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Distribution of snake species and snakebites in hotspots of Ethiopia

Gashaw Gebrewold[1], Timothy J Colston[2], Ashebir Abebe[3], Karifa Kourouma[4], Robinah Najjemba[5], Demise Mulugeta[1], Hailu Lumma[1], Sintayehu Abdella[1], Tamrat Haile[6], Maria Zolfo[7], Veerle Vanlerberghe[8]

[1] *Ethiopian Public Health Institute, Addis Ababa, Ethiopia*
[2] *Biology Department, University of Puerto Rico at Mayagüez, Mayagüez, Puerto Rico*
[3] *National Animal Health Diagnosis and Research Center, Sebeta, Ethiopia*
[4] *Center National de Formation et Recherche en Santé Rurale de Maferiyah (CNFRSR), Forécariah, Guinea*
[5] *Independent Public Health Consultant, Geneva, Switzerland*
[6] *Ethiopian Wildlife Conservation Authority, Addis Ababa, Ethiopia*
[7] *Institute of Tropical Medicine, Clinical Sciences Department, Antwerp, Belgium*
[8] *Institute of Tropical Medicine, Public Health Department, Antwerp, Belgium*

Abstract

Introduction: In Sub-Saharan Africa, snakebites are a public health problem. In Ethiopia, clinical cases have been described, but little information exists on snakebites burden and its geographical distribution. The aim of this study was to document the spatial distribution of venomous snakes and snakebites in Ethiopia.

Methodology: In a cross-sectional observational study, venomous snakes were collected during snake catching activities in six Ethiopian hotspot areas between April 2015 and September 2020. Species and habitat were described. In the hotspot areas, routine health information data on reported snakebites was collected in 78 districts and subsequently used to map annual incidence per district.

Result: A total of 333 snakes were collected and 14 species were identified. The most prevalent species were *Bitis arietans, Bitis arietanus somalica, Echis pyramidum,* known as vipers, and *Naja pallida,* known as cobra. The highest number of snakes (75) was observed in the Northwest and Eastern parts of Ethiopia, mostly in cultivation and man-made farm land, wooded and moist dry savanna. In each hotspot a wide variety of species was observed, although composition was different. The highest snakebite incidence overlapped with the high snakes densities in Northwest Ethiopia. The snakebite annual average incidence at district level was very heterogeneous and ranged from < 15 cases/100,000 inhabitants (44% of the districts) to 309.2 cases/100,000 inhabitants.

Conclusions: Snake diversity and distribution, linked to high incidence of snakebites in the hotspots, suggests a close interconnection between human, animal and environmental systems and could inform the need for antivenoms per geographical locality.

Key words: Snakebite incidence; habitat; operational research; Sort IT.

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Introduction

Snakebite is a potential life-threatening medical emergency and a public health concern worldwide. According to the last World Health Organization (WHO), every year an estimated 5.4 million people are bitten by snakes worldwide with a burden of 81,000-138,000 deaths and 400,000 permanent disabilities [1]. Snakebite envenoming is one of the many health problems, the world's poorest citizen's face, especially in the rural communities in tropical and sub-tropical countries where snakes are most abundant [2]. WHO currently focuses on a diverse group of diseases and included snakebites to the list of NTDs [3, 4], aiming to reduce its morbidity and mortality by 50% before the year 2030 [2].

A large number of medically important snake species including various types of cobras, mambas and a range of vipers are found in Africa [5]. Management of snakebite has traditionally received little attention in many African countries. Patients rarely seek appropriate health care or often present themselves to health facilities too late, and most of the time an antivenom is not available or affordable [6].

In Ethiopia, the burden of snakebites is poorly documented [7]. The Ethiopian Public Health Institute (EPHI) is mandated to generate evidence to inform policy and practice. In 2014, EPHI conducted a study to estimate the burden of the problem, revealing a number of hotspots predominant for venomous snakes species throughout the country [8]. This work documented that

