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From the Mountains to the Morgue: A Comprehensive Checklist of Forensically Relevant Diptera of Ladakh, India including a New National Record

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Abstract: Forensic entomology, the meticulous study of insects associated with criminal investigations, relies predominantly on Diptera (flies) to ascertain the postmortem interval (PMI). A comprehensive checklist of forensic Diptera serves as an indispensable resource for forensic scientists, delineating species that are frequently implicated in decomposition processes. This represents the inaugural report examining the forensically significant flies in the Ladakh region of the Indian subcontinent. The checklist encompasses a diverse array of species within families such as Calliphoridae (blowflies), Sarcophagidae (flesh flies), and Muscidae (house flies), which are routinely encountered at crime scenes and on carrion. The checklist underscores key species such as *Calliphora vicina* Robineau-Desvoidy 1830, *Calliphora vomitoria* (Linnaeus 1758), *Lucilia sericata* (Meigen 1826), *Protophormia terraenovae* Robineau-Desvoidy 1830, *Musca domestica* Linnaeus 1758, *Ravinia pernix* (Harris 1780), and *Sarcophaga (Bercaea) africa* (Wiedemann 1824), all of which are commonly encountered in temperate regions. The inclusion of rare or region-specific species provides valuable insights for broader forensic investigations and future reference. Additionally, species belonging to the families Calliphoridae and Muscidae are reported for the first time from the region, including *Chrysomya phaonis* (Seguy 1928), *Hydrotaea cyrtoneurina* (Zetterstedt 1845), *Hydrotea dentipes* (Fabricius 1805), *Musca autumnalis* De Geer 1776, and *Muscina stabulans* (Fallén 1817). The checklist further features species such as *Wohlfahrtia bella* (Macquart 1839) and *Sarcophaga (Liosarcophaga) portschonskyi* (Rohdendorf 1937), which are documented for the first time in the country.

Keywords: Forensic investigation, Checklist, PMI, Diptera, Calliphoridae, Sarcophagidae, Muscidae

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Introduction

Forensic entomology represents a scientific examination of arthropods associated with discipline dedicated to the meticulous deceased organisms (Catts and Goff, 1992;

Anderson, 1997; Hall, 2009). Subsequent to death, the corporeal remains undergo a series of natural transformations as they decompose, thereby attracting necrophagous insects. These insects are pivotal in the decomposition process, and their presence and developmental stages can yield invaluable insights into the postmortem interval (PMI) (Catts and Goff, 1992). The arrival of insects at a decomposing body adheres to a specific sequence known as ecological succession (Byrd and Castner, 2001). Consequently, these insects congregate in a predetermined order, resulting in species addition and/or substitution. A comprehensive understanding of this pattern, coupled with their preferences for various stages of decomposition and meteorological data, facilitates the calculation of the postmortem interval (PMI) (Abdulla and Mohammad, 2024). Furthermore, insects can elucidate the cause of death and ascertain whether the body has been relocated (Catts and Goff, 1992; Anderson, 1997).

The primary rationale for the utilization of insects in criminal investigations, particularly through the discipline of forensic entomology, is their role as the initial organisms to detect and locate a cadaver. Insects are present at every stage of decomposition, and certain species are specifically adapted to particular environments and seasonal conditions. Moreover, it is crucial to recognize that oviposition can occur within mere minutes postmortem (Smith, 1986). It is noteworthy that insects of forensic relevance are those that not only visit the remains as adults but also engage in reproduction on these cadaverous tissues. By comprehending the developmental stages of their larvae, estimations regarding the time of death can be accurately ascertained.

