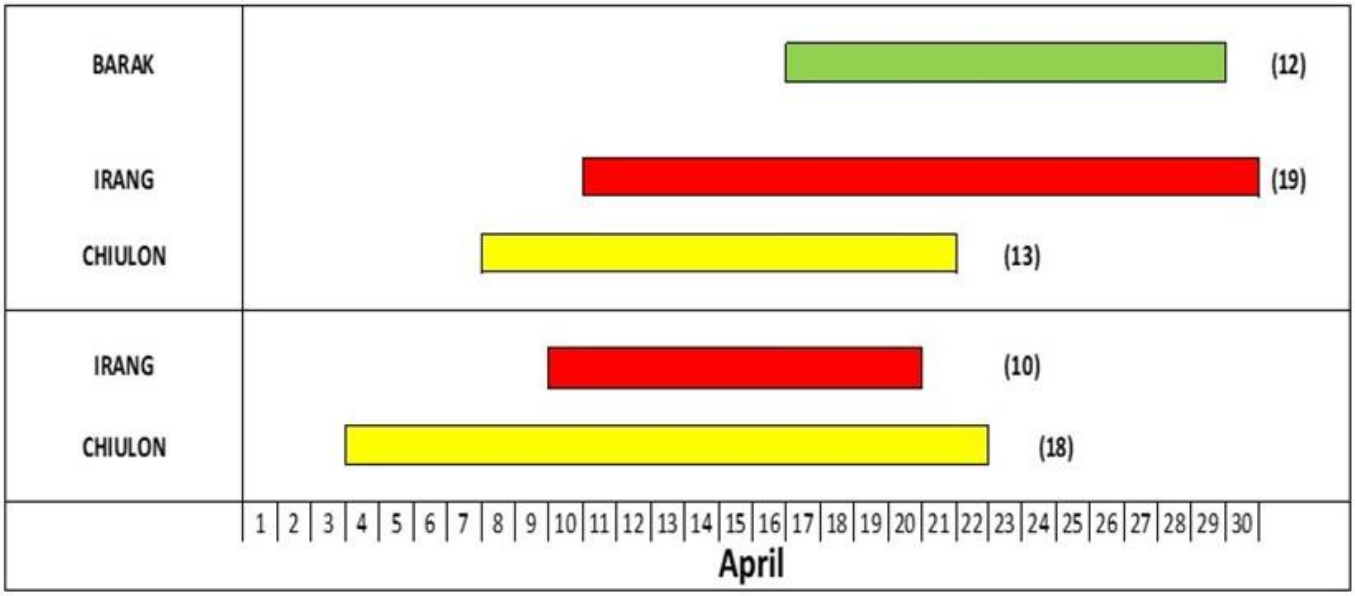


Figure 13 Amur Falcons stop-over in Somalia during their northbound migration (April). A: shows the stop-over range using Kernel Density of tagged falcons in the region, B: shows the residency period where the color of the bars corresponds to the color of the tracks shown above (A).

Modelling Amur Falcon Stop-over Sites across Manipur

In order to identify potential stop-over sites in Manipur other than the existing important stop-over sites (Chiulon, Bhalok and Puching), a multi-criterion Site Suitability Modelling (SSM) approach was adopted. For this analysis we only used surveyed stop-over locations as training data to feed into the modelling approach and did not use the tracking data of the tagged falcons. This was due to the reason of inherit error associated with the accuracy of the location in tracking data. The spatial attributes of the stop-over sites; elevation, slope, aspect and forest cover were thought to influence site selection and were therefore, identified as the criterion for the SSM. From the existing knowledge of known stop-over sites, the influence of one criterion over the other was determined and individual weights were then generated for these criteria in an Analytic Hierarchy Process (AHP), through a pairwise comparison matrix on a nine-point weighing scale following Saaty (1980). The Consistency Ratio (CR), which is a measure of how much variation is allowed was checked to accept the results of AHP generated weights and then the relative weights were used to perform the weighted overlay analysis in ArcGIS Pro platform.

Spatial layers for each of the criterion; elevation, slope and aspect were prepared using the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) Version 3 (ASTGTM) data of 30 m resolution obtained from NASA's Earthdata (https://earthdata.nasa.gov). The Land Use/Land Cover (LULC) layer for the region was obtained from the European Space Agency (ESA) Climate Change Initiative (CCI) database (https://www.esa-landcover-cci.org) for the year 2018 of 300 m resolution, which was then reclassified to five LULC classes and to a resolution of 30 m.

All of the spatial layers were standardized by converting them into same units of resolution to execute weighted overlay. The identified criterion for the site suitability modelling were then individually scored for the sub-criterion on a scale of 1-3 with 3 being the highly suitable class and then the input spatial layers were reclassified as per the scores given for

common evaluation scale of suitability. In the weighted overlay tool, the weights generated for each of the criterion using AHP were then entered to generate the final output (Table 6). The resulting output generated a raster layer of three classes wherein the suitable class of maximum score (class 3) was identified as the class containing regions of high suitability for Amur Falcons potential stop-over.

Table 6 Criteria chosen for modelling potential Amur Falcon stop-over sites with details on weight and influence of each criterion generated using Analytic Hierarchy Process (AHP) and scores given to sub-criterion with related suitability.

Criteria	Sub-criteria	Score	Suitability	Weight	Influence (%)
Aspect	NW	3	Highly suitable	0.44	44
	W	2	Moderately suitable		
	N- SW	1	Least suitable		
Elevation (m)	300-400	3	Highly suitable	0.37	37
	400-500	2	Moderately suitable		
	<300 & >500	1	Least suitable		
LULC	Dense & Moderately Dense Forest	3	Highly suitable	0.16	16
	Open Forest	2	Moderately suitable		
	Sparse Vegetation & Other	1	Least suitable		
Slope (%)	20-30	3	Highly suitable	0.03	3
	10-20	2	Moderately suitable		
	0-10 & >30	1	Least suitable		

The suitability map generated showed potential Amur Falcon stop-over along the western parts of Manipur next to Imphal valley where the tracking data of Amur Falcons was also located and also on the borders of eastern Manipur (Figure 14). These sites were found to be located primarily in the hilly tracts along the middle stretches of rivers flowing into the Brahmaputra. The sites identified overlapped with the stop-over sites identified during the field surveys as well as with the tracking data of Amur Falcons. The highly suitable area for the Amur Falcon to stop-over accounted 0.3% area in Manipur. Further, Tamenglong and Churachandpur districts were found to have more potential area for the Amur Falcons to stop-over (Table 7).

