



Viperidae snakebites in Ecuador: A review of epidemiological and ecological aspects

Angélica Ochoa-Avilés^{a,b}, Odalys S. Heredia-Andino^b, Samuel A. Escandón^b,
Christopher A. Celorio-Carvajal^b, María C. Arias-Peláez^b, Fausto Zaruma-Torres^{b,e},
Cleópatra A. da S. Caldeira^{c,d}, Andreimar M. Soares^{c,d}, Saulo L. Da Silva^{b,e,f,*}

^a Department of Biosciences, Faculty of Chemical Sciences, University of Cuenca, Cuenca, Azuay, Ecuador

^b College of Biochemistry and Pharmacy, Faculty of Chemical Sciences, University of Cuenca, Cuenca, Azuay, Ecuador

^c Biotechnology Laboratory for Proteins and Bioactive Compounds from the Western Amazon, Oswaldo Cruz Foundation Rondonia, Porto Velho, Rondonia, Brazil

^d Graduate Program in Experimental Biology (PGBIOEXP), Federal University of Rondonia (UNIR), Porto Velho, Rondonia, Brazil

^e Health Innovation Center - (CIS), Cuenca, Azuay, Ecuador

^f LAQV - REQUIMTE, University of Porto, Porto, Portugal

ARTICLE INFO

Keywords:

Epidemiology of snakebites
Viperidae
Snakebite envenoming
Ecuadorian vipers
Ecuador

ABSTRACT

Snakebite envenoming is a neglected disease of public health concern. Most snakebite accidents occur in developing countries. In Ecuador, 17 viper species are responsible for 99% of official accidents, and ten species are in critical conservation states. This report analyzes the snakebite incident cases and mortality rates in Ecuador between 2014 and 2019. The data obtained from the national surveillance system suggests that the incidence and mortality rates remained constant. The geographic region with the highest incidence rates is the Amazonian region. National policies are urgently needed to prevent snakebite accidents and to protect snakes in danger of extinction.

Snakebite envenoming continues to be a neglected disease. This problem affects approximately five million people each year worldwide (Chippaux, 2017a; Perry et al., 2020) and constitutes a significant health problem in tropical Latin American regions (Chippaux, 2017b; Gutierrez et al., 2017; Marcussi et al., 2011). Particularly in Ecuador, the last available scientific publication estimated incidence and mortality rates of 9.5 and 0.058 cases per 100.000 inhabitants between 2014 and 2016 (Chippaux, 2017a). It is necessary to improve our understanding of this critical health problem to identify research gaps that can guide public health programs in Ecuador. This report comprises two sections: an updated summary of snakebite incident cases and deaths in Ecuador between 2014 and 2019, and an analysis of the snakes' species distribution and conservation status in the country.

A literature review was carried out to summarize the available data regarding the snakes' species distribution and conservation in the country. Snakebite incidence rates and mortality rates were calculated using secondary data. Cumulative data of snakebite cases of the last week of each year was obtained from the National Surveillance System webpage (Gaceta Epidemiológica Ecuador, n.d.). Snakebite deaths data

was obtained from the causes of death datasets in the general population publicly available on the National Institute of Statistics webpage (INEC, n.d.). The total population and population per region were obtained from the inter-census projections from the last census (INEC, n.d.). Data were analyzed and managed using Origin 8 v8.0891, Origin Lab Corporation, Northampton, MA USA.

Ecuador is located in the northwestern region of South America; its continental territory comprises three geographic regions. The Coastal region concentrates 49% of the total population (altitude: 0–1200 m above sea level; temperature: 20–40 °C, and pluviometric indexes below 1000 mm/year). The Andean region houses 45% of the Ecuadorian population (altitude: 1200–6400 m above sea level; temperatures usually below 15 °C, and pluviometric indexes below 500 mm/year). Finally, the Amazonian region is the least populated, with 5% of the Ecuadorian inhabitants (altitude below 750 m above sea level; temperature above 28 °C, and pluviometric indexes between 2000 and 3000 mm/year) (INEC, n.d.; Derrotero, 2005) (Fig. 1A and 1B).