Notable forensic fly families encompass blowflies (Calliphoridae), flesh flies (Sarcophagidae), and house flies (Muscidae and Fanniidae) (Savage, 2002). Their forensic importance is underscored by their propensity to consume both human and animal remains. The decomposing and synanthropic characteristics of these fly families render them especially pertinent

in forensic contexts (Catts and Goff, 1992; John *et al.*, 2025). These flies also serve as vectors for a myriad of pathogens of both medical and veterinary significance, encompassing bacterial, viral, protozoan, and helminthic species, which they disseminate among various animal species, including humans (Greenberg, 1971; Aziz *et al.*, 2016; Tomberlin *et al.*, 2017). In addition to these families, other fly taxa, such as Ulididae, Phoridae, Sepsidae, Stratiomyidae, Piophilidae, and Sphaeroceridae, have been documented visiting carcasses (Catts and Goff, 1992; Vasconcelos *et al.*, 2013; Rochefort *et al.*, 2015; Abd Al Galil *et al.*, 2016; Vasconcelos *et al.*, 2016; Chakraborty *et al.*, 2017; Heo *et al.*, 2020; Queiroz *et al.*, 2021). In the field of medical entomology, these necrophagous insects contribute to the diagnosis and treatment of conditions such as myiasis. Myiasis transpires when fly larvae infest living tissues, such as wounds, ulcers, and mucous membranes, leading to tissue destruction and subsequent infections (Zumpt, 1965). This affliction impacts a diverse array of hosts, including both wild and domestic animals, as well as humans (Francesconia and Lupi, 2012).

The present study was conducted to survey forensically significant Diptera in Ladakh, India, a region that has not been extensively explored in this field of research. It entailed a systematic field survey and the meticulous collection of specimens from carrion-feeding flies. Approximately 19 species spanning 11 genera across four families were documented during the survey. While considerable research has been undertaken globally and in other regions of India regarding the taxonomy, diversity, distribution, and economic implications of forensically significant flies, carrion insects remain inadequately investigated in the trans-Himalayan territories of India. Given the critical importance of forensic flies, an extensive field study was executed to amass forensically pertinent fly species from various locales within the districts of Ladakh. The objective of the present study was to compile a comprehensive checklist of fly species from this region for future reference.

Table 1: Collection sites of the district Kargil and Leh of UT Ladakh

District	Valley	Locality	Latitude	Longitude	Altitude
Kargil	Suru-valley	Shilikchey	34°35'08"N	76°07'30"E	2633m
	Suru-valley	Kanoor	34°25'11"N	76°03'13"E	2807m
	Suru-valley	Sankoo	34°16'53" N	75°58'20" E	2977m
	Suru-valley	Rangdum	34°03'21" N	76°19'30" E	4014m
	Shingo-valley	Lato	34°35'41"N	75°58'32"E	2736m
	Drass-valley	Gyndial	34°25'54"N	75°47'58"E	3100m
	Zaskar-valley	Padum	33°28'10"N	76°52'40"E	3600m
	Sub-valley (Indus)	Chiktan	34°28'57"N	76°27'49"E	3280m
	Indus-valley	Garkone	34°38'06" N	76°25'35" E	2767m
Leh	Indus-valley	Skara	34°09'11" N	77°34'20" E	3417m
	Indus-valley	Chhushot	34°05'40" N	77°35'17" E	3241m
	Indus-valley	Upshi	33°49'03" N	77°49'09" E	3520m
	Indus-valley	Gompa	34°11'01" N	77°35'33" E	3674m
	Nubra-valley	Taqsha	34°48'27" N	77°30'49" E	3222m
	Shyog-valley	Khardung	34°23'54" N	77°39'18" E	4002m
	Shyog-valley	Turtuk	34°50'44" N	76°49'28" E	2880m
	Changthang-valley	Pangong	33°54'29" N	78°27'25" E	4302m

Materials and Methods

Study area:

Adult flies were meticulously collected utilizing chicken bait from diverse localities across the two districts, namely Kargil and Leh, within the Union Territory of Ladakh. The localities investigated are delineated in Table 1 and illustrated in Fig. 1.

Collection of Forensically Relevant Insects:

Chicken meat (weighing between 1-3 kg) was used as bait to attract forensically significant insects. The meat was sourced from a local slaughterhouse. The bait was placed on the ground and covered with an iron cage (1'×1'×1') constructed with wire mesh featuring 1-inch holes to allow the free movement of insects. The cage was used to protect the bait from scavengers while still enabling insect access. Flies were collected by sweeping a hand net over the bait, and the captured insects were then transferred to a killing jar containing ethyl acetate.

