

## Supplementary Information

Thermal drones for wildlife research in tropical forests: A review of best practices, challenges, and opportunities

*Biodiversity and Conservation*

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**Online Resource 1.** Summary of drone models and thermal infrared sensors used in 38 reviewed studies applying thermal drones to detect fauna in tropical forests, including drone and sensor specifications, survey objectives, date and season of surveys, vegetation types, locations, target species, and references; full references are provided in the main paper.

| Drone type | Drone model                     | Thermal sensor specifications                                                                                                        | Date and season                                                             | Vegetation type                                       | Location                                                    | Target species                                             | Reference                         |
|------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|-----------------------------------|
| Quadcopter | DJI Matrice 350 RTK             | DJI Zenmuse H30T payload<br>24 mm focal length<br>8 – 14 µm spectral range<br>≤ 50 mK thermal sensitivity<br>1280×1024 px resolution | May 2025<br>(dry season)                                                    | Tropical lowland eucalypt forest                      | Bambaroo, Queensland, Australia                             | Mahogany glider<br><i>Petaurus gracilis</i>                | Norris <i>et al.</i> 2025         |
|            |                                 |                                                                                                                                      | November 2024<br>(wet season)                                               | Complex mesophyll vine forest                         | Cape Tribulation, Queensland, Australia                     | Bennett’s tree kangaroo<br><i>Dendrolagus bennettianus</i> | Norris and Larson (2025)          |
|            |                                 |                                                                                                                                      | September 2024<br>(dry season)                                              | Complex notophyll vine forest<br>Open eucalypt forest | North-eastern Queensland, Australia                         | Spectacled flying-fox<br><i>Pteropus conspicillatus</i>    | Norris (2025)                     |
|            | DJI Mavic 3 Thermal             | Integrated sensor<br>9.2 mm focal length<br>8 – 14 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution         | January – June 2024<br>(dry season)                                         | Secondary forest                                      | Mauritius                                                   | Long-tailed macaque<br><i>Macaca fascicularis</i>          | Reinegger <i>et al.</i> 2025      |
|            |                                 |                                                                                                                                      | January – April 2023<br>(dry season)                                        | Tropical dry evergreen forest                         | Cat Tien National Park, Dong Nai Province, southern Vietnam | Black-shanked douc langur<br><i>Pygathrix nigripes</i>     | Gazagne <i>et al.</i> (2025)      |
|            |                                 |                                                                                                                                      | April – November 2022<br>(wet season)<br>January – May 2023<br>(dry season) | Tropical dry evergreen forest                         | Cat Tien National Park, Dong Nai Province, southern Vietnam | All primate species endemic to study area                  | Gazagne <i>et al.</i> (2024a)     |
|            | DJI Mavic 2 Enterprise Advanced | Integrated sensor<br>9.2 mm focal length<br>8 – 14 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution         | October 2023 – April 2024<br>(wet season)                                   | Tropical moist forest                                 | Brazilian Atlantic Forest, Brazil                           | Northern maned sloth<br><i>Bradypus torquatus</i>          | dos Santos <i>et al.</i> (2025)   |
|            |                                 |                                                                                                                                      | May – July 2023<br>(wet season)                                             | Tropical evergreen forest                             | Tulum, Quintana Roo, Mexico                                 | Geoffroy’s spider monkey<br><i>Ateles geoffroyi</i>        | Pinel-Ramos <i>et al.</i> (2024a) |
|            |                                 |                                                                                                                                      | Not specified                                                               |                                                       |                                                             |                                                            | Pinel-Ramos <i>et al.</i> (2024b) |
|            |                                 |                                                                                                                                      | October – November 2021<br>(dry season)                                     | Monsoon tropical rainforest                           | Northern Vietnam and Hainan, China                          | Cao vit gibbon<br><i>Nomascus nasutus</i>                  | Wearn <i>et al.</i> (2023, 2024)  |
|            |                                 |                                                                                                                                      | October – December 2022<br>(dry season)                                     | Tropical limestone rainforest                         | Northern Vietnam                                            | Delacour’s langur<br><i>Trachypithecus delacouri</i>       | Trinh-Dinh <i>et al.</i> (2024)   |
|            |                                 |                                                                                                                                      | July 2021<br>(wet season)                                                   | Monsoon tropical rainforest                           | Hainan, China                                               | Hainan gibbon<br><i>Nomascus hainanus</i>                  | Zhang <i>et al.</i> (2023)        |
|            |                                 |                                                                                                                                      | October 2021<br>(wet season)                                                | Tropical rainforest                                   | Mai-Ndombe Province, DR Congo                               | Bonobo<br><i>Pan paniscus</i>                              | van Berkel <i>et al.</i> (2023)   |
|            |                                 |                                                                                                                                      | April 2022<br>(dry season)                                                  | Tropical limestone rainforest                         | Ninh Binh Province, Northern Vietnam                        | No target species<br>(multiple taxa observed)              | Gazagne <i>et al.</i> (2023)      |

