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Venomous snake distribution in Indonesia from citizen science and museum data

A recent study showed that reliable information about snake demography is needed in Indonesia for mitigating snakebite risk (Malhotra *et al*. 2021). There are more than 300 known snake species in Indonesia, of which 57 species, or about 19% belong to the Elapidae, and 22 species (about 7%) to the Viperidae (Uetz *et al*. 2025). Only a few species of snakes in Indonesia are viewed as medically important species by the World Health Organization (WHO 2016). Most of the snakes categorized as medically important are based on their number of snakebites, resulting in high levels of morbidity, disability, or mortality in humans. Another consideration in classifying the medical importance of snakes is how frequently the species encounters large human populations. This highlights the need to better understand venomous snake diversity and distribution, particularly in areas of high human population density.

Biological collections in museums have potential as resources that can be used to understand the impact of human activities on biodiversity and ecosystems (Meineke *et al*. 2018), to develop strategies to help mitigate climate change (Lacey *et al*. 2017), or to understand the spread of invasive species (Ferguson *et al*. 2020). In addition to museum collections, utilising opportunistic data collected through citizen science has become popular for studying biodiversity and ecological dynamics. Citizen science initiatives have recently increased in number, size, and scope, potentially contributing to biodiversity monitoring and ecological studies, particularly in regions with limited resources or little data available (Theobald *et al*. 2015). Recent studies demonstrated the reliability of utilising data from the citizen science platform to study biodiversity, conservation, and ecology and predict the distribution patterns of species (van der Velde *et al*. 2017, Sumner *et al*. 2019, Callaghan *et al*. 2020, Wangyal *et al*. 2022, Febbraro *et al*. 2023). This study provides data on the distribution and diversity of venomous snake species, lists frequently encountered species and identifies the regions with frequent encounters by exploring collections at the Museum Zoologicum Bogoriense (MZB) and snake observation data from the website iNaturalist (hereafter iNat; iNaturalist 2024). The MZB is a prominent zoological museum that has had collections of preserved fauna since 1894 and is currently managed by the National Research and Innovation Agency of Indonesia (BRIN). These records indicate how often people encounter snakes. By focusing on two venomous snake families, Elapidae and Viperidae, we highlight the species that could pose a risk of snakebites in Indonesia and provide information to help mitigate human-snake conflicts.

Data collection. We use the Elapidae and Viperidae specimens collected from 1905 to 2023 in the MZB as species occurrence records in Indonesia. The primary information collected is date, species, and locality. Records without dates but with geographic details are included. This resulted in 598 MZB records for the analysis. We also utilised snake observation records in iNat reported from 2006 to 2024. The research-grade dataset was downloaded directly from iNat observations for all reptile taxa recorded in Indonesia. We then restricted the observations to include only Elapidae and Viperidae, yielding a sample of 1486 records. All geographic information was grouped at the provincial level, which was then used for further analysis.

Species identification may be affected by the dynamics of species taxonomy studies. Thus, we also carefully reviewed species identifications from both data sources. We reviewed both the specimen (in MZB) and the photograph (in iNat). Any doubtful identifications were removed from the analysis. We modified several species identifications based on the latest species designation. For example, several species in the *Trimeresurus* group have recently been reclassified into the *Craspedocephalus* group. Morphological identification to differentiate *T. albolabris* and *T. insularis* from Jawa Tengah, which are mainly based on their body pattern and coloration, cannot be done with museum specimens. Tentatively, we consider five museum specimens from Jawa Tengah Province to be *T. albolabris* and all specimens from Jawa Timur Province as *T. insularis*. Meanwhile, iNat data shows nine records of *T. insularis* in the Jawa Tengah area. The Russel's viper distributed in Indonesia is identified as *Daboia siamensis* and named eastern Russel's viper (Uetz 2025).

Data analysis. The two existing datasets were used to develop species encounter lists and to compare species distributions across regions in Indonesia. We used the R statistical program version 4.2.2. (R Core Team 2022) to analyse and visualise our data. We categorized the data based on genus, species, and region, allowing us to focus our analysis on the most significant records for each category. We performed a Mann-Whitney-Wilcoxon Test to examine differences in records between two groups (MZB and iNat). We used an edited heatmap of Looker Studio (www.lookerstudio.google.com) from Google Data Studio to create a hotspot map based on the number of records to visualize trends in the data. The two data sources we used show differences. MZB has fewer specimen records (598 records) than iNat (1,486 records). But there are more species in MZB (66 species) compared to iNat (31 species). Statistical analysis indicates that the number of records for each species between the two datasets is not significantly different (Wilcoxon Signed-Rank Test, P>0.05). Both datasets covered nearly all provinces in Indonesia, but there are significant differences in record numbers between provinces in MZB and iNat (Wilcoxon Signed-Rank Test, P<0.05).