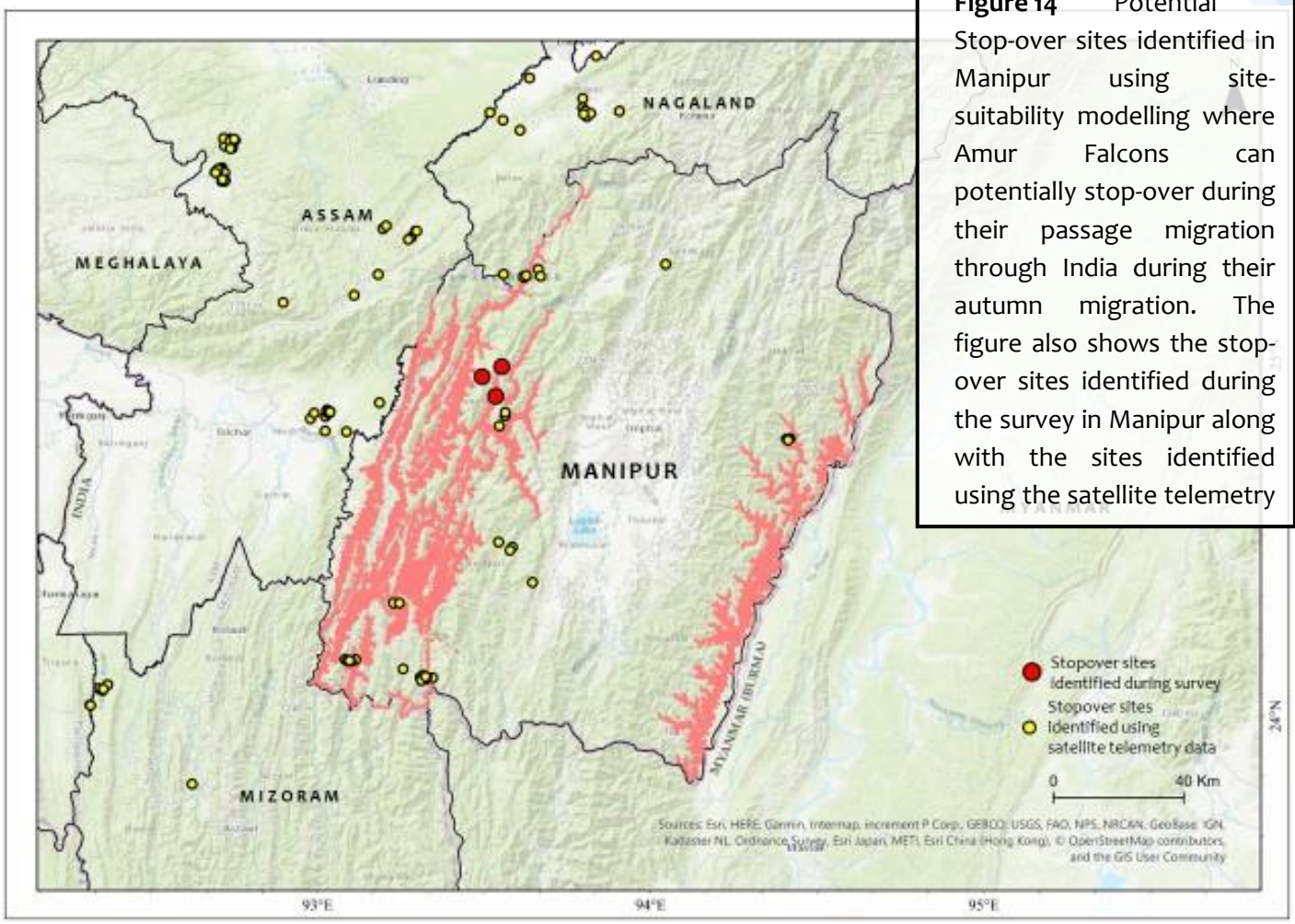


Figure 14 Potential Stop-over sites identified in Manipur using site-suitability modelling where Amur Falcons can potentially stop-over during their passage migration through India during their autumn migration. The figure also shows the stop-over sites identified during the survey in Manipur along with the sites identified using the satellite telemetry

Table 7. District-wise suitable area (in percentage) for the Amur Falcon to stop-over generated using the site-suitability modelling across Manipur.

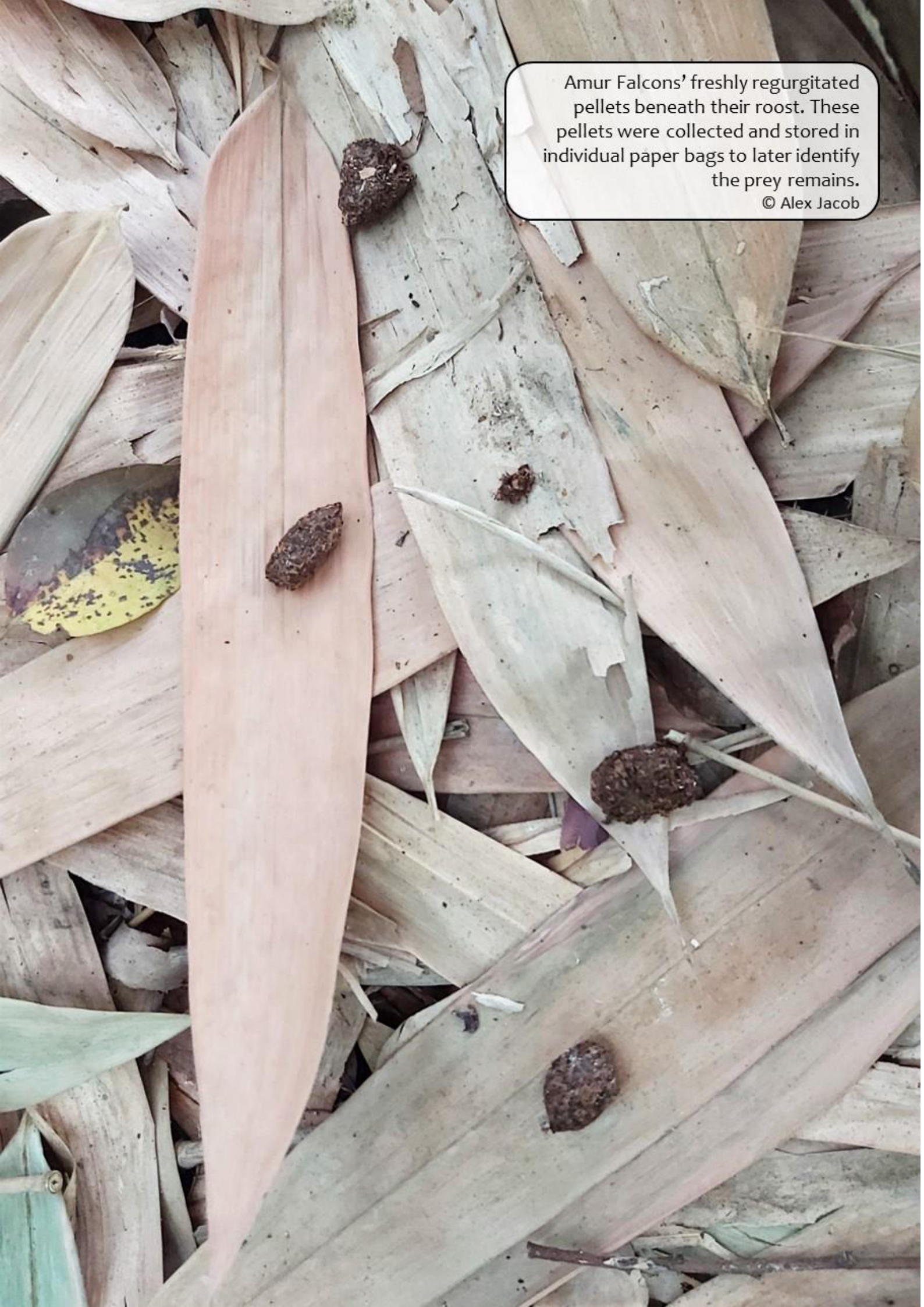
S.no	District	District area (sq. km)	Highly suitable area (sq. km)	% Area for district	% Contribution of district
1	Tamenglong	4036.16	114.36	2.83	4.68
2	Churachandpur	4536.88	113.73	2.51	4.65
3	Chandel	3063.69	36.91	1.20	1.51
4	Ukhrul	4283.05	23.45	0.55	0.96
5	Imphal East	575.31	2.65	0.46	0.11
6	Senapati	3351.72	0.27	0.01	0.01

Stop-over to Refuel!

- *diet of the Migrating Amur Falcons*

Amur Falcons during their passage migration through India are reported to forage aerially on swarms of insects such as winged termites and ants (Ali and Ripley 1978, Naoroji 2006). However, Information on their diet is primarily limited to the non-breeding grounds in Southern Africa where they are reported to feed on Insects mainly Coleoptera, Orthoptera, Isoptera and Solufigae, and occasionally on rodents and small birds (Kopij 2010, Pietersen and Symes 2010, Alexander and Symes 2016). Our study revealed that every year in autumn, Amur Falcons make a long stop-over at select stop-over sites in the North-eastern region of India. This led us to ask a series of questions as to what is it that the Amur Falcons forage on during their stop-over in Manipur? Why Amur Falcons stopped over in such large numbers at select sites in Manipur and not elsewhere, especially since similar habitats exist elsewhere along their migratory route during the passage across India. Lastly, why stop-over in such large numbers only during their southbound autumn migration and not during spring passage? We suspected this to may be due to the availability of abundant insect food in the area. To investigate this, we undertook a study to document the prey species in their diet. This was done through examination of regurgitated pellets that were found at the roosting sites.

We collected freshly regurgitated and whole pellets of Amur Falcons from the forest floor at Puching stop-over site in Manipur. This was carried out along with the diet examination at three major stop-over sites in Nagaland: Yaongyimchen, Pangti and Hakhizhe and at Umrangso stop-over site in Assam. The pellets were picked up far and wide at each site and the collections were only made in the morning soon after the falcons left the roost. The collected pellets were stored in individual paper bags and labelled. The pellets were later sundried to remove any moisture. As a reference to identify insect prey remains in the pellets, we made opportunistic collection of large-bodied insects such as Coleoptera, Orthoptera, Odonata, Isoptera in and around the stop-over sites.