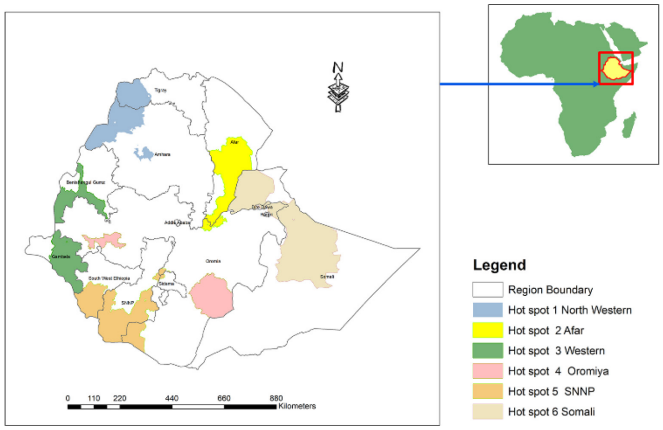
antivenom was often not available at health facility level and there was limited knowledge on the distribution of predominant venomous snakes in the country. This information is as critical for the case management, including antivenom selection, as the clinical manifestations, induced by haemotoxins, cytotoxins and neurotoxins [9], of snakebites envenomation are determined by the species and the composition of the venom. The treatment with antivenoms is considered cost-effective as the Incremental Cost-Effectiveness Ratio per DALY averted is reported to be within the range from 69.87 to 256.62 US$ [10]. Reduction of morbidity and mortality following snakebites would require availability of antivenoms against the specific snake prevalent in that area, besides good supportive medical management and care. Information on the predominant venomous snakes along with their predominant habitat in Ethiopia is essential for decision making on distribution and provision of antivenoms, and on the specific training needed for communities and health care workers. To obtain this evidence, EPHI started a snake catching program in the different known venomous snakes hotspots in 2015, and collects information on the predominant snake species with their habitat along with the reported cases of snakebites.

Methodology

Study design

A cross-sectional observational study on venomous snake species distribution in six hotspots for snake activity in Ethiopia was conducted. The snakes were collected during snake catching activities between April 2015 and September 2020. This was complemented with secondary data from routine health information of 78 districts on reported snakebites.

Figure 1. Map of six venomous snakes hotspot areas in Ethiopia, 2015-2020.



General setting

Ethiopia is located in the Horn of Africa and covers a land area of about 1.1 million square kilometers with a 2020 population estimated by UN worldometers at 114,963,588 (mid years), of which 21.3% is living in an urban environment. The climate condition of the country varies greatly from West to East and from North to South. The weather is sunny and dry from February to April and the typical rain season starts in mid-June and lasts up to mid-September. The central part of the country mainly consists of highlands surrounded by low land.

Specific settings

The study, characterizing distribution of snakes and snakebites, was conducted in the six known hotspot regions for venomous snakes in Ethiopia, which were defined based on information from (i) EPHI 2014 epidemiological study, (ii) WHO venomous Snake and Antivenom database, (iii) the antivenom dissemination plan by Ethiopian Pharmaceutical Fund and Supply Agency (PFSA) and (iv) the Ethiopian Wildlife Conservation Authority (EWCA). The six hotspots (Figure 1) are Amhara and Tigray (hotspot 1), Afar (hotspot 2), Gambela and Benshangul Gumize (hotspot 3), Oromia (hotspot 4), South National Nationality People (SNNP) (hotspot 5) and Somalia (hotspot 6) [11]. These areas are mainly low land with altitude ranging from 400 to 1,900 meters above sea level. Ethiopia holds a wide variation of habitats prone to venomous snakes especially in the hotspots areas. During this study, we focused on the most common habitats such as national park, wildlife sanctuaries, community conservations and controlled hunting areas along with some cultivation and plantation areas, where there exists a high risk for human exposure.

Snakes were caught during field surveys, using visual encounter surveys, which are an established method for snake detection. These surveys are part of the EPHI routine activities. Within each hotspot, catch locations were defined based on previous program reports and on discussions with community village leaders, staff from the wild life conservation authorities (in case of national parks), plantations workers and farmers. In these places, trained snake catchers walked around, preferably at night, exploring known snake hiding sites such as under rocks, in tree logs, close to water sources, or in the parks, while searching for prey. In national parks, the catchers joined the wild life conservation staff during their activities. In addition, catchers went to places, where community members indicated to have noticed a snake. Snakes were caught

using snake hooks and/or tongs, and afterwards kept in a secure bag during transfer to a cage at the base camp, where the snakes underwent a detailed examination for species identification. In accordance with the Ethiopian wild life conservation regulations, snakes were released once identified, and also only one or two snakes per species were to be caught in the same place.

Snakebite information

As snakebites are not included in the national surveillance system, first line health facilities near and within the hotspot areas were purposively chosen based on case reports. In total 78 districts were included. The health facilities were approached by EPHI team to collect information on the number and gender of patients presenting at their outpatient departments with snakebites over the study period 2015 to 2020. A specific form was designed to collect these data. The forms were collected by the EPHI team on a yearly basis, as part of their routine and supervision activities.