Identification:

Specimens were meticulously classified using the identification keys provided by Akberzadeh *et al.* (2015) and Nandi (2002) at the Department of Zoology and Environmental Sciences, Punjabi University Patiala, India.

Results

This checklist presents a comprehensive overview of the various forensically significant fly families within the order Diptera in the Ladakh region of India, cataloging 18 species across 10 genera and 3 families. The findings of this study emphasize that the families Sarcophagidae, Calliphoridae, and Muscidae are of paramount importance from a forensic perspective. Genus *Sarcophaga* representing the highest proportion of species (27.7%), followed by Calliphora, Musca, and Hydrotaea (11.11%), and the remaining species (0.05%) distributed among the other genera (Fig. 2).

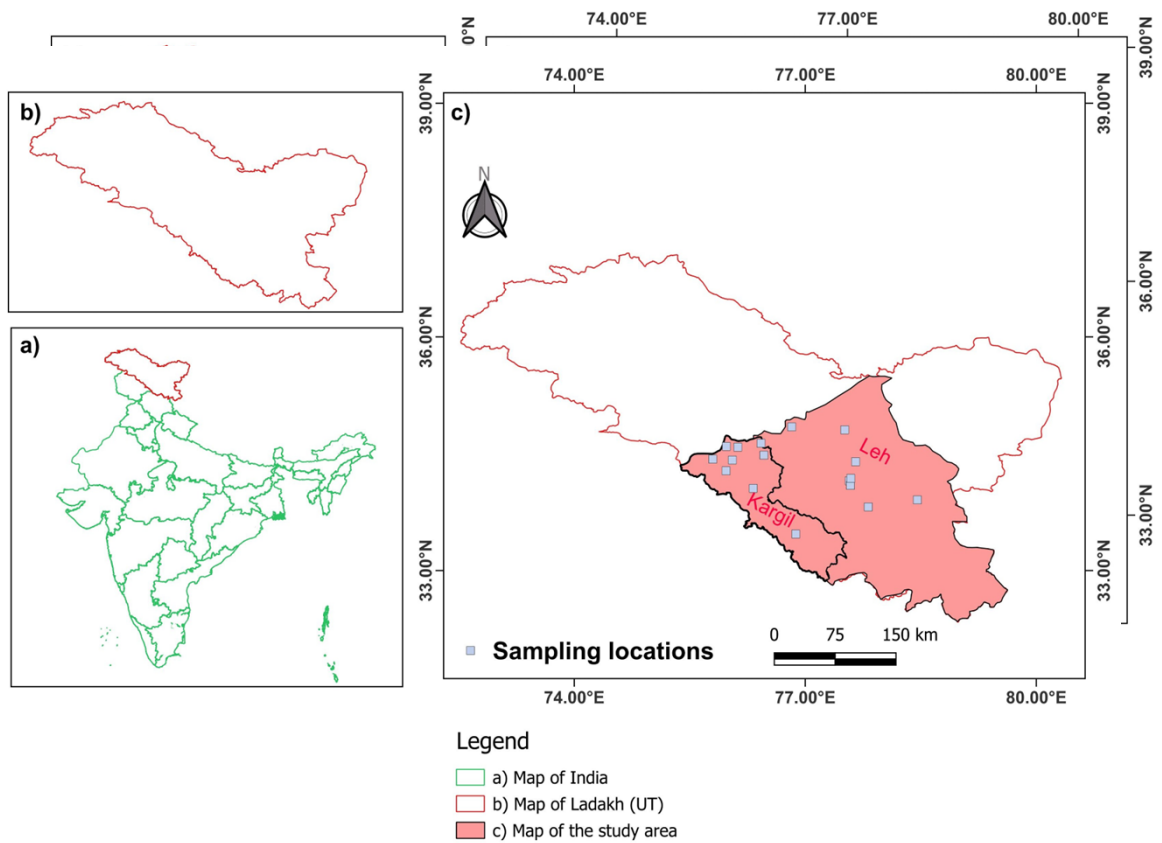


Fig. 1: Map illustrating the collection site within the districts of Kargil and Leh in the Ladakh region.