Amur Falcons' freshly regurgitated pellets beneath their roost. These pellets were collected and stored in individual paper bags to later identify the prey remains.
© Alex Jacob

In lab, we placed individual pellets in a petri dish, and gently segregated it for any visible prey remains. We then examined the pellet under a dissecting microscope (10X to 40X optical zoom), wherein we identified the prey remains up to the taxonomic Order. Following Kopij (2010), we calculated the frequency of occurrence of each prey item as the proportion of the total number of pellets examined containing a given taxon. We labelled the unidentified prey remains as unknown and stored for later identification. For those insect prey that occurred more frequently in a pellet we attempted to quantify for their abundance and then identified the commonly occurring prey remain up to species level.

We collected 270 pellets from Puching Stop-over site and only found insects (invertebrate) prey in the pellets of the Amur Falcons. This was consistent in the pellets sampled from other stop-over sites during the study. At Puching, the prey remains identified to be of four insect orders and in increasing order of their occurrence: Isoptera, Hemiptera, Coleoptera and Orthoptera (Figure 15). However, the insect order Hymenoptera which was additionally found in the diet of Amur Falcons at sites in Nagaland was not seen in the pellets collected from Puching and Umrangso.

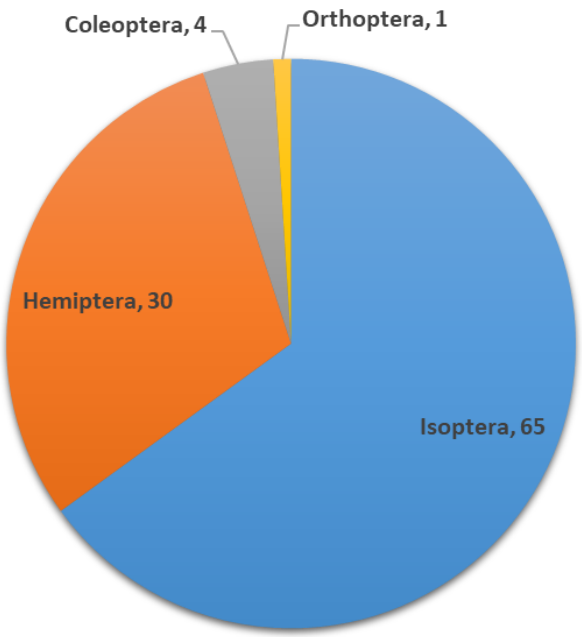


Figure 15 Percentage frequency of occurrence of prey items in the diet of Amur Falcons at Puching stop-over site, Manipur in 2019.

© Saikat Banik

Foraging Observations

During the study, we recorded four different types of foraging by Amur Falcons wherein on a sunny day we observed the falcons to be taking advantage of thermals, and they would mill above the roosting area in large congregations and dispersing far off in search of food. The second type of foraging activity was usually during the early evening hours, where we observed falcons to be flying in one direction often in large groups of tens of thousands of individuals, followed by "feeding frenzy", hawking and feeding on emerging termite alates. We saw falcons flying very low to the riverine grasslands hovering and picking up insects possibly grasshoppers. On one instance, just before roosting, we observed large number of falcons flying close to the river and sweeping off emerging Mayflies. At times, Amur Falcons also made visits to a nearby water source to drink water during the morning or afternoon hours. Lastly, we made frequent observations on falcons often in small numbers perched on electricity lines and posts, snags, practicing ambush hunting strategies.

We observed Amur Falcons opportunistically foraging on various other insects such as Cicadas (Hemiptera), Dragonflies (Odonata) and Mayflies (Ephemeroptera). One instance of such observation was at the Puching stop-over site in Tamenglong in Manipur where we observed mass emergence of Mayflies from *Irang* River right next to the stop-over site early in the evening. This emergence coincided with the falcons returning to the roost and as a result falcons used the opportunity by swooping over the emerging mayflies and foraging actively before roosting. These group of insects, however, did not show up in the pellets during the diet examination suggesting that these taxa do not contribute majorly in their diet and are only constitute in the diet when available. It is also speculated that other taxa such as Lepidoptera and Diptera may potentially be part of the diet of Amur Falcons but because of the complete digestion of such soft-bodied prey, detection in the pellets becomes difficult resulting in underestimating the importance of such taxa (Kopij 2010).


© Vignesh Chandran

Termites & their Emergence

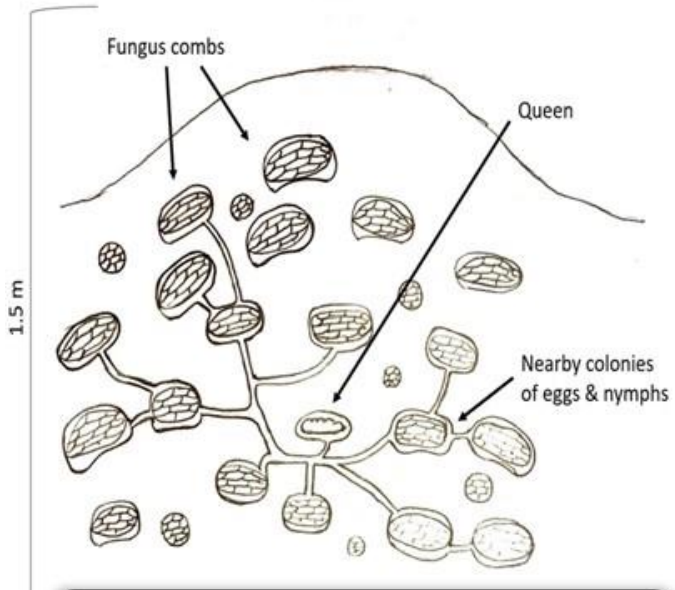
The arrival of Amur Falcons in northeast India during October appears to coincide with the mass emergence of termites in the area. This is also the time of year when the period of high rainfall (Southwest Monsoon) from June to September comes to an end, and likely triggers termite emergence. Swarming behaviour in termites is generally known to occur after periods of rain and soon after when the weather is warm and the soil is moist (Roonwal and Verma 1991, Pervez 2018). The local tribal people related to the Amur Falcons as the insect-eater referring to their feeding on termites. Further, local hunters in Nagaland reported the falcon meat to be lean at the time of their arrival in early to mid-October and preferred to hunt them at the time of their departure in early to mid-November for they are high on fat. Thus, this high energy diet during passage stop-over in Northeast India is what appears to fuel Amur Falcon migration across the Indian Subcontinent. It was therefore natural to know what this species of termite that important prey is of Amur Falcons and gather more information on the termites in the region, the species identity, whether the termites in the diet included one or multiple species, and their swarming behaviour. Therefore, to identify the termite species in the diet of the Amur Falcons we undertook explorations to locate termite colonies and collect termite specimens for taxonomic examination (Kumar 2021).

Based on the presence of a tooth on the left mandible and tongue-shaped labrum with a pointed tip, the species at Puching stop-over site was identified to be *O. feae* (Table 8, Fig. 16). Other than this species, we also found *O. horni* at other sites in Nagaland and Umrangso. From our findings it appears that *O. feae* is commonly occurring species across the Amur Falcon stop-over sites in the region that *O. horni.*

O. feae is said to be widely distributed in South and Southeast Asia with specific records of its occurrence in India, Nepal, Bhutan, Bangladesh, Sri Lanka, Myanmar, Thailand and Vietnam. In India, the species occurs in all regions except in extreme north (Jammu & Kashmir) and in the western drier regions of Rajasthan (Roonwal and Verma 1991). The species is reported to prefer humid areas and is mainly a subterranean burrower, building its nest underground and only rarely building of mounds by this species is reported. In northeast India, Bose (1999) reported finding the species to be building mounds near Imphal, Manipur. The nest structure is reported to be large, complex and cryptic in nature, and impossible to locate except during swarming time (Roonwal and Verma 1991). It is only shortly before swarming begins in this species that the workers open several holes on the ground surface from which the winged alates emerge one after the other, thus betraying the presence of the nest (Holmgren 1913).