Records by taxa. There are 326 Elapid and 272 Viperid specimens in the MZB, for a total of 66 species from 19 genera (Fig. 1). The top five genera based on these records are *Trimeresurus* (22.9%, *n*=137), *Hydrophis* (13.0%, *n*=78), *Bungarus* (10.5%, *n*=63), *Naja* (9.9%, *n*=59), and *Craspecodephalus* (8.5%, *n*=51). There are 15 species with ≥2% of the total records (Table 1), they are *Trimeresurus insularis* (11.9%, *n*=71), *Naja sputatrix* (7.5%, *n*=45), *Bungarus candidus* (7.5%, *n*=45), *Tropidolaemus wagleri* (6.8%, *n*=41), *Craspedocephalus puniceus* (6.2%, *n*=37), *Calliophis intestinalis* (6.0%, *n*=36), *Calloselasma rhodostoma* (4.0%, *n*=24), *Trimeresurus sumatranus* (3.0%, *n*=18), *Acanthophis praelongus* (3.0%, *n*=18), *Trimeresurus albolabris* (2.3%, *n*=14), *Naja sumatrana* (2.3%, *n*=14), *Craspedocephalus borneensis* (2.2%, *n*=13), *Ophiophagus bungarus* (2.2%, *n*=13), *Bungarus fasciatus* (2.0%, *n*=12), and *Hydrophis schistosus* (2.0%, *n*=12).

Table 1. The most common venomous species reported from highest to lowest frequency in two datasets (MZB and iNat; ≥2% of the total records). Species in both datasets are marked with *

	MZB		iNat
1	*Trimeresurus insularis**	1	*Trimeresurus albolabris**
2	*Naja sputatrix**	2	*Trimeresurus insularis**
3	*Bungarus candidus**	3	*Laticauda colubrina*
4	*Tropidolaemus wagleri**	4	*Tropidolaemus wagleri**
5	*Craspedocephalus puniceus**	5	*Naja sputatrix**
6	*Calliophis intestinalis*	6	*Bungarus candidus**
7	*Calloselasma rhodostoma**	7	*Tropidolaemus subannulatus*
8	*Trimeresurus sumatranus*	8	*Bungarus fasciatus**
9	*Acanthophis praelongus*	9	*Craspedocephalus puniceus**
10	*Trimeresurus albolabris**	10	*Naja sumatrana**
11	*Naja sumatrana**	11	*Ophiophagus bungarus**
12	*Craspedocephalus borneensis*	12	*Calloselasma rhodostoma**
13	*Ophiophagus bungarus**		
14	*Bungarus fasciatus**		
15	*Hydrophis schistosus*		

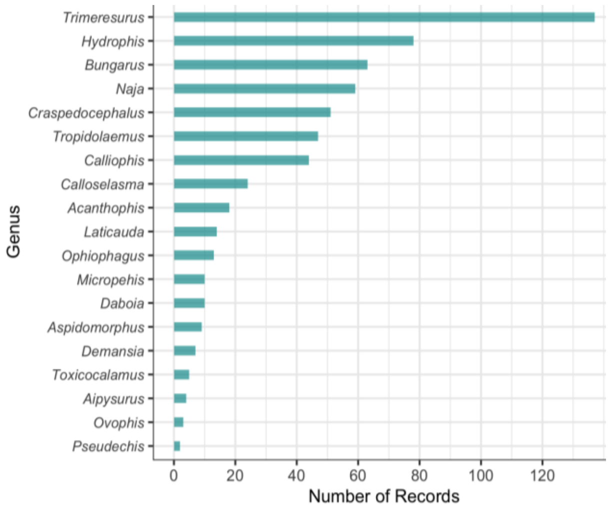

Figure 1. The number of records for each genus of Elapidae and Viperidae based on the MZB.