Study population

All venomous snakes collected in the six hotspot areas, during the catching activities between April 2015 and September 2020 were included in this study. The population of these areas attending first line health care facilities were the study population for the snakebite surveillance.

Study variables and data analysis

Number and type of venomous snake species and year of snake catching activity were collected. The location of the catchment was geo-referenced and habitat described, basing on the categories used by the EWCA. The species of snakes are identified by an EPHI expert group, existing of EPHI biologists receiving guidance from a herpetologist, following Warrell [12], Largen and Spawls [13] and Largen and Rasmussen [14], guidelines, and basing on: 1) body shape; 2) shape of the scale; 3) head shape; 4) patterns on the back. From all snakes pictures were taken and stored (hard and soft copy).

Data were extracted from the EPHI snake catching program reports and entered in an Excel sheet (version 16.0). A map was elaborated with Google Earth and Quantum Geographical Information System (QGIS) to present the geographical distribution of the snake species. This was complemented by a descriptive analysis of species variety per hotspot area and per habitat type.

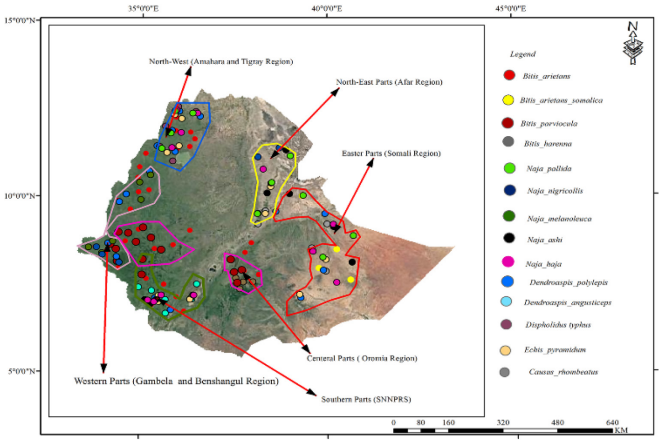
Concerning the snakebite cases, information on the gender and the year of presentation was collected per health facility in the selected districts. Data were entered in an Excel sheet. The population data were retrieved from the 2007 census from the Central Statistical Agency of Ethiopia, and the population growth, as specified by the World Bank, was applied to obtain an estimate of population during the study period.

Snakebite incidence per 100,000 inhabitants was calculated per district and per hotspot for each year. An average annual incidence was calculated averaging the yearly district incidences over the period 2015-2020. Google earth and QGIS was used to map the average annual incidence categories (< 15, 15-29, 30-49, 50-99, > 100 cases/100,000 inhabitants over 1 year).

Ethical approval

Permission to conduct the study was obtained from EWCA No. 18/2015 Addis Ababa, Ethiopia. Local ethical approval was received from EPHI, Addis Ababa, Ethiopia (Version No. 03), and also approved by the Ethical Advisory Groups of the International Union against Tuberculosis and Lung Disease, Paris, France (No. 25/2020). Since this study used secondary data and did not directly involve patients, the issue of informed consent did not apply.

Figure 2. Geographic distribution of venomous snake species in Ethiopia, 2015-2020.



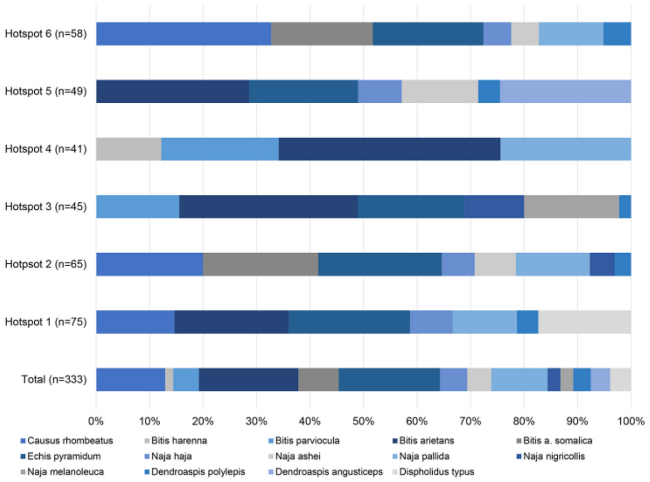
Results

A total of 333 snakes and 14 types of venomous snakes were collected in the six hotspot areas during the study period. Figure 2 shows the distribution of the species in the country. Sixty two *Bitis arietans* of the Vipers family were collected from hotspots in the North, West and South Ethiopia. In the North-Western and Eastern hotspots, *Echis pyramidum* (a species of