Termite soldiers working on the mound opening (holes) to let the alates (reproductives) emerge out of the colony

On digging up the termite mound,, we observed fungal combs made from macerated woody material and within which fungus is cultivated as food source for the growing colony. This represents a symbiotic association between the termite and fungus



a Sketch of termite mound

b Excavated fungal combs

Odontotermes feae

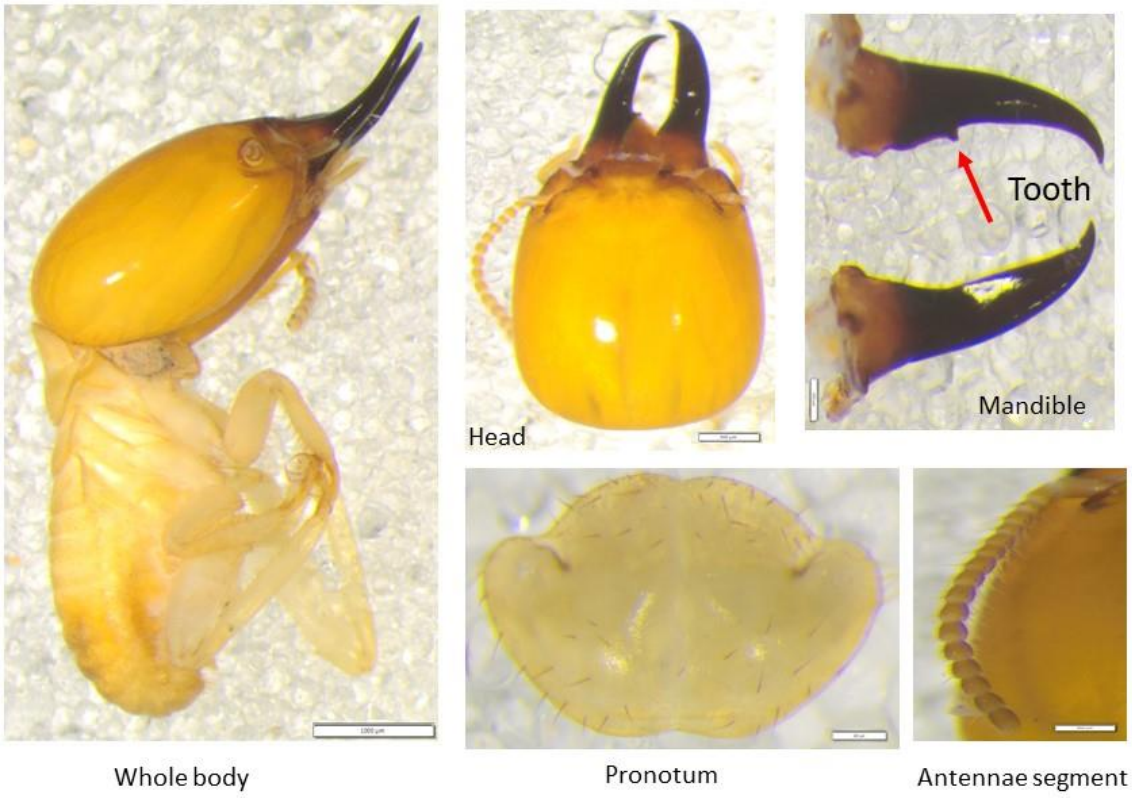


Figure 16 Morphological characters of the species *Odontotermes feae*, notice the presence of tooth in the left mandible (distinguishing character of the species).

Swarming in *Odontotermes* species is thought to occur only once a year, and the swarming season to vary with geographic location from early June to the last week of November (Roonwal and Verma 1991). In Manipur and Nagaland, we recorded termite swarming only after the South West monsoon receded, and occurred from last week of September to first week of December. A short swarming event was also observed during pre-monsoon season in May-June. In support of our observation local people in the area also reported termite swarming in the pre-monsoon season to not be as large as during post-monsoon season.

Table 8. Morphological characters of this study specimens (soldiers) with that of *Odontotermes feae*.

Characters	*Odontotermes feae*	*Manipur termite samples*
Head colour	Yellow to Reddish Brown	Yellowish
Labrum colour	Paler than Head	Brownish
Antennae colour	Paler than Head	Yellowish paler
Mandible colour	Blackish	Blackish
Head hair	Moderately hairy	Sparsely Hairy
Body colour	Creamy Yellow to Pale Rusty Yellow	Creamish Yellow
Body hair	Moderately Hairy	Hairy
Total body-length (mm)	6.5-9.0	5.00-6.86
Head shape	Subrectangular	Subrectangular
Length of head to base of mandibles	2.25-3.10	2.30-2.59
Head Max. width	1.80-2.50	1.91-2.15
Head Width at base of Mandible	1.20 - 1.60	1.10-1.38
Head index max. width/length	0.76 - 0.87	0.51-0.85
Index width at base of mandibles/max. width	0.58 - 0.67	0.59-0.69
Antennae segment	17	17
Antenna shortest segment	3	3
Labrum	Tongue-shaped, narrowed in front to a pointed tip	Tongue-shaped, narrowed in front to a pointed tip
Mandible shape	stout, strong, sabre-shaped	stout, sabre-shaped
Mandible length (mm)	1.20 - 1.65	1.30-1.59
Index mandible-length /head-length	0.51 - 0.59	0.54-0.63
Left mandible	With a medium sized tooth near middle	Tooth located just below the middle of the mandible
Tooth-distance from tip (mm)	0.62 - 0.90	0.60-0.89
Index tooth distance/ mandible-length	0.50 - 0.55	0.43-0.64
Right mandible	a minute tooth at basal third	a minute tooth almost same level of tooth on left mandible
Postmentum	Subrectangular, somewhat swollen near basal third	Subrectangular swollen at the proximal region
Postmentum length	1.30 - 2.00	1.37-1.65
Postmentum width	0.73 - 0.93	0.70-0.77
Pronotum length	0.75 - 1	0.78-0.85
Pronotum width	1.40 - 1.83	1.35-1.53

We observed termite swarming to occur only on clear sunny days and this often occurred within days after heavy rainfall and only during late afternoon to evening from 1500 to 1700 hr. Coinciding with this time of day, Amur Falcons that appeared resting throughout the day start to fly out from the stop-over sites, and then begin to actively forage. The termite swarming that we observed at select termitaria appeared to last only for 5 to 15 minutes each day. At the end of the swarming each day the workers close the holes from which the winged alates emerged and left no sign of the presence of the nest.

It is evident that the large-scale mass emergence of the subterranean termites of the genus *Odontotermes* primarily influences the huge congregations of Amur Falcons in the Northeast Indian region. This is also evident from the fact that across sites that were sampled in Northeast India, nearly 90% of the Amur Falcon diet is of winged termites. Termite prey being high energy diet it plays a crucial role in sustaining the congregations of the Amur Falcons in the region during the autumn passage and helps fuel their non-stop flight thereafter to Africa. Information on termite ecology including swarming behaviour is still poorly known and requires further research. The increasing deforestation and predominant shifting cultivation practices in the region may likely influence the presence of termite species, and this in turn may influence the presence of Amur Falcons in the area. Future research therefore should focus on how or whether land use changes are affecting termite populations in the region. It will also be interesting to document how Amur Falcons act as biocontrol agents keeping a check on termite populations that are generally regarded as pests.


© Rajaram Vasudevan

The Trans-Equatorial Migrant...

The findings of this study corroborate with a previous tracking study by Kumar (2021) of the falcons from Nagaland. The trans-hemispheric migration of Amur Falcons clearly coincides with the onset of northern summer in their breeding and austral summer in their non-breeding grounds. Similar to the Amur Falcons, several other long-distance migrants take the benefit of the reversing of seasons by migrating to the opposite hemispheres (Alerstam et al. 2003, Newton 2008). Further, across these two regions the summer months are predominantly wet and the falcons as a result benefit from the abundant food resources becoming available during that period (Thorup et al. 2017).

In the breeding season, the Amur Falcons are reported to range largely across east Asia covering the eastern Siberia from Transbaikalia eastward through Amurland and Ussuriland, southward through northeast Mongolia and Manchuria to North Korea and eastern China (Ferguson-Lees and Christie 2001). In this study, the two tagged Amur Falcons *Chiulon* and *Irang* spent their breeding season entirely within the Manchurian Plains to northeast China breeding between east longitude 113° to 140° and north latitude from 37° to 57° in northeast China. Across the two years of their tracking both Chiulon and Irang arrived at their breeding grounds in the month of May and departed in late September to mid-October and showed high breeding site fidelity. We found that the Amur Falcons timed their arrival and departure from the breeding sites with the period of heavy rainfall in the region (Kumar 2021).