The Andean mountains shape the Ecuadorian landscape with heterogeneous environments, climatic conditions, and diverse flora and

* Corresponding author. College of Biochemistry and Pharmacy, Faculty of Chemical Sciences, University of Cuenca, Cuenca, Azuay, Ecuador.

E-mail addresses: saulo.da.silva@ucuenca.edu.ec, biomol2@hotmail.com (S.L. Da Silva).

<https://doi.org/10.1016/j.toxcx.2020.100051>

Received 15 May 2020; Received in revised form 25 June 2020; Accepted 28 June 2020

Available online 8 July 2020

2590-1710/© 2020 The Authors.

Published by Elsevier Ltd.

This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

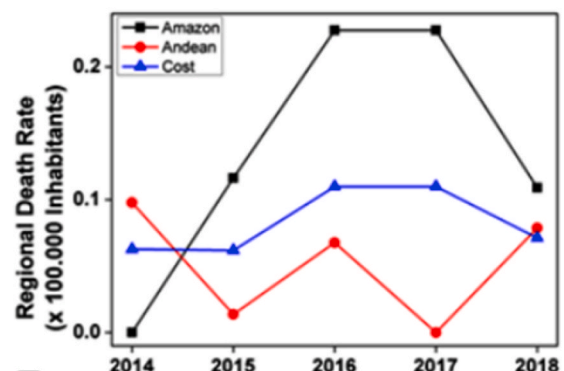
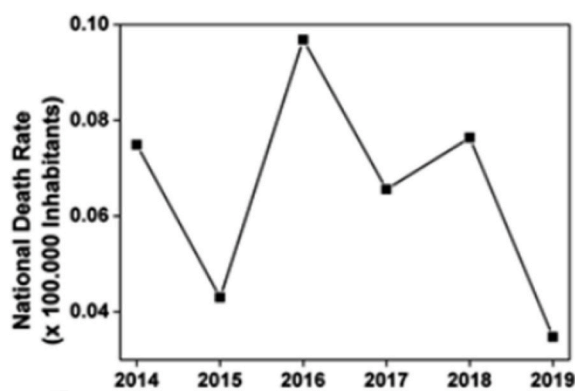
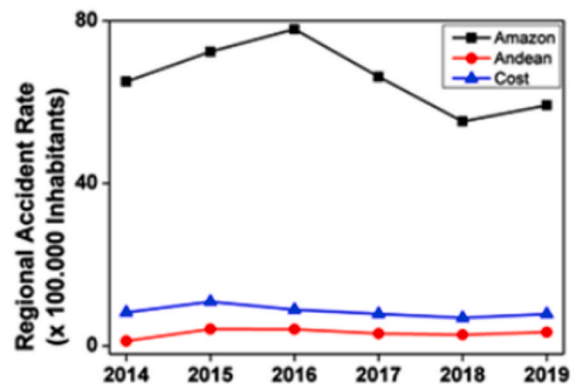
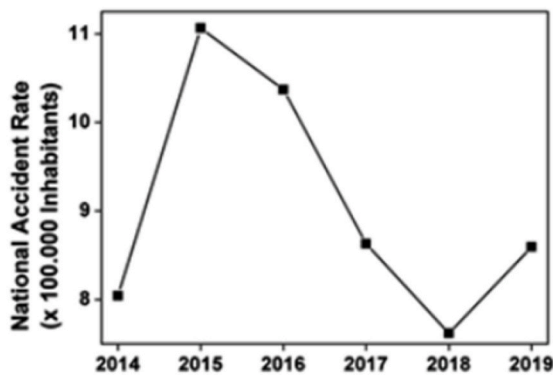
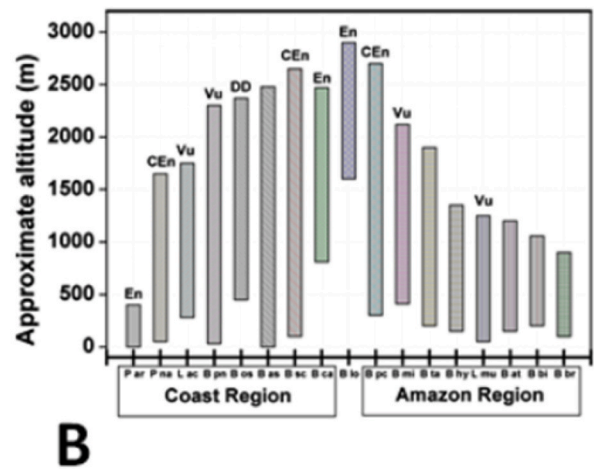
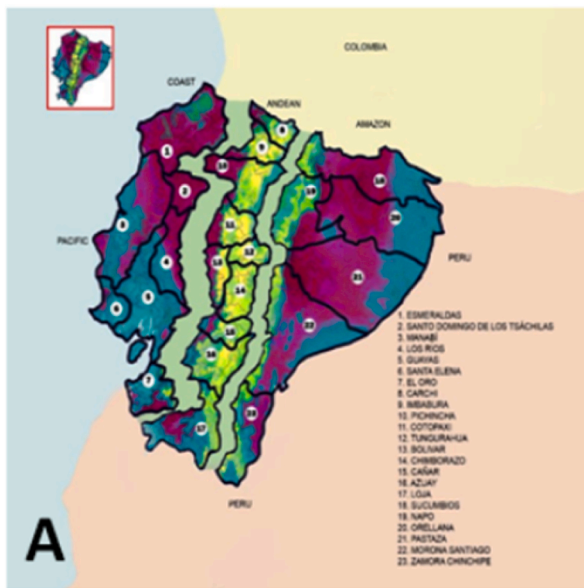