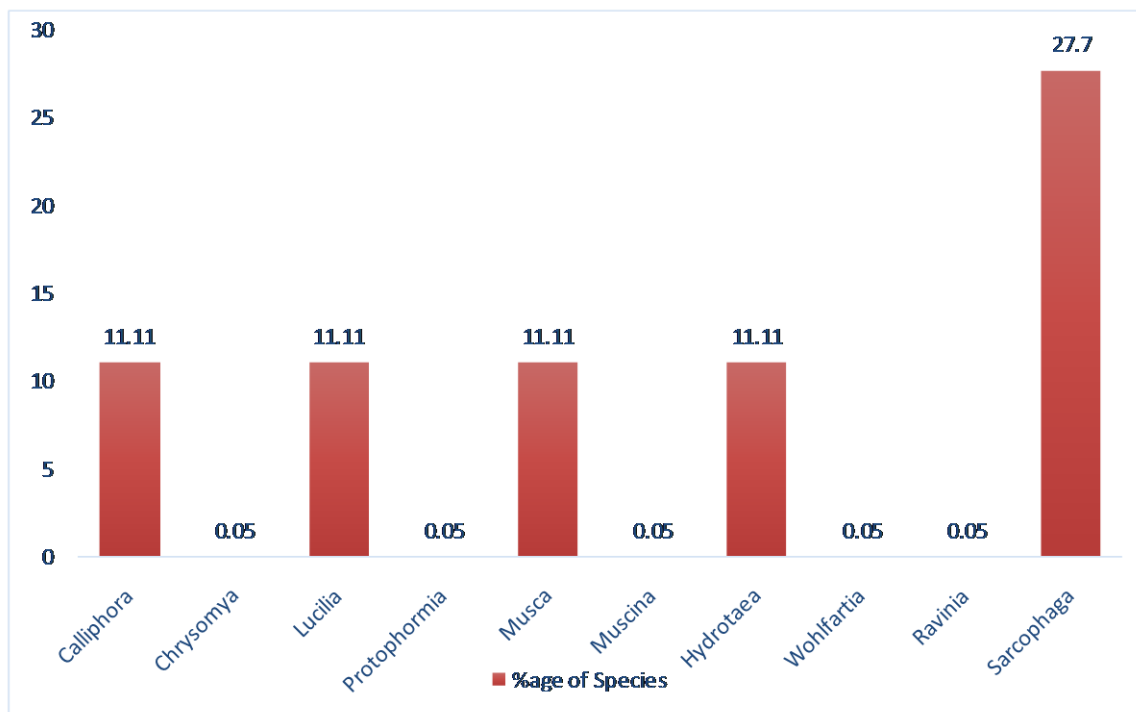


Fig. 2: Percentage of species in the various genera.

The checklist provided herein can serve as an invaluable resource for investigations related to criminal and wildlife offenses in the region. Furthermore, supplementary reports detailing various species from different Indian states would be instrumental in clarifying any ambiguities concerning the identified forensic flies, which may arise due to the presence of certain species in disparate regions of the country.

Family: Calliphoridae

Subfamily: Calliphorinae

(I) Genus: *Calliphora*

(1) *Calliphora vicina* Robineau-Desvoidy 1830

Robineau-Desvoidy, J. B. (1830). Essai sur les Myodaires. *Mémoires Présentés par divers Savants a l'Académie Royale des Sciences de l'Institut de France*, 2(2):1-813.

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk, and Upshi.

Distribution: Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Pakistan, Saudi Arabia, Syria, Turkey, United States of America, United Kingdom, and Yemen.

(2) *Calliphora vomitoria* (Linnaeus 1758)

Linnaeus, Carl (1758). *Systema naturae*, 10th edition, pp. 1-824.

Basionym: *Musca vomitoria* Linnaeus, 1758

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk, and Upshi.