Following the change in the seasons, the tagged Amur Falcons spent their austral summer in the southern countries of Africa; Botswana, Mozambique, Zimbabwe and South Africa largely between 15° to 35° east longitude and 15° to 35° south latitude. Across years, the tagged falcons arrived at their non- breeding grounds between December – January and departed between March – April, coinciding with the austral summer and period of high rainfall in the region (World Bank Group, Climate Change Knowledge Portal 2021). At the non-breeding grounds, Amur Falcons largely used multiple sites throughout the entire

season, however similar to the breeding grounds falcons showed affinity to non-breeding sites as well.

The Amur Falcons took much longer to complete their autumn migration (47 – 91 days) than their spring migration of 39 to 52 days. Given the strong competition at breeding grounds for best territories and resources (Kokko 1999), migratory birds time their arrival at the breeding sites early (Moore et al. 2005) to increase their reproductive performance (Van Noordwijk et al. 1995). In the case of Amur Falcons, their obligatory "nest – cleptoparasite" behaviour likely influences their early arrival to the breeding sites given the competition to occupy nests of other birds such as Eurasian Magpies *Pica pica* (Zhou et al. 2009, Burner et al. 2019, Frommhold et al. 2019). Further, the timing and arrival to the breeding and nonbreeding grounds also determine the reproductive success, survival and fitness of migratory species (Arzel et al. 2006, Ely et al. 2007) and therefore, migratory birds time their migration to coincide with the seasonal food abundance (Arzel et al. 2009) and also with the optimal weather conditions (Shamoun-Baranes et al. 2017).

Long-distance migratory birds that migrate between continents invariably face the challenge of crossing large ecological barriers that was also seen in the case of the Amur Falcons. While sea crossing by landbirds is often considered as examples of endurance flights (Newton 2008), we believe that prevalent wind conditions during the migration influence such non-stop flights. It is reported that birds especially raptors that alternate between soaring and flapping flights including Amur Falcons regularly perform long sea crossings of thousands of kilometres (Agostini et al. 2005, Bildstein 2006, Gschweng et al. 2008, Dixon et al. 2011, Meyburg et al. 2017) and are assisted by tailwinds (Meyer et al. 2000, Agostini et al. 2002, Agostini et al. 2004, Nourani et al. 2016, Nourani et al. 2021), and possibly sea thermals (Bildstein 2006, Yamaguchi et al. 2012). In our study, we also found that during the oceanic crossing, the presence of optimal wind conditions including the wind direction as well as wind speed largely facilitated the Amur Falcons' non- stop flights over the Arabian Sea. Further, it is evident from our study that the Amur Falcons also make use of the trade winds which act as a conveyor belt and a migration corridor facilitating the Arabian Sea crossing (Kumar 2021).

Stop-over sites located specifically adjacent or just before the barriers are critical in determining the overall success of migration (Delingat et al. 2008, Bonter et al. 2009, Bayly et al. 2012, Gómez et al. 2017). This was true in the case of Amur Falcons as we observed that just before undertaking the non-stop overwater flights over the Arabian Sea, the tagged falcons made several days stop-overs at Northeast India and Somalia during autumn and spring migratory cycles respectively. At both of the stop-over regions, the Amur Falcon spent about 13 to 14 days, a considerable period to fatten before their non – stop flights.

Across Northeast India, we found that Amur Falcon stop-over sites were located primarily along the western side of the Naga hills at low elevations. It is suspected that the regions at higher elevations pose challenges of colder climes while regions at lower elevations are more humid, which likely influences the insect prey and in turn the foraging behaviour of the Amur Falcons. Across the sites, Amur Falcons congregate and roost communally primarily close to river valleys or waterbodies, where they likely benefit from rising thermals during the day that not only assists them to soar but also to forage aerially. Soaring land birds mainly raptors are reported to use such orographic lift where they use thermals to gain height (Newton 2008). Communal roosting by migrants also offers the benefit of timing their migration including synchronized departures (Helm et al. 2006), which help reduce flight costs (Cutts and Speakman 1994, Weimerskirch et al. 2001).

Amur Falcons in the Northeast India appears to be congregating majorly in the Naga and adjoining North Cachar hills while are not observed stopping over in the other hills in the region. It is interesting to note that while flying from their breeding grounds in northern China the tagged Amur Falcons predominantly flew in the southwest direction to enter into Myanmar and then changed their flight course to northwest where just before reaching near to the Naga – Chin hills range, took detour and headed straight north to enter making landfall in the Naga hills (Kumar 2021). Using Site – suitability Modelling we identified suitable areas across the region and in hills other than Naga hills where Amur Falcons can potentially stop-over. However, reports on large congregations of Amur Falcons stopping over at these sites are absent. Given the limitations of remote and mountainous terrain, we adopted a basic approach in identifying potential sites with limited information so as to assess the landscape. Since our understanding of why Amur

Falcons are stopping over at select sites is not clear, it is important to include fine-scale habitat information into the model. Other than Manipur, Nagaland, and Assam, surveys to locate the presence of Amur Falcon stop-over sites in Arunachal Pradesh, Mizoram and Tripura are required in order to confirm the model's result. Our findings serve as a baseline for measurement of effectiveness of future management and conservation efforts on identified stop-over sites.

We believe that it is primarily the prey availability particularly abundant termite prey which likely influences stop-over site selection by the Amur Falcons in the Naga and adjoining hills. During the stop-over period, we observed flocks of Amur Falcons feeding primarily on huge swarms of termites in Manipur and at sites in Nagaland and Assam. Therefore, we undertook a study on understanding the diet of Amur Falcons during their stop-over in Nagaland and Manipur by examining their regurgitated pellets. Our study revealed that Amur Falcons primarily stop-over in Manipur to refuel and prepare for their non-stop flights to the non-breeding grounds. This is evident by the results of our study which indicates that during the stop-over period Amur Falcons extensively forage in the region building up their fat reserves.

During the stop-over Amur Falcons prey almost entirely on invertebrates which is similar with their diet in their non-breeding grounds in Southern Africa (Kopij 2010, Pietersen and Symes 2010, Alexander and Symes 2016), however, in Manipur the diet consisted of four insect orders; Isoptera, Hemiptera, Coleoptera and Orthoptera. Apart from these four groups of insects, Hymenoptera was seen at sites in Nagaland (Kumar 2021). Among these, Isoptera was the dominant and major prey in the diet of Amur Falcons with highest frequency of occurrence (65%) throughout the stop-over season while Hemiptera contributed 30% in the diet. This significantly differed with the prey contribution in their diet from non-breeding grounds where Coleoptera, Orthoptera and Solifugae were the most dominant prey groups (Kopij 2010, Pietersen and Symes 2010, Alexander and Symes 2016).

In Northeast India, we also observed Amur Falcons opportunistically foraging on various other insects such as Cicadas (Hemiptera), Dragonflies (Odonata) and Mayflies

(Ephemeroptera). One instance of such observation was at Puching where we observed mass emergence of Mayflies from Irang River right next to the stop-over site early in the evening. This emergence coincided with the falcons returning to the roost and as a result falcons used the opportunity by swooping over the emerging mayflies and foraging actively before roosting. These group of insects, however, did not show up in the pellets during the diet examination suggesting that these taxa do not contribute majorly in their diet and are only constitute in the diet when available. It is also speculated that other taxa such as Lepidoptera and Diptera may potentially be part of the diet of Amur Falcons but because of the complete digestion of such soft-bodied prey, detection in the pellets becomes difficult resulting in underestimating the importance of such taxa (Kopij 2010).

During the stop-over in Northeast India, millions of falcons congregate across different roost sites and feed extensively on abundant insect prey. Given, Amur Falcon being a versatile species feeding on a wide range of invertebrates, and also efficiently track their resources both spatially and temporally (Kopij 2010, Symes and Woodborne 2010, Alexander and Symes 2016), their presence thus becomes critically important in regulating insect populations. We observed that in Northeast India, Amur Falcons tend to move between different stop-over sites during the stop-over season and similar to the non-breeding grounds, effectively track the resources. We also observed that in the Northeast India, Amur Falcons shift their stop-over sites over the years (Kumar 2021), which we believe is the response to seasonal prey availability and termite emergence in the region and is dictating the presence of Amur Falcons. Therefore, we attempted to identify the termite species in the diet of Amur Falcons.