venomous viper, 63 snakes) and *Naja pallida* (the "red spitting cobra" from the *Elapide*a family, 35 snakes) were observed, while *Bitis arietans somalica* (the "Somali puff adder", 25 snakes) were only found in the Eastern part. *Dendroaspis species* (36 snakes) among which is the Black Mamba (*Dendroaspis polylenis*) were collected in almost all sites, except in the central part. All other species were not geographically dependent, but linked to a certain habitat (Table 1). For example, most of the *Naja* species was found in the National Parks, except the *Naja pallida* found in cultivation and man-made land forest and semi desert habitat. On the contrary, the *Bitis* species and the Black Mamba were widely distributed in most of the habitats - with the exception of arid semi desert. *Echis pyramidum* viper is also found in different habitats: 40% of them were collected in the cultivated land and man-made forest, 22% in moist dry savanna, 30% in rocky grass land. The spatial scales related to biotic and abiotic factors shape the geographic pattern across hotspot areas and habitats with a higher risk of snakebite. The percentage of venomous snakes caught in cultivated and man-made farm land is much higher than in other habitats. In forested bushy grassland, the least variation was found.

The number of snakes collected per hotspot area varied (Figure 3), with the highest number of 75 in hotspot 1 (Amhara and Tigray) and the lowest number of 41 snakes in hotspot 4 (Oromia). *Echis pyramidum* viper and *Dendroaspis polylepis* (Black Mamba) were present in 5 of the 6 hotspots while *B. arietans* was in 4 of the 6 hotspots (Amhara and Tigray, Gambela and Benshangul Gumize, SNNP and Oromia) and *B.a.somalica* was only observed in Afar and Somali hotspot areas. However, these data should be interpreted with the caveat that different numbers of snake-catchers were used, and varied in their expertise, among the different sites.

Figure 3. Relative importance of venomous snake species per hotspot area in Ethiopia, 2015-2020.



The incidence of snakebites showed a geographically heterogeneous distribution in the districts (Figure 4), but also per hotspot area. The lowest average annual incidence was in district Goma in Oromia, with 3.4 cases/100,000 inhabitants, while the

Table 1. Predominant habitat associated to venomous snake species in six hotspot areas, Ethiopia, 2015-2020.

Habitats / Species (number of snakes)	% of snake species*
Cultivation and man-made farm land	
Bitis arietans (16)	24.61%
Echis pyramidum (26)	40.0%
Causus rhombeatus (11)	16.9 %
Naja pallida (9)	13.8 %
Dendroaspis polylepis (3)	4.6 %
Arid Semi desert	
Causus rhombeatus (19)	41.3 %
Naja haja (8)	17.4 %
Naja ashei (**7**)	15.2 %
Naja pallida (10)	21.7 %
Dendroaspis polylepis (2)	4.3 %
Wooded savanna land forest	
Causus rhombeatus (13)	45.5 %
Bitis parviocula (7)	21.2 %
Naja nigricollis (2	6.1 %
Naja melanoleuca (8)	24.2 %
Dendroaspis polylepis (3)	9.1 %
Moist dry Savanna	
Bitis arietans (15)	32.6 %
Bitis a.somalica (8)	17.4 %
Echis pyramidum (10)	21.7 %
Dispholidus typus (8)	28.3 %
Rocky grass land	
Bitis arietans (17)	42.5 %
Echis pyramidum (12)	30.0 %
Naja nigricollis (2)	5.0 %
Naja haja (9)	22.5 %
Dry grassland	
Bitis a.somalica (9)	28.1 %
Echis pyramidum (15)	46.9 %
Naja ashei (8)	25.0 %
Grassy plain (Nech sar national park)	
Dendroaspis polylepis (3)	20.0 %
Dendroaspis angusticeps (12)	80.0 %
Fragment forest	
Bitis a.somalica (8)	44.4 %
Naja nigricollis (4)	22.2 %
Naja pallida (6)	33.3 %
Coffee and sugar plantation	
Bitis arietans (14)	58.3 %
Naja pallida (10)	41.7 %
Forested Bushy grassland	
Bitis harenna (5)	23.8 %
Bitis parviocula (9)	42.9 %
Dispholidus typus (5)	23.8 %