Distribution: Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Pakistan, Saudi Arabia, Syria, Turkey, United States of America, United Kingdom, and Yemen.

Subfamily: Chrysomyinae

(II) Genus: *Chrysomya*

(3) *Chrysomya phaonis* (Séguy 1928)

Séguy, E. 1928. Description de diptères nouveaux. *Bulletin de la Société Entomologique de France*, pp. 152-154.

Basionym: *Cyaneosomyia phaonis* Séguy 1928

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Taqsha and Turtuk.

Distribution: Pakistan. Possible occurrence in southeast Iran.

Subfamily: Lucilinae

(III) Genus: *Lucilia*

(4) *Lucilia cuprina* (Wiedemann 1830)

Wiedemann, C.R. (1830). *Auss. Zweifl. Ins ii*, pp. 1-654.

Basionym: *Musca cuprina* Wiedemann 1830

Material examined: Kargil; Shilikchey, Kanoor, Chiktan and Padum.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk and Upshi.

Distribution: Egypt, Iran, Iraq, Israel, Pakistan, Turkey. Possible occurrence in all countries of the Middle East.

(5) *Lucilia sericata* (Meigen 1826)

Meigen, J. W. (1869). Systematische Beschreibung der bekannten europäischen zweiflügeligen Insecten. *HW Schmidt*. 8: 1-412

Basionym: *Musca sericata* Meigen 1826

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk and Upshi.

Distribution: Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Oman, Pakistan, Saudi

Arabia, Syria, Turkey, Yemen. Possible occurrence in all countries of the Middle East.

(IV) Genus: *Protophormia*

(6) *Protophormia terraenovae* Robineau- Desvoidy 1830

JB, R. D. (1830). Essai sur les Myodaires. Memoires Presentes par divers Savans a l'Academie Royale des Sciences de l'Institut de France. *Sciences Mathematiques et Physiques*, 2, 1-813.

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk, and Upshi.

Distribution: Pakistan. Possible occurrence in Turkey and north-west Iran.

Family: Muscidae

Subfamily: Muscinae

(V) Genus: *Musca*

(7) *Musca domestica* Linnaeus, 1758

Linnaeus C (1758). Systema Naturae. Regnum animale, ed. 10, vol. 1. Stockholm, 824 pp.

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk, and Upshi.

Distribution: This fly is found on all continents except Antarctica; however, it is native to the Afrotropical and Oriental regions and was most likely introduced into the Americas by Europeans during colonial periods (Moon 2002).

(8) *Musca autumnalis* De Geer 1776- (reported first time from the region)

De Geer, C. (1776). *Memoirs to serve the history of insects*. P. Hesselberg, Stockholm. Vol. 6, viii + 523 pp.

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Sankoo, and

Shilikchey

Leh; Chhushot, Gompa, Skara, Taqsha, Turtuk, and Upshi

Distribution: Belgium, Denmark, Greece, Italy, India, Norway, Poland, Portugal, Russia, Switzerland.

(VI) Genus: *Muscina*

(9) *Muscina stabulans* (Fallén 1817)- (reported first time from the region)

Fallén, C. F. (1817) Beskrifning of verge of i Sverige funna fluge arter, som kunna foras till slagtet Musca. Forsta afdelningen. K. Svenska VetenskAkad. Handl. pp. 226-254.

Basionym: *Musca stabulans* Fallén 1817

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk, and Upshi.

Distribution: Canada, Finland, India, Norway, Portugal, Poland, Spain, USA, UK.

Subfamily: Azeliinae

(VII) Genus: *Hydrotaea*

(10) *Hydrotaea cyrtoneurina* (Zetterstedt 1845)- (reported first time from the region)

Zetterstedt, J.W. 1845. Diptera Scandinaviae disposita et descripta. Tomus quartus. Officina Lundbergiana, Lundae. Pp. 1281-1738.

Basionym: *Aricia cyrtoneurina* Zetterstedt 1845

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Skara, Taqsha, and Turtuk.

Distribution: A widespread Holarctic species, also from Pakistan, South India, Myanmar and Taiwan; known from Iran and Georgia.