We identified the termite species to be *Odontotermes feae,* which largely emerges in the region during the stop-over season. Although *O. feae* has a wide geographical distribution reported from across India and Southeast Asia, however, the swarming or emergence is seen at different seasons across the region (Roonwal and Verma 1991). In the Naga hills and adjoining region, we observed prolonged and intense termite swarming throughout the stop-over season supporting huge congregations of Amur Falcon. Local people in the region also reported Amur Falcons to forage actively on the swarming termite alates during the stop-over period. This suggests that the Northeast Indian region and

particularly select sites in Manipur and adjoining areas are resource-abundant site for the falcons to refuel. Interestingly, during the return passage from Africa on their spring migration, Amur Falcons do not stop-over in large congregations in Northeast India suggesting the non-availability of prey is likely the reason.

In recent years, global climate change events have affected many species including the ones that migrate over intercontinental distances as they experience different ecological conditions and habitats in their breeding, wintering and stop-over areas, as well as en route (Robinson et al. 2009, Both et al. 2010, Saino et al. 2011). While several threats posing limitations in breeding areas of Amur Falcons have been reported (Zhou et al. 2009, Burner et al. 2019 and Heim et al. 2019), reports from the changing habitat in nonbreeding range, the South African grasslands are also concerning (Mendelsohn 1997, Jenkins 2005), along with rapidly changing climate, restricting the potential habitats for the species (Bernitz 2006, Pietersen and Symes 2010, Symes and Woodborne 2010, BirdGuides 2019).

Further, growing evidence on impact of climate change on the phenology of bird migration (Ahola et al. 2004, Parmesan 2007, Saino and Ambrosini 2008) challenges the ability of migratory species to adapt to these changing environmental conditions (Webster et al. 2002). In addition to this, a recent study by Nourani et al. (2017) suggested that climate change can also disturb the wind assistance, impacting particularly the species that depend on the winds to cross large ecological barriers. Further, any change in resource base at stop-over sites makes migratory birds more vulnerable (Baker et al. 2004), especially if populations rely on a small number of sites to acquire energy (Bayly et al. 2013, McKinnon et al. 2013a).

Future Actions

As part of the Amur Falcon Conservation Initiative this study as originally conceived helped create mass awareness and garner support of local people bringing about a change in their attitude towards hunting practices. This has led to a significant reduction in hunting Amur Falcons at their stop-over sites during passage migration through Manipur and neighboring States. Echoed as a conservation success story, Amur Falcons are now the flagship species for conservation as many local communities at few sites across Manipur are coming forward to set aside community lands for not only Amur Falcon conservation but for all other biodiversity in the area. Along with this, administrative orders banning hunting, media campaigns, conservation awareness through the forest department and support of the church, and community ownership helped effectively in halting the large-scale harvest of Amur Falcons in the region.

The present study was a pilot effort where we tagged eight Amur Falcons however due to transmitter failure at least three falcons could be tracked for a minimum of one cycle to their non-breeding and two to their breeding grounds. Given the small sample size of falcons that were tracked in the study it is suggested to continue track more Amur Falcons in Tamenglong and elsewhere in the region. This study through the use of satellite telemetry has helped in our understanding of Amur Falcon migration, however many important facets about their migration strategy remains unknown. And therefore, tracking more Amur Falcons will help in understanding the Amur Falcon populations arriving in Northeast India, which we believe represent populations from different parts of their very wide breeding range.

While the present study has generated important baseline information on stopover sites in the Northeast region, securing the habitats however requires a more in-depth understanding of habitat characteristics that influence site selection by Amur Falcons. For this, an extensive field study across the northeast region focusing on identification of stopover sites and documenting their habitat characteristics is required. Along with this, a detailed study on variability of termite prey across these sites is essential. Whether, the

termite swarming events observed during Amur Falcon stop-over are cyclic in nature, and whether or how this is influenced by climatic factors, particularly monsoonal rains. This is also important as during this study it was documented that Amur Falcon population as a whole shift stop-over site. What factors influence the non-use of certain sites that previously used to host large congregations of the falcons requires further investigation. A detailed ecological study is required to plan the restoration of habitats across the region in better conservation management not only for Amur Falcons but also for other biodiversity in the region.

Lastly, conservation measures for Amur Falcon should adopt a landscape-based approach and not site-specific, as Amur Falcons shift stop-over sites over the years which is possibly determined by monsoonal rain in a given year and that very likely influences emergence of termites that the falcons are dependent on. It is recommended that a network involving local communities, forest department personnel, the church, administrators, media personnel representing each of the stop-over sites across the Northeast Indian region be formed. And, the network through consultations works together in planning, strategizing and adopting measures that better benefit Amur Falcon conservation in the region.

References

Agostini, N., Baghino, L., Coleiro, C., Corbi, F. and Premuda, G., 2002. Circuitous autumn migration in the Short-toed Eagle (*Circaetus gallicus*). *Journal of Raptor Research,* 36, pp.111–114.

Agostini, N., Panuccio, M. and Massa, B., 2005. Flight behaviour of Honey Buzzards (*Pernis apivorus*) during spring migration over the sea. *Buteo*, 14(1), pp.3-9.

Agostini, N., Premuda, G., Mellone, U., Panuccio, M., Logozzo, D., Bassi, E. and Cocchi, L., 2004. Crossing the sea en route to Africa: autumn migration of some Accipitriformes over two central Mediterranean islands. *The Ring*, 26(2), p.71.

Ahola, M., Laaksonen, T., Sippola, K., Eeva, T., Rainio, K. and Lehikoinen, E., 2004. Variation in climate warming along the migration route uncouples arrival and breeding dates. *Global Change Biology*, 10(9), pp.1610-1617.

Alerstam, T., Hedenström, A. and Åkesson, S., 2003. Long-distance migration: evolution and determinants. *Oikos*, 103(2), pp.247-260

Alexander, J. and Symes, C.T., 2016. Temporal and spatial dietary variation of Amur Falcons (*Falco amurensis*) in their South African nonbreeding range. *Journal of Raptor Research*, *50*(3), pp.276-288.

Ali, S. and Ripley, S. D., 1978. *Handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka*. 2nd edn. Vol. 1. Oxford University Press, Delhi.

Arzel, C., Elmberg, J. and Guillemain, M., 2006. Ecology of spring-migrating Anatidae: a review. *Journal of Ornithology*, 147(2), pp.167-184.

Arzel, C., Elmberg, J., Guillemain, M., Lepley, M., Bosca, F., Legagneux, P. and Nogues, J.B., 2009. A flyway perspective on food resource abundance in a long-distance migrant, the Eurasian teal (*Anas crecca*). *Journal of Ornithology*, 150(1), pp.61-73.

Ash, J. and Atkins, J., 2009. *Birds of Ethiopia and Eritrea: An Atlas of Distribution*. Christopher Helm, London.

Baker, A.J., Gonzalez, P.M., Piersma, T., Niles, L.J., de Lima Serrano do Nascimento, I., Atkinson, P.W., Clark, N.A., Minton, C.D., Peck, M.K. and Aarts, G., 2004. Rapid population decline in red knots: fitness consequences of decreased refuelling rates and late arrival in Delaware Bay. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 271(1541), pp.875-882.

Bayly, N.J., Gómez, C. and Hobson, K.A., 2013. Energy reserves stored by migrating Gray-cheeked Thrushes *Catharus minimus* at a spring stop-over site in northern Colombia are sufficient for a long-distance flight to North America. *Ibis*, 155(2), pp.271-283.

Bayly, N.J., Gómez, C., Hobson, K.A., González, A.M. and Rosenberg, K.V., 2012. Fall migration of the Veery (*Catharus fuscescens*) in northern Colombia: determining the energetic importance of a stop-over site. *The Auk*, 129(3), pp.449-459.

Bernitz, Z., 2006. Mass die-off of migrating kestrels: Ventersdorp. *Gabar*, 17(1), pp.2-4.

Bildstein, K.L. and Zalles, J.I., 2005. Old World versus New World long-distance migration in Accipiters, Buteos, and Falcons: the interplay of migration ability and global biogeography. *Birds of Two Worlds: The Ecology and Evolution of Migration*. The Johns Jopkins University Press, Baltimore, pp.154-167.

Bildstein, K.L., 2006. *Migrating raptors of the world: their ecology & conservation*. Cornell University Press, Ithaca, New York.

Bonter, D.N., Gauthreaux Jr, S.A. and Donovan, T.M., 2009. Characteristics of important stop-over locations for migrating birds: remote sensing with radar in the Great Lakes Basin. *Conservation Biology*, 23(2), pp.440-448.

Bose, G, 1999. *Termite fauna of north eastern India*. Zoological Survey of India.