* number of snakes of a certain species found in specific habitat/total number of snakes of that species in the study.

highest incidence was in Medebay Zana district in Tigray with 309.2 cases/100,000 inhabitants. Forty four percent of the districts had an average annual incidence below 15/100,000 inhabitants, 24% had between 15 and 30, 19% between 30 and 50, while 9% had between 50 and 100 cases/100,000 inhabitants. Three districts (4%) had above 100 cases/100,000 inhabitants. Two of these districts were located in Gambela and Benshangul Gumize and the other one in Tigray hotspot area.

For the snakebite surveillance, over the 5 years a total of 9,152 snakebites were reported at healthcare facilities. These increased steadily over the years from 986 in 2015 to 1761 in 2020. The majority (87.5%) of the snakebite patients were male. Figure 5 shows an increasing trend of reported cases of snakebites in all hotspot areas over the 5 years. Annual incidences on hotspot level ranged from 4 to 45 snakebites/100 000 inhabitants per year. Hotspot Afar had the highest incidence while hotspot Oromia had the lowest. Of the 1761 snakebites for the year 2020, 614 (35%) were from Amhara and Tigray (1), 334 (19%) from Gambela and Benshangul Gumize (3), 243 (14%) from Somali (6), 200 (11%) from Afar (2), 192 (11%) from Oromia (4) and 178 (10%) from SNNP (5).

Discussion

Based on the collection of 333 snakes in the period 2015-2020, this study evidenced the spatial distribution of the various species of venomous snakes in six hotspot areas of Ethiopia. The highest number of venomous snake population was observed in the Northwest and Eastern part of the country, mostly in cultivation and man-made forest, moist and wooded savanna land forest areas. The districts with the highest

Figure 5. Reported snakebite incidence (/100,000 inhabitants) in six hotspot areas, Ethiopia, 2015-2020.

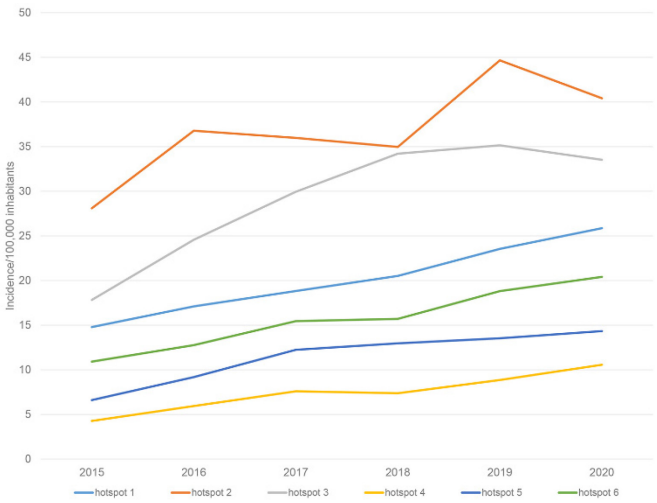
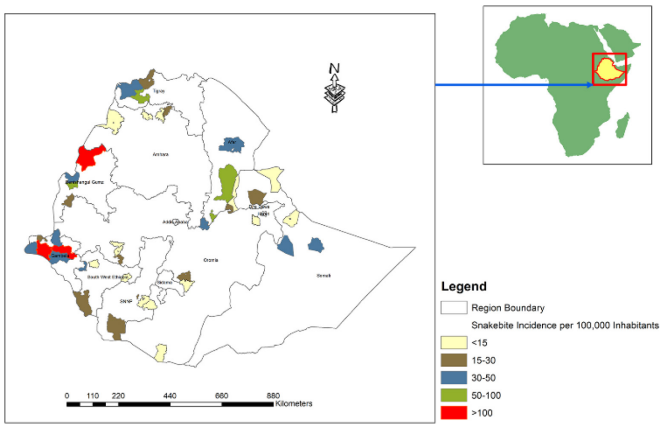


Figure 4. Average annual snakebite incidence in six hotspot areas, Ethiopia, 2015-2020.



incidence of snakebites, up to an annual average of 309 snakebites/100,000 inhabitants, were within the Northern and Western region.