(11) *Hydrotaea dentipes* (Fabricius 1805)- (reported first time from the region)

Fabricius, J. C. (1805). Systema Antliatorum,

secundum ordines, genera, species: adjectis synonymis, locis, observationibus, descriptionibus. pp. 15-372

Basionym: *Musca dentipes* Fabricius 1805

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo, and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk, and Upshi.

Distribution: A common Holarctic species, also in Pakistan, India, Nepal, China and Vietnam; known from Azerbaijan, Georgia and Turkey.

Family: Sarcophagidae

Subfamily: Paramacronychiinae

(VIII) Genus: *Wohlfahrtia*

(12) *Wohlfahrtia bella* (Macquart 1839)- (first time from India)

Macquart, P.J.M., 1839. Diptères. In Webb, P.B. and S. Berthelot (Eds.): Histoire Naturelle des Iles Canaries. Tome deuxième. Deuxième partie. Contenant la zoologie. [Entomologie]: 97-119.

Basionym: *Agria bella* Macquart 1839

Material examined: Kargil; Rangdum.

Leh; Pangong.

Distribution: Afghanistan, Algeria, Azerbaijan, Iran, Israel, Jordan, Kazakhstan, Lebanon, Morocco, Pakistan, Portugal, Spain, Turkiye.

Subfamily: Sarcophaginae

(IX) Genus: *Ravinia*

(13) *Ravinia pernix* (Harris 1780)

Harris, M. 1776-1780. An exposition of English insects ... Decad I, pp. 1-40, Robson Co., London 1776

Basionym: *Musca pernix* Harris 1780

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara,

Taqsha, Turtuk and Upshi.

Distribution: India, Bangladesh (Dacca), Bhutan, Nepal, Pakistan, China, Europe, Iran, Iraq, Israel, Japan (including Ryukyu Islands), Korea and Switzerland.

(X) Genus: *Sarcophaga*

Sub genus: *Bercaea*

(14) *Sarcophaga (Bercaea) africa* (Wiedemann 1824)

Wiedemann, C. R. W. (1824). *Analecta entomologica ex Museo Reg. Havniensi maxime congesta*. e regio typographeo scholarum. Pp. 1-60.

Basionym: *Musca Africa* Wiedemann 1824

Material examined: Kargil; Chiktan, Garkone, Gyndial, Kanoor, Latoh, Padum, Rangdum, Sankoo and Shilikchey.

Leh; Chhushot, Gompa, Khardung, Pangong, Skara, Taqsha, Turtuk and Upshi.

Distribution: India, Bhutan, Nepal, Pakistan, Europe, Afghanistan, Australia, Austria, Canada, China, Costa Rica, Egypt, Iran, Japan and Korea.

Sub genus: *Liopygia*

(15) *Sarcophaga (Liopygia) argyrostoma* (Robineau-Desvoidy 1830)

Robineau-Desvoidy, J.B. 1830. Essai sur les myodaires. Mémoires présentés par divers savans à l'Académie Royale des Sciences de l'Institut de France (Sciences Mathématiques et Physiques). 2(2):1-813

Basionym: *Myophora argyrostoma* Robineau-Desvoidy 1830

Material examined: Kargil; Material examined: Kargil; Kanoor and Shilikchey.

Leh; Chhushot, Gompa, and Turtuk

Distribution: Afghanistan; Australia; Canada; China; Cuba; Cyprus; Czech Republic; Denmark; Europe; India; Iran; Iraq; South Africa; Turkey; Turkmenistan; Ukraine; United Kingdom; United States of America; and Uzbekistan.

Subgenus: *Liosarcophaga*

(16) *Sarcophaga (Liosarcophaga) aegyptica* Salem 1936

Salem, H.H. 1935. The Egyptian species of the genus *Sarcophaga* (Diptera. Tachinidae). *Publs Fac. med. Egypt. Univ.* 5: 1-61.

Material examined: Kargil; Shilikchey, Latoh, and Kanoor. Leh; Gompa.