Both, C., Van Turnhout, C.A., Bijlsma, R.G., Siepel, H., Van Strien, A.J. and Foppen, R.P., 2010. Avian population consequences of climate change are most severe for long-distance migrants in seasonal habitats. *Proceedings of the Royal Society B: Biological Sciences*, 277(1685), pp.1259-1266.

Burner, R.C., Gombobaatar, S., van Els, P., Burner, L.R., Usukhjargal, D. and Bayasgalantselmeg, M., 2019. Nesting ecology of solitary-nesting Amur Falcons (*Falco amurensis*) in central Mongolia. *Journal of Field Ornithology*, 90(3), pp.266-276.

Cutts, C. and Speakman, J., 1994. Energy savings in formation flight of pink-footed geese. The Journal of experimental biology, 189(1), pp.251-261.

Dalvi, S. and Sreenivasan, R., 2013. *Shocking Amur Falcon Massacre in Nagaland*. http://www.conservationindia.org/campaigns/amur-massacre. (Accessed: 30 October 2022).

Delingat, J., Bairlein, F. and Hedenström, A., 2008. Obligatory barrier crossing and adaptive fuel management in migratory birds: the case of the Atlantic crossing in Northern Wheatears (*Oenanthe oenanthe*). *Behavioral Ecology and Sociobiology*, 62(7), pp.1069-1078.

Dixon, A., Batbayar, N. and Purev-Ochir, G., 2011. Autumn migration of an Amur Falcon *Falco amurensis* from Mongolia to the Indian Ocean tracked by satellite. *Forktail*, 27, pp.81-84.

Ely, C.R., Bollinger, K.S., Densmore, R.V., Rothe, T.C., Petrula, M.J., Takekawa, J.Y. and Orthmeyer, D.L., 2007. Reproductive strategies of northern geese: why wait? *The Auk*, 124(2), pp.594-605.

Ferguson-Lees, J. and Christie, D.A., 2001. *Raptors of the world*. United Kingdom, Houghton Mifflin.

Frommhold, M., Heim, A., Barabanov, M., Maier, F., Mühle, R.U., Smirenski, S.M. and Heim, W., 2019. Breeding habitat and nest-site selection by an obligatory "nest-cleptoparasite", the Amur Falcon *Falco amurensis*. *Ecology and evolution*, 9(24), pp.14430-14441.

Gómez, C., Bayly, N.J., Norris, D.R., Mackenzie, S.A., Rosenberg, K.V., Taylor, P.D., Hobson, K.A. and Cadena, C.D., 2017. Fuel loads acquired at a stop-over site influence the pace of intercontinental migration in a boreal songbird. *Scientific reports*, 7(1), pp.1-11.

Gschweng, M., Kalko, E.K., Querner, U., Fiedler, W. and Berthold, P., 2008. All across Africa: highly individual migration routes of Eleonora's falcon. *Proceedings of the Royal Society B: Biological Sciences*, 275(1653), pp.2887-2896.

Heim, R.J., Hölzel, N., Heinken, T., Kamp, J., Thomas, A., Darman, G.F., Smirenski, S.M. and Heim, W., 2019. Post-burn and long-term fire effects on plants and birds in floodplain wetlands of the Russian Far East. *Biodiversity and Conservation*, 28(6), pp.1611-1628.

Helm, B., Piersma, T. and Van der Jeugd, H., 2006. Sociable schedules: interplay between avian seasonal and social behaviour. *Animal Behaviour*, 72(2), pp.245-262.

Holmgren, N., 1913. Termites from British India (near Bombay, in Gujarat and Bangalore) collected by Dr. J. Assmuth, SJJ Part II. J. *Bombay National History Society, Bombay,* 22 (1), pp. 101-117.

Jenkins, A.R., 2005. *Amur Falcon Falco amurensis. Roberts' birds of southern Africa*. 7th edn. Cape Town, South Africa: Trustees of the John Voelcker Bird Book Fund, pp.552-553.

Kokko, H., 1999. Competition for early arrival in migratory birds. *Journal of Animal Ecology*, 68(5), pp.940-950.

Kopij, G., 2010. Seasonal variation in the diet of the Amur kestrel (*Falco amurensis*) in its winter quarter in Lesotho. *African Journal of Ecology*, *48*(2), pp.559-562.

Kumar, R.S. (Ed.), 2021. *Understanding the Amur Falcon Falco amurensis their stop-over sites in Nagaland and their migratory routes for better conservation planning*. Wildlife Institute of India. Technical Report No. 2021/21. Pg. 191.

McKinnon, E.A., Fraser, K.C. and Stutchbury, B.J., 2013a. New discoveries in landbird migration using geolocators, and a flight plan for the future. *The Auk*, 130(2), pp.211-222.

Mendelsohn, J.M., 1997. Eastern Red-footed Kestrel *Falco amurensis. The atlas of South African birds*, 1, pp.262-263.

Meyburg, B.U., Meyburg, C. and Pretorius, R., 2017. *Year-round satellite tracking of Amur Falcon (Falco amurensis) reveals the longest migration of any raptor species across the open sea*. In From avian tracking to population processes, British Ornithologists' Union Annual Conference University of Warwick.

Meyer, S.K., Spaar, R. and Bruderer, B., 2000. To cross the sea or to follow the coast? Flight directions and behaviour of migrating raptors approaching the Mediterranean Sea in autumn. *Behaviour*, pp.379-399.

Moore, F.R., 2005. *Stop-over ecology of intercontinental migrants: en route problems and consequences for reproductive performance*. Birds of two worlds: the ecology and evolution of migration, pp.251-261.

Naoroji, R., 2006. *Birds of prey of the Indian subcontinent*. Christopher Helm, London.

NASA, 2022. *NASA Measures Rainfall from Cyclone Amphan*. Available at: https://appliedsciences.nasa.gov/our-impact/story/nasa-measures-rainfall-cyclone-amphan (Accessed: 01 November 2022)

Newton, I., 2008. *The migration ecology of birds*. Academic Press, United Kingdom.

Nourani, E., Bohrer, G., Becciu, P., Bierregaard, R.O., Duriez, O., Figuerola, J., Gangoso, L., Giokas, S., Higuchi, H., Kassara, C. and Kulikova, O. et al., 2021. The interplay of wind and uplift facilitates over-water flight in facultative soaring birds. *Proceedings of the Royal Society B,* 288, pp. 20211603.

Nourani, E., Yamaguchi, N.M. and Higuchi, H., 2017. Climate change alters the optimal wind dependent flight routes of an avian migrant. *Proceedings of the Royal Society B: Biological Sciences*, 284(1854), p.20170149.

Nourani, E., Yamaguchi, N.M., Manda, A. and Higuchi, H., 2016. Wind conditions facilitate the seasonal water-crossing behaviour of Oriental Honey-buzzards *Pernis ptilorhynchus* over the East China Sea. *Ibis*, 158 (3), pp.506-518.

Parmesan, C., 2007. Influences of species, latitudes and methodologies on estimates of phenological response to global warming. *Global Change Biology*, 13(9), pp.1860-1872.

Pervez, A., 2018. Termite biology and social behavior. In *Termites and Sustainable Management* (pp. 119-143). Springer, Cham.

Pietersen, D.W. and Symes, C.T., 2010. Assessing the diet of Amur Falcon *Falco amurensis* and Lesser Kestrel *Falco naumanni* using stomach content analysis. *Ostrich*, *81*(1), pp.39-44.

Robinson, R.A., Crick, H.Q., Learmonth, J.A., Maclean, I.M., Thomas, C.D., Bairlein, F., Forchhammer, M.C., Francis, C.M., Gill, J.A., Godley, B.J. and Harwood, J., 2009. Travelling through a warming world: climate change and migratory species. *Endangered species research*, 7(2), pp.87-99.

Roonwal, M.L. and Verma, S.C., 1991. *The South Asian Wood-destroying Termite, Odontotermes Feae (synonym O. Indicus): Identity, Biology and Economic Importance (Termitidae, Macrotermitinae)* (Vol. 129). Zoological Survey of India.

Saino, N. and Ambrosini, R., 2008. Climatic connectivity between Africa and Europe may serve as a basis for phenotypic adjustment of migration schedules of trans-Saharan migratory birds. *Global Change Biology*, 14(2), pp.250-263.

Saino, N., Ambrosini, R., Rubolini, D., von Hardenberg, J., Provenzale, A., Hüppop, K., Hüppop, O., Lehikoinen, A., Lehikoinen, E., Rainio, K. and Romano, M., 2011. Climate warming, ecological mismatch at arrival and population declines in migratory birds. *Proceedings of the Royal Society B: Biological Sciences*, 278(1707), pp.835-842.