The main strength of this study is the species identification, by an expert group, on a large sample of venomous snakes, together with their habitat description, from different geographical areas of the country, which is the largest survey ever described in Ethiopia. It gives complementary information to the catalogue made by Largen and Rasmussen in 1993 [14]. A limitation however is that these results cannot be generalized to the whole country, since the snake collection was targeted in hotspots and in places accessible to the catchers. However, the information on the geographical distribution of the 9,152 snakebites is a new piece of information, as previous studies mainly focused on clinical data [15–17] except one study in 2014 describing the burden at national level over a short period of 10 months [8]. Furthermore, whereas snakebites were not compulsory reported at the time of the study in Ethiopia, the simple parallel system set-up, enabled the program to capture all relevant information. Analyzing such routinely collected data in 78 districts has some weaknesses, in that such data collection is less standardized than in experimental research and quality control was in this case only happening during the yearly supervision visits. Besides the known problems of under-reporting with routine data, such data stay well fitted to evaluate geographical distribution patterns. There are no indications that underreporting would be differential over the districts, and it could only mean that the true incidence of snakebites is higher than the one we report here. However, caution is needed to interpret trends, as in the recent years there is more awareness about the importance and reporting of snakebites, we can only observe an increasing trend of

reporting over the years, which could be biased in the beginning by an overall underreporting.

WHO recently created a database and image library that enable users to (i) easily identify the most important venomous snakes in their country, territory or area; (ii) see the distributions of each species; and (iii) find information about antivenom products for treating envenoming caused by their bites [1]. The snake species collected within this study were all reported on this recently published platform, except for two species, namely *Bitis harenna*, which is found only in Ethiopia in the hardly accessible, deep jungle, - and *Causus rhombeatus* - a less medically important species. Several species (*Naja ashei, B. a. somalica, B. harenna, Dendroaspis angusticeps)* were not in the list of the 1993 national Ethiopian catalogue [14].

The incidence of snakebite found in this study (between 4 and 45 snakebites/100 000 inhabitants/year) is on the lower end of what was observed (65.1; 95% CI = 39.2-90.9; envenoming per 100,000 inhabitants) by a meta-analysis estimating the burden of snakebites in Sub-Saharan Africa [18]. However, as in this meta-analysis, our study also showed a high spatial heterogeneity. In 2014, Aga *et al*. [8] reported in Ethiopia 949 snakebite cases in similar selected health facilities over a period of 10 months, which is comparable to the 986 snakebites reported in this study in year 2015 (12 months), but lower than the 1,761 cases reported in 2020. The increasing incidence of snakebite reporting found in our study over the years, may be explained by (besides the earlier discussed reporting issues) an increased exposure to snakes through change of location of human activities towards snake habitats or to change of location of snakes due to deforestation and land cultivation. Future qualitative studies can provide information on the knowledge of the population concerning snakes and snakebites, but also on the age of the persons being exposed, as the location and activity of the person when being bitten by the snakes. This information can orient public health messages and education.

The integration of information on medically important snake species, habitat and burden of disease is critical to understand the natural phenomena of this health problem. The incidence of snakebites is usually inversely correlated with population density. However, we did observe that snakes are found in populated areas all over the country, where a human snake contact can be expected when people, especially farmers, are disturbing the resting site of the snake or crossing the path of the snake when in search for a prey. Education of the population within the snake hotspot areas about snakes and the risk of envenomation is important in order to prevent, but also rapidly seek care when a bite occurs. Additionally, mortality can only be prevented if within these health services, the staff is well trained and anti-venoms are available.

The "Structured Operational Research and Training Initiative (SORT IT)" is supporting the Sustainable Development Goal target of eliminating NTDs by 2023 [19]. NTDs are public health problems that need a global and national strategy to reach its control or elimination. Since Ethiopia is one of the highest burden countries for NTDs, it has taken the opportunity to set-up an integrated NTD approach including the fight against snakebites.

Conclusions

Different medically important species of venomous snakes are in six hotspot areas in Ethiopia, each within their preferred habitat. Snake diversity and distribution, linked to the high incidence of snakebite in these hotspot, suggests a close interconnection between human, animal and environmental systems. More attention needs to be paid to this public health problem starting from community education. Beside healthcare workers need to be prepared on case management with effective and affordable treatment available at the most decentralized health facilities.

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Corresponding author

Gashaw Gebrewold
Ethiopian Public Health Institute, 2PWJ+PSC, Addis Ababa, Ethiopia
Phone: +251 911715350
Fax: +251 11 2758634
Email: gwold71@gmail.com

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