Distribution in the world: India; Pakistan, Albania, Armenia, Austria, Azerbaijan, Bulgaria, Czech Republic, Egypt, Ethiopia, Hungary, Iran, Isreal, Kazakhstan, Moldova, Northwest China, Romania, Russia, Slovakia, Tajikistan, Turkmenistan, Ukraine.

(17) *Sarcophaga (Liosarcophaga) dux* Thomson 1869

Thomson, C.G. 1869. *Diptera. Species nova descripsit*, pp. 443-614. In: *Kongliga svenska fregatten Eugenie's resa omkring jorden under befäl af C.A. Virgin, åren 1851-1853. 2 (Zoologi) 1, Insecta. "1868". P.A. Norstedt and Soner, Stockholm.* 617 pp., pl. 9. [1869.03.10]

Material examined: Kargil; Kanoor and Shilikchey. Leh; Chhushot and Gompa.

Distribution: Australia, China, Egypt, India, Indonesia, Iran, Japan, Pakistan, Saudi-arabia, South-Korea, Thailand and United States of America.

(18) *Sarcophaga (Liosarcophaga) portschonskyi* (Rohdendorf 1937)- (first time from India)

Rohdendorf, B.B. 1937. In Stackelberg, A. A. (ed.). *Fauna U.S.S.R., Ins., Dipt., vol. 19(1). Fam. Sarcophagidae. Acad. Sci. U.S.S.R.* pp. 1-501.

Basionym: *Parasarcophaga portschonskyi* Rohdendorf 1937

Material examined: Kargil; Shilikchey, Latoh, Kanoor, Gyndial, Chiktan, and Padum. Leh; Chhushot and Gompa.

Distribution: Pakistan, Albania, Armenia, Austria, Azerbaijan, Bulgaria, China, Czech Republic, Denmark, Estonia, Finland, France, Greece, Gruzia, Hungary, Ireland, Italy, Kazakhstan, Malta,

Moldova, Mongolia, Norway, Poland, Romania, Russia, Slovakia, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan, and Yugoslavia (former).

Discussion

This study scrutinizes the trans-Himalayan region of India, an area that has remained relatively underexplored in terms of scientific inquiry, particularly concerning the forensically significant Diptera. Flies play an indispensable role in forensic entomology, as they are among the initial organisms to colonize decomposing cadavers, thereby facilitating the estimation of the Post Mortem Interval (PMI). The primary forensic fly families, including Calliphoridae (blowflies), Sarcophagidae (flesh flies), and Muscidae (house flies and Fannidae), are pivotal for this process, feeding on both human and animal remains. These flies can also induce myiasis, an infestation of living tissues in both humans and animals (Chakraborty *et al.*, 2018). The distinctive conditions at these elevated altitudes are mirrored in the remarkable number of generations many Diptera species complete during the ephemeral summer. In contrast to most terrestrial Diptera, which typically undergo three to four generations from early spring to late autumn, flies in the nival zone emerge from hibernation earlier and remain active longer, extending even into autumn when other insects have already commenced hibernation. Despite the brevity of summer, numerous species manage to complete at least two generations, particularly during the months of August and September. In the nival zone, Diptera typically hibernate in their larval stage, as observed by Mani (1969).

Conclusion

This study consolidates a checklist of forensic fly species from the Ladakh region. To date, 18 species from 10 genera across three families—namely Calliphoridae, Muscidae, and Sarcophagidae—have been documented, with the genus *Sarcophaga* representing the highest proportion of species (27.7%), followed by

Calliphora, Musca, and Hydrotaea (11.11%), and the remaining species (0.05%) distributed among the other genera. This checklist serves as an invaluable resource for investigations pertaining to both criminal and wildlife-related cases within the region.

Ethical Statement

The authors confirm that all ethical issues have been dealt with the research ethics guidelines provided by the Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab, India.

Author Contributions

Shazed Fatima: wrote the manuscript, conducted data acquisition and collection, and performed species identification; *Madhu Bala*: conceived and designed the study, analyzed the data. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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