We identified 15 genera, composed of 31 species from 1,486 observations of 661 Elapidae and 825 Viperidae in iNat (Fig. 2). The top five genera observed are *Trimeresurus* (32.2%, *n*=479), *Tropidolaemus* (14.9%, *n*=221), *Bungarus* (13.4%, *n*=199), *Naja* (12.4%, *n*=185), and *Laticauda* (12.4%, *n*=185). There are 12 species with more than 2% of the records (Table 1), they are *T. albolabris* (16.1%, *n*=240), *T. insularis* (13.0%, *n*=194), *Laticauda colubrina* (10.4%*n*=154), *T. wagleri* (9.1%, *n*=135), *N. sputatrix* (8.5%, *n*=126), *B. candidus* (7.5%, *n*=112), *Tropidolaemus subannulatus* (5.2%, *n*=77), *B. fasciatus* (5.1%, *n*=76), *C. puniceus* (4.6%, *n*=68), *N. sumatrana* (4.0%, *n*=59), and *O. bungarus* (3.0%, *n*=44), and *C. rhodostoma* (2.4%, *n*=36).

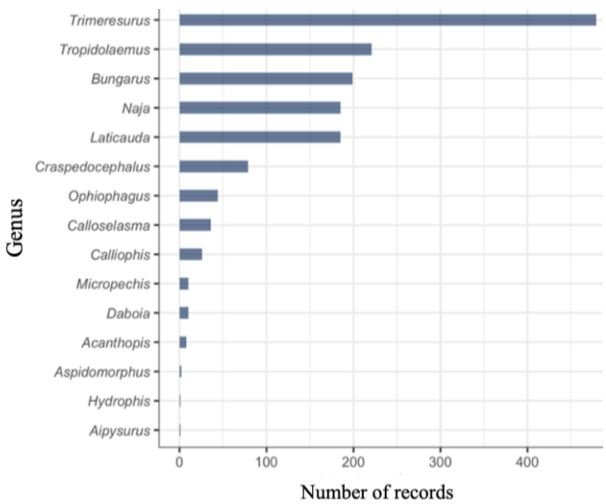

Figure 2. The number of records for each genus of the Elapidae and Viperidae based on iNat

Records by region. Specimens recorded in MZB are spread across all 38 provinces of Indonesia. (Fig. 3). The ten provinces with the highest records are Jawa Barat (22.1%, *n*=132), Nusa Tenggara Timur (10.9%, *n*=65), Jawa Timur (7.3%, *n*=44), Sumatera Utara (4.5%, *n*=27), Sumatera Barat (3.8%, *n*=23), Lampung (3.8%, *n*=23), Nusa Tenggara Barat (3.5%, *n*=21), Jawa Tengah (3.5%, *n*=21), Sulawesi Selatan (3.3%, *n*=20), and Maluku (2.8%, *n*=17). Snakes recorded in iNat are spread across 34 provinces (Fig. 4). The ten provinces with the highest number of records in iNat are Jawa Barat (29.3%, *n*=437), Bali (12.4%, *n*=185), Nusa Tenggara Timur (7.8%, *n*=116), Sumatera Utara (7.4%, *n*=110), Jambi (4.3%, *n*=64), Jawa Tengah (3.5%, *n*=52), Kalimantan Barat (3.2%, *n*=47), Sulawesi Utara (3.1%, *n*=46), Kalimantan Tengah (2.8%, *n*=42), and D.I. Yogyakarta (2.6%, *n*=39).

The distribution and abundance of venomous snake species in Indonesia, based on the MZB and iNat provide different results. These differences are reasonable, given that each dataset was compiled differently. Most herpetological specimens at MZB were gathered through standardized scientific surveys or structured research activities. Collection sites are usually selected based on the absence or scarcity of data for a particular area. On the other hand, iNat records were compiled from a wide range of unstructured activities carried out by users with diverse backgrounds, including nature enthusiasts, professional biologists, and researchers; each may visit a site for different purposes.

Our results indicate that the frequently encountered Viperidae and Elapidae species are indeed the ones that commonly cause snakebite envenomation (Table 1), which is also categorized as the most important snake species from a medical point of view by the WHO (2016). The species included in this category, which are also commonly observed in this study, are *T. albolabris*, *T. insularis*, *N. sputatrix*, *N. sumatrana*, *B. candidus*, *B. fasciatus*, *C. intestinalis*, *C. rhodostoma*, *O. bungarus*, *Micropechis ikaheka*, and species from the genus *Acanthophis*. Our analysis also suggests that several species were commonly sighted but are not included in the medically important category because they have not been widely recorded as causing snakebite envenomation, such as species in the *Tropidolaemus* and *Craspedocephalus* groups. WHO (2016) has listed several antivenoms for treating Southeast Asian snakebites. The Thai Red Cross Society

(Thailand) produces antivenoms to treat bites from common species found in this study, such as *T. albolabris*, *O. bungarus*, *C. rhodostoma*, *B. candidus*, and *D. siamensis*.

