**Georeferencing Sunda pangolin *Manis javanica* records in Singapore for conservation**

Muhammad Khairuldin Aziz, Anthony O’Dempsey, Ng Bee Choo, Kalai Vanan Balakrishnan, Sonja Luz, Charlene Yeong, Sharon Chan and Marcus A. H. Chua

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Supplementary Material 1 Description of methods for georeferencing compiled Sunda pangolin records from Singapore.

Pangolin sightings, roadkill, rescues, and release data were extracted from the Singapore Pangolin Working Group (SPWG) consolidated database and other publicly available data in July 2021. These records ranged from 1996 to 30 June 2021 and were compiled from SPWG member organisations: Animal Concerns Research and Education Society, Vertebrate Study Group of the Nature Society (Singapore), Lee Kong Chian Natural History Museum, National University of Singapore, and Mandai Nature, the conservation arm of Mandai Wildlife Group. Many of these records came from citizen science, public reports, and wildlife surveys. Social media posts of pangolin sightings on Singapore-based nature groups ‘Nature Society (Singapore)’ and ‘Singapore Wildlife Encounters’ on Facebook were compiled using the search term ‘pangolin’. To eliminate the risk of misidentification, records were included if photographic or video evidence of the sightings, date, and location of the observation were provided.

Records from 2015 have improved detail owing to a standard procedure for pangolin rescues. Pangolins found injured or weak, at risk of getting injured, in urban areas, and carcasses are rescued or salvaged by the National Parks Board (NParks) or ACRES. They are then admitted to the Mandai Wildlife Group, where a health assessment or post-mortem examination are conducted, and treatment and rehabilitation are carried out as necessary. Suitable release candidates are microchipped using a passive integrated transponder tag and released at an NParks managed area. We incorporated associated data from this process, including rescue and release locations.

We ensured the quality of the georeferenced data based on suitability and accuracy of the records. Records that lacked location descriptions, had multiple candidates for a location description, and duplicates were excluded. Common georeferencing problems such as textual locality descriptions without coordinates, and localities that changed over time (e.g., realigned roads) were addressed as outlined in Supplementary Table 1.

We used a hybrid method of georeferencing adapted from the point-radius method and the shape method (Wieczorek et al., 2004), while following best practices by Chapman & Wieczorek (2020). This approach suited our data which often had reference to point locations or specific structures. The point-radius method represents locality descriptions as geographic coordinates with a maximum uncertainty distance. The shape method produces polygons, buffered points, or buffered polylines without a single geographic coordinate. Georeferencing work was performed in ArcMap 10.8.1, using OneMap Web Tile Map Service (WTMS) as the base map. ESRI World Imagery satellite map was used for additional location identification.

After quality checks, we assigned unique identifying numbers to each record and categorised them based on their locality types (Supplementary Table 2). We used geographical coordinates directly where provided, with a circular 25 m uncertainty buffer for GPS error. The same buffer was applied to the Lamppost locality type, which were identified and located using Google Street View (google.com/maps).

We digitised perimeter-bounded localities (i.e., Address, Area, Road Junction, and Road Sections) in a shape based on their locality description. Using the point radius method, we generated coordinates and a circular uncertainty that encompassed the polygon. Offsets in descriptions were handled following Zermoglio et al. (2020). For roads, we used a buffered centreline, or a polygon for irregularly roads, with coordinates generated from their geographical centroids.

We mapped the georeferenced points to visualise the locations of rescues, roadkill and sightings. To analyse the trends of pangolin reports in Singapore, we used a biplot of the frequency of rescues, roadkill, and sightings over time, and calculated the coefficient of determination (r2) of each report type. We used the period from 2011–2020 to avoid zero inflation bias, and as it was also the time when most records occurred. To determine if any demographic group is more at risk of death or needing rescue, we compared the demographics of rescued and roadkill animals by sex and age following Yang et al. (2010), and performed Chi-squared tests for differences between age-sex classes.

**References**

Chapman, A. & Wieczorek, J. (2020) Georeferencing Best Practices. GBIF Secretariat.

Wieczorek, J., Guo, Q. & Hijmans, R. (2004) The point-radius method for georeferencing locality descriptions and calculating associated uncertainty. *International Journal of Geographical Information Science*, 18, 745–767.

Yang, L., Su, C., Zhang, F.-H., Wu, S.-B. & Ma, G.-Z. (2010) Age structure and parasites of Malayan pangolin (*Manis javanica*). *Journal of Economic Animal*, 14, 22–25.

Zermoglio, P., Chapman, A., Wieczorek, J., Luna, M.C. & Bloom, D. (2020) Georeferencing Quick Reference Guide. *Copenhagen: GBIF Secretariat.*, 65. GBIF Secretariat.

Supplementary Table 1 Common georeferencing issues and solutions used.

|  |  |
| --- | --- |
| Common georeferencing issues | Solution |
| Textual description without coordinates | Apply georeferencing methods to spatially represent the description, usually a singular point and uncertainty polygon |
| Formatting and spelling inconsistency | Using a standard gazetteer, i.e., OneMap to standardise spelling of location names |
| Outdated locality description | Check against old version of maps, e.g., Google Earth; consulting government agencies responsible for the locations |
| Ambiguously described locations | Do not georeference |

Supplementary Table 2 Classes of locality types and their description used in this georeferencing project.

|  |  |
| --- | --- |
| Locality Types | Description |
| Address | Description contains a searchable address or feature with a determined boundary, e.g., Shuqun Primary School, Lorong Rusuk bus stop no. 34109, 100 Upper Jurong Road, Labrador Nature Park |
| Area | Descriptions containing a general location, e.g., Choa Chu Kang, Woodlands |
| Coordinates | The locality description contains coordinates in any format |
| Lamppost | Description contains a lamppost number on a road, e.g., at lamppost 54, first lane towards MacRitchie Reservoir Park |
| Road | Description contains only road names, e.g., Mandai Road, Sembawang Road area |
| Road Junction | Description contains mentions of a crossing, junction, intersection or other terms related to an intersection of two or more paths, e.g., Lornie Road at the entrance of Sime Road, Upper Thomson Road opposite Tagore Drive |
| Road Section | Description containing a road between two points or a road and an adjacent feature, e.g., vicinity of Punggol towards Central Expressway between lampposts 650 and 694 |

Supplementary Table 3 Summary of compiled Sunda pangolin records from Singapore from 2011 to June 2021.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Rescues | Roadkills | Sightings | Total |
| 2011 | 5 | 4 | 6 | 15 |
| 2012 | 18 | 3 | 7 | 28 |
| 2013 | 7 | 4 | 6 | 17 |
| 2014 | 16 | 4 | 9 | 29 |
| 2015 | 24 | 6 | 19 | 49 |
| 2016 | 24 | 6 | 26 | 56 |
| 2017 | 21 | 12 | 21 | 54 |
| 2018 | 28 | 8 | 14 | 50 |
| 2019 | 23 | 9 | 10 | 42 |
| 2020 | 11 | 9 | 19 | 39 |
| 2021 (to end June) | 12 | 10 | 3 | 25 |

Supplementary Table 4 Sunda pangolin roadkills in Singapore from 1996 to June 2021 by sex and age classifications. Individuals with unknown sex were omitted.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sex | Adult | Subadult | Juvenile | Age unknown |
| Female | 1 | 1 | 0 | 3 |
| Male | 5 | 1 | 1 | 11 |