| Drone type | Drone model                   | Thermal sensor specifications                                                                                                         | Date and season                                | Vegetation type                                                            | Location                          | Target species                                              | Reference                                                                             |
|------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------------|-----------------------------------|-------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Fixed-wing | DJI Mavic 2 Enterprise Dual   | Integrated sensor<br>9 mm focal length<br>8 – 14 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×360 px resolution            | May 2022<br>(dry season)                       | Tropical moist forest                                                      | Brazilian Atlantic Forest, Brazil | Southern maned three-toed sloth<br><i>Bradypus crinitus</i> | dos Santos <i>et al.</i> (2023)                                                       |
|            |                               |                                                                                                                                       | October – November 2022<br>(dry season)        | Tropical rainforest                                                        | Ferney, Mauritius                 | Mauritian flying-fox<br><i>Pteropus niger</i>               | Seegobin <i>et al.</i> (2024)                                                         |
|            | DJI Mavic 2 Enterprise Dual   | Integrated sensor<br>9 mm focal length<br>8 – 14 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×360 px resolution            | June – September 2020<br>(dry season)          | Tropical rainforest                                                        | West Java, Indonesia              | No target species<br>(multiple taxa observed)               | Rahman and Setiawan (2020)<br>Rahman <i>et al.</i> (2020)<br>Rahman and Rahman (2021) |
|            |                               |                                                                                                                                       | January – March 2021<br>(wet season)           | Tropical rainforest                                                        | West Java, Indonesia              | Javan langur<br><i>Trachypithecus auratus</i>               | Rahman <i>et al.</i> (2021)                                                           |
|            | DJI Matrice 300 RTK           | DJI Zenmuse H20T payload<br>13.5 mm focal length<br>8 – 14 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution  | May – June 2021<br>(wet season)                | Perennial wetland, semi-deciduous, closed forest, regrowth, rehabilitation | Christmas Island, Indian Ocean    | Christmas Island flying-fox<br><i>Pteropus natalis</i>      | Dorrestein <i>et al.</i> (2025)                                                       |
|            |                               |                                                                                                                                       | June – July 2023<br>(dry season)               | Tropical rainforest                                                        | Sipirok, South Tapanuli           | Tapanuli orangutan<br><i>Pongo tapanuliensis</i>            | Rahman <i>et al.</i> (2025)                                                           |
|            |                               |                                                                                                                                       | January – August 2021<br>(wet and dry seasons) | Mangrove, savanna, montane forests                                         | Java, Indonesia                   | Various waterbird, ungulate, and primate species            | Rahman <i>et al.</i> (2022)                                                           |
|            |                               |                                                                                                                                       | November 2022<br>(wet season)                  | Tropical rainforest                                                        | Jambi Province, Indonesia         | Sumatran elephant<br><i>Elephas maximus sumatrensis</i>     | Wijayanto <i>et al.</i> (2023)                                                        |
|            |                               |                                                                                                                                       | August 2023<br>(dry season)                    | Rainforest and plantations                                                 | Jambi Province, Indonesia         | Sumatran elephant<br><i>Elephas maximus sumatrensis</i>     | Rahman (2024)                                                                         |
|            | DJI Inspire 1                 | DJI Zenmuse XT<br>6.8 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>336×256 px resolution         | March 2020<br>(wet season)                     | Miombo woodland                                                            | Issa Valley, Tanzania             | Humans (poachers)<br><i>Homo sapiens</i>                    | Doull <i>et al.</i> (2021)                                                            |
|            |                               | DJI Zenmuse XT 640 Pro<br>13 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution  | Not stated                                     | Tropical rainforest                                                        | Central Kalimantan, Indonesia     | Bornean orangutan<br><i>Pongo pygmaeus</i>                  | Dahlen and Traeholt (2018)                                                            |
|            | DJI Phantom 4 Pro             | FLIR Vue Pro 640 (9 Hz)<br>13 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution | September 2020<br>(dry season)                 |                                                                            | Sarawak, Malaysia                 |                                                             | Ampeng <i>et al.</i> (2021)                                                           |
|            | DJI Phantom 3 Pro             |                                                                                                                                       | Not stated                                     | Tropical rainforest                                                        | Sarawak, Malaysia                 | Bornean orangutan<br><i>Pongo pygmaeus</i>                  | Mutalib <i>et al.</i> (2019)                                                          |
|            | Autel Robotics EVO II Dual 8K | Integrated sensor<br>13 mm focal length<br>8 – 14 µm spectral range                                                                   | April 2021<br>(dry season)                     | Lowland tropical rainforest                                                | Osa Peninsula, Costa Rica         | No target species<br>(multiple taxa observed)               | Whitworth <i>et al.</i> (2022)                                                        |