Shamoun-Baranes, J., Liechti, F. and Vansteelant, W.M., 2017. Atmospheric conditions create freeways, detours and tailbacks for migrating birds. *Journal of Comparative Physiology A*, 203(6), pp.509-529

Thorup, K., Tøttrup, A.P., Willemoes, M., Klaassen, R.H., Strandberg, R., Vega, M.L., Dasari, H.P., Araújo, M.B., Wikelski, M. and Rahbek, C., 2017. Resource tracking within and across continents in long-distance bird migrants. *Science Advances*, 3(1), p.e1601360.

Van Noordwijk, A.J., McCleery, R.H. and Perrins, C.M., 1995. Selection for the timing of great tit breeding in relation to caterpillar growth and temperature. *Journal of Animal Ecology*, pp.451-458.

Visualisation of Earth Observation Data and Archival System (VEDAS), Space Applications Centre, Indian Space Research Organisation, Government of India 2022. Available at: https://vedas.sac.gov.in/vegetation-monitoring/index.html (Accessed: 01 November 2022).

Webster, M.S. and Marra, P.P., 2005. *The importance of understanding migratory connectivity and seasonal interactions*. Birds of Two Worlds: The Ecology and Evolution of Temperate-Tropical Migration.

Weimerskirch, H., Martin, J., Clerquin, Y., Alexandre, P. and Jiraskova, S., 2001. Energy saving in flight formation. *Nature*, 413(6857), pp.697-698.

World Bank Group, Climate Change Knowledge Portal 2021. Available at: https://climateknowledgeportal.worldbank.org/country/china/climate-data-historical (Accessed: 15 October 2021).

World Bank Group, Climate Change Knowledge Portal 2021. Available at: https://climateknowledgeportal.worldbank.org/country/south-africa/climate-data--historical (Accessed: 15 October 2021).

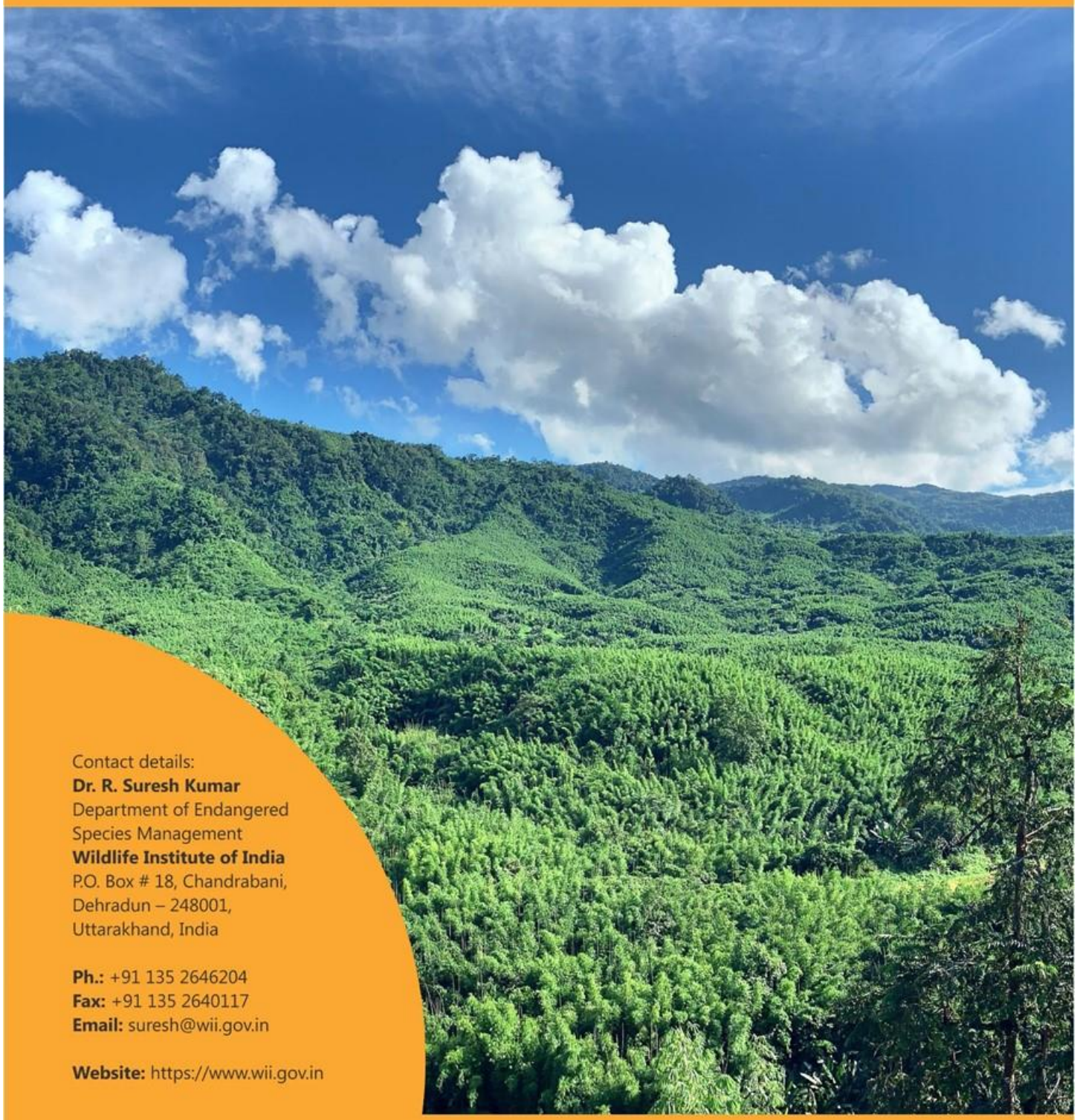
Yamaguchi, N.M., Arisawa, Y., Shimada, Y. and Higuchi, H., 2012. Real-time weather analysis reveals the adaptability of direct sea-crossing by raptors. *Journal of ethology*, 30(1), pp.1-10.

Zhou, T., Wang, H., Liu, Y., Lei, F. and Gao, W., 2009. Patterns of magpie nest utilization by a nesting raptor community in a secondary forest. *Progress in Natural Science*, 19(10), pp.1253-1259.

Annexure

Table. Morphometric data of all 28 captured Amur Falcons during the two seasons of tagging (2018 and 2019), Falcons highlight in bold are those that were deployed with satellite tags.

S.no.	Year	Amur Falcon	Sex	Weight (g)	Wing length (mm)	Tail length (mm)	Ring no.
1	2018	**Tamenglong**	Female	164	234	123	-
2		**Manipur**	Male	149	237	138	-
3		Bird 3	Male	145	240	125	-
4		Bird 4	Male	152	236	130	-
5		Bird 5	Juvenile	157	238	127	-
6	2019	Bird 1	Juvenile	110	233	126	C-58301
7		**Puching**	Female	195	299	125	C-58302
8		**Irang**	Female	155	230	121	C-58303
9		Bird 4	Female	150	236	122	C-58304
10		Bird 5	Juvenile	125	224	113	C-58305
11		Bird 6	Juvenile	140	230	122	C-58306
12		Bird 7	Male	125	234	124	C-58307
13		**Chiulon**	Male	150	242	130	C-58308
14		Gonmei	Female	145	231	126	C-58309
15		Bird 10	Female	145	225	123	C-58310
16		**Phalong**	Male	170	225	125	C-58311
17		Nehemiah	Female	165	230	129	C-58312
18		Bird 13	Female	135	235	136	C-58313
19		Bird 14	Juvenile	125	230	123	C-58314
20		Bird 15	Juvenile	135	230	120	C-58315
21		**Barak**	Female	185	230	129	C-58316
22		Bird 17	Male	160	234	127	C-58317
23		Bird 18	Female	155	231	126	C-58318
24		Bird 19	Juvenile	160	235	121	C-58319
25		Bird 20	Juvenile	145	230	125	C-58320
26		Bird 21	Male	140	236	127	C-58321
27		Bird 22	Male	150	226	125	C-58322
28		Bird 23	Juvenile	130	220	117	C-58323



Contact details:
Dr. R. Suresh Kumar
Department of Endangered Species Management
Wildlife Institute of India
P.O. Box # 18, Chandrabani,
Dehradun – 248001,
Uttarakhand, India

Ph.: +91 135 2646204
Fax: +91 135 2640117
Email: suresh@wii.gov.in

Website: https://www.wii.gov.in