One notable viper species is *C. puniceus*, widely documented in Jawa Barat. Its presence poses a potential risk for snakebite envenomation, mainly because Jawa Barat is the most populous region in Indonesia. The venom of *C. puniceus* from Java Island has been shown to have intraspecific variation and different composition from other viper venoms of close geographic regions (Anita *et al*. 2022, 2024). Currently, no specific antivenom is available for this species from Indonesia, but studies have suggested that the Thai Green Pit Viper Antivenom may cross-neutralize and is effective at immune recognition of venom fractions containing high molecular weight proteins from the *C. puniceus* venom (Lee *et al*. 2021, Tan *et al*. 2017). *Tropidolaemus* species commonly observed from both datasets are *T. wagleri* and *T. subannulatus*. There is poor documentation on the significance of *Tropidolaemus* bite envenomation in Indonesia. However, in Malaysia, these two species are identified as common causes of snake bites, although no deaths have been recorded yet (Ismail *et al*. 2023).

The findings of this study emphasize the importance of examining marine elapid snakes as well. The MZB data mostly consists of *Hydrophis* species, while in iNat, *Laticauda* (particularly *L. colubrina)* is common.

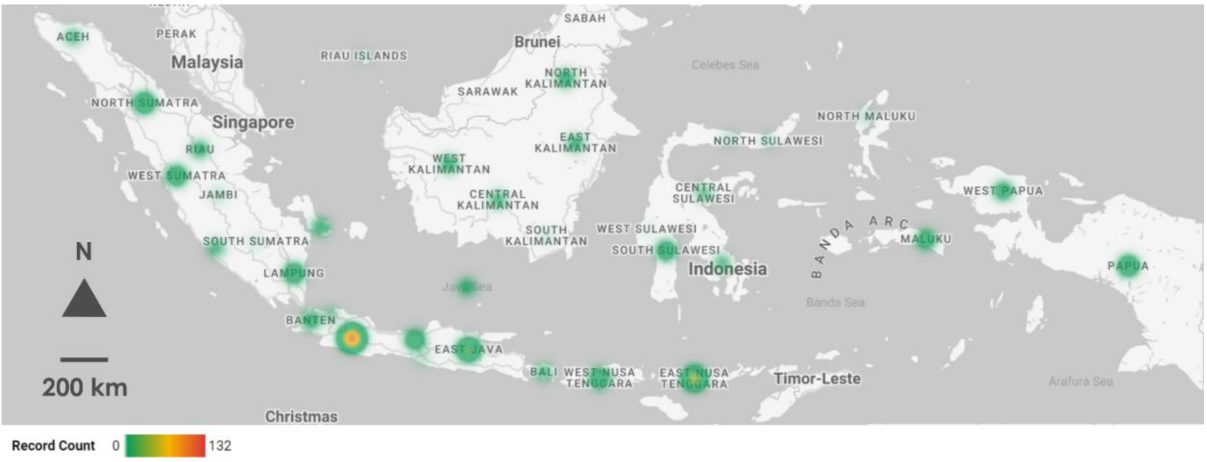

Figure 3. Number of records of Elapidae and Viperidae in each province in the MZB collection. Each province's capital city is used as the location marker. The size of the circles represents the number of records for each province. A larger circle size with a deeper yellow-to-red colour indicates more records.