| Drone type | Drone model         | Thermal sensor specifications                                                                                                           | Date and season                                                   | Vegetation type                             | Location                          | Target species                                                                                           | Reference                     |
|------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|---------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------|
|            |                     | ≤ 50 mK thermal sensitivity<br>640×512 px resolution                                                                                    |                                                                   |                                             |                                   |                                                                                                          |                               |
|            | Tarot X4            | FLIR Tau2 640 sensor<br>19 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity                               | May 2018<br>(dry season)                                          | Tropical rainforest                         | Borneo, Malaysia                  | Bornean orangutans<br><i>Pongo pygmaeus</i><br>Proboscis monkey<br><i>Nasalis larvatus</i>               | Burke <i>et al.</i> (2019b)   |
|            | Custom-built drone  | ≤ 50 mK thermal sensitivity<br>640×512 px resolution                                                                                    | June 2018<br>(wet season)                                         | Evergreen forest                            | Tulum, Quintana Roo, Mexico       | Geoffroy's spider monkey<br><i>Ateles geoffroyi</i>                                                      | Spaan <i>et al.</i> (2019)    |
| Quadcopter | DJI Matrice 200     | DJI Zenmuse XT V2 payload<br>13 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution | January, February, August, November 2020<br>(wet and dry seasons) | Tropical moist forest                       | Brazilian Atlantic Forest, Brazil | Northern muriqui<br><i>Brachyteles hypoxanthus</i><br>Southern muriqui<br><i>Brachyteles arachnoides</i> | de Melo (2021)                |
|            | DJI S900            | FLIR Vue Pro 336<br>13 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>336×256 px resolution          | 2018-19<br>(month & season not stated)                            |                                             |                                   |                                                                                                          |                               |
| Hexacopter | DJI Matrice 600 Pro | DJI Zenmuse XT V2 payload<br>13 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution | February 2018<br>(dry season)                                     | Semi-deciduous lowland forest               | Barro Colorado Island, Panama     | No target species<br>(multiple taxa observed)                                                            | Kays <i>et al.</i> (2019)     |
|            | DJI Matrice 600 Pro | FLIR Tau2 640 sensor<br>19 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity                               | April 2019<br>(dry season)                                        | Tropical rainforest                         | Hainan, China                     | Hainan gibbon<br><i>Nomascus hainanus</i>                                                                | Zhang <i>et al.</i> (2020)    |
|            | DJI F550            | ≤ 50 mK thermal sensitivity<br>640×512 px resolution                                                                                    | March 2017<br>(wet season)                                        | Miombo woodland                             | Issa Valley, Tanzania             | Humans (poachers)<br><i>Homo sapiens</i>                                                                 | Hambrech <i>et al.</i> (2019) |
| Fixed wing | SenseFly eBee X     | SenseFly Duet T<br>13 mm focal length<br>7.5 – 13.5 µm spectral range<br>≤ 50 mK thermal sensitivity<br>640×512 px resolution           | February 2021 & June 2022<br>(wet and dry seasons)                | Semi-agricultural tropical savanna woodland | Northern Territory, Australia     | Feral pig<br><i>Sus scrofa</i>                                                                           | Hvala <i>et al.</i> (2023)    |