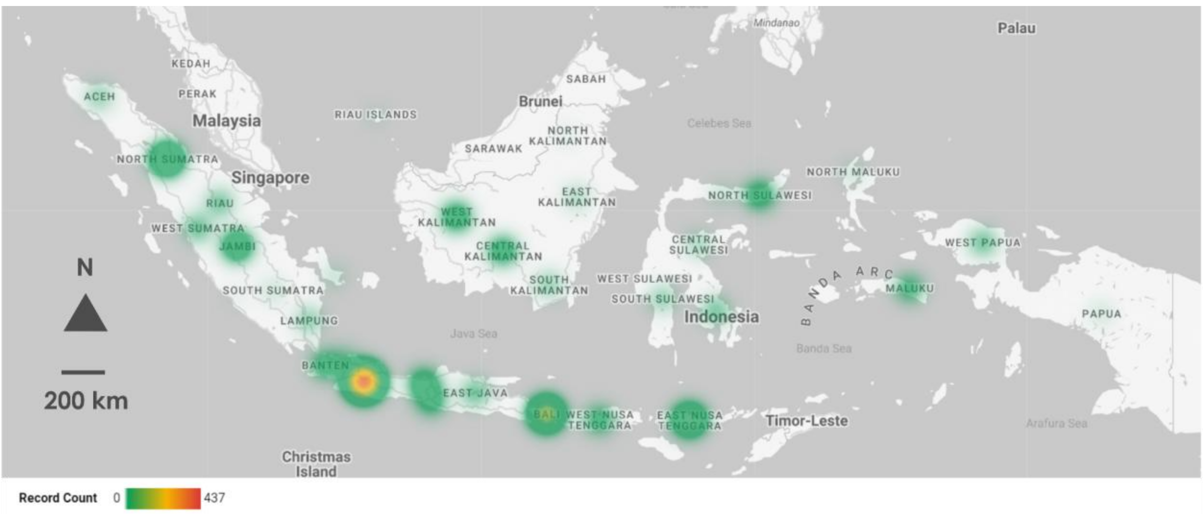

Figure 4. The number of records of Elapidae and Viperidae in each province from the iNat records. Each province's capital city is used as the location marker. The size of the circles represents the number of records for each province. A larger circle size with a deeper yellow-to-red colour indicates more records.

Table 2. The top ten provinces that have the most common venomous species records from highest to lowest frequency in the two datasets (MZB and iNat). Provinces common to both datasets are marked with *

MZB		iNaturalist	
1	Jawa Barat*	1	Jawa Barat*
2	Nusa Tenggara Timur*	2	Bali
3	Jawa Timur	3	Nusa Tenggara Timur*
4	Sumatera Utara*	4	Sumatera Utara*
5	Sumatera Barat	5	Jambi
6	Lampung	6	Jawa Tengah*
7	Nusa Tenggara Barat	7	Kalimantan Barat
8	Jawa Tengah*	8	Sulawesi Utara
9	Sulawesi Selatan	9	Kalimantan Tengah
10	Maluku	10	D.I. Yogyakarta

Marine elapid snakes in MZB usually come from captures by fishermen, indicating that fishermen are potentially at risk of snake bites. Although fishermen commonly encounter marine elapid snakes, there is relatively little documentation on envenomation by marine elapid snakes. One recent study reported the bite of *Hydrophis curtus* on a young fisherman from northern Sri Lanka (Chathuranga *et al*. 2024). The clinical manifestation suggests myotoxicity, and the patient made a complete recovery without the need for antivenom therapy. Neurotoxins are considered to be the main functional component of most sea snake venoms (Neale *et al*. 2017, Wang *et al*. 2020). However, a recent study has shown that Australian sea snake envenomation can also cause myotoxicity, posing a risk of significant morbidity and mortality (Johnston *et al*. 2022). Although marine elapid snakes are commonly encountered in Indonesia, the risk of envenomation may be low. The sea snakes are reluctant to bite, even when harassed by humans, possibly due to their adaptive behaviour (Udyawer *et al*. 2021).

The results from both datasets indicate that several regions in Indonesia (Table 2), such as Jawa Barat, Jawa Tengah, Jawa Timur, Sumatra Utara, Bali, and Nusa Tenggara Timur, have high snake occurrence records. The large human populations in these regions may explain the high number of recorded snakes. Over half of the Indonesian population lives on Java Island, and Jawa Barat is the most populated area. Based on this study, Java also has the highest number of venomous snakes. The results also indicate that Sumatra Utara, Bali and Nusa Tenggara Timur, to the eastern part of the Indonesian archipelago, are common areas for encountering *D. siamensis*, *T. insularis*, and *N. sputatrix*.

This study highlights the distribution of important venomous snake species of the families Viperidae and Elapidae in Indonesia. This study also identified provinces requiring attention for managing venomous snakebite risks and, at the same time, promoting snake conservation. We recommend focusing on the most common species records from both datasets, which comprise the ten species: *T. albolabris*, *T. insularis*, *N. sputatrix*, *N. sumatrana*, *B/ candidus*, *B. fasciatus*, *C. rhodostoma*, *C. puniceus*, *O. bungarus*, and *T. wagleri*. Based on our study, Jawa Barat, Jawa Tengah, Sumatra Utara, and Nusa Tenggara Timur are the regions deserving more attention to mitigating human-snake conflicts.

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