Fig. 1. Human demographics and snake population distribution in Ecuador: A) Political map of Ecuador: the continental area comprises three regions with its provinces (Coast: provinces 1–7; Andean: provinces 8–17; and Amazon: provinces 18–23) (Modified from Yañez-Arenas et al., 2018), B) Viperidae Family snake species in the country and altitudes where they are found. The species in critical state of preservation are denoted: Endangered (En), Critically Endangered (CEn), Vulnerable (Vu), Date Deficient (DD) (Birkis-Barros, 2019; Carrillo et al., 2005). C) National snakebite incidence rate per year (per 100.000 inhabitants). D) Snakebite incidence rate per year per geographic region (per 100.000 inhabitants). E) National snakebite mortality rate per year (per 100.000 inhabitants). E) Snakebite mortality rate per year per geographic region per (100.000 inhabitants).

fauna in the lowlands compared to the highlands (INEC, n.d.; Derrotero, 2005). The last explains the country's vast biodiversity, considered as one of the most megadiverse in the world (Moura et al., 2014; Esquerre et al., 2019; Almeida et al., 2020).

Ecuador's exuberant biodiversity is also reflected in the variety of its venomous snakes, exemplified by the presence of Elapidae and Viperidae families in the country. The Elapidae family comprises two genera and 19 species distributed at different altitudes, from zero to 2100 m above sea level: *Hydrophis platurus* and 18 *Micrurus* species. Among the *Micrurus* species, seven (*ancoralis*, *bocourti*, *mipartitus decussates*, *dumerilii trasandinus*, *multiculatus*, *tschudii olsoni*, *mertensi*) are distributed in the Coastal region, and eleven in the Amazonian region (*peruvianus*, *petersi*, *steindachneri*, *melanotus*, *obscurus*, *ortoni*, *scutiventris*, *langsdorffii*, *helleri*, *ornatissimus*, *surinamensis*). In Ecuador, however, snakebite accidents caused by the Elapidae family are unusual (less than 1% of total accidents), with *M. mipartitus decussates* and *M. helleri* being the most common species responsible for these accidents (Torres-Carvajal et al., 2020; MSP, 2017; Valencia et al., 2016).

On the other hand, the Viperidae family is concentrated in Ecuador's Coastal (8 species) and the Amazonian regions (8 species). This family comprises five distinct genera and 17 species that can be found in several provinces at different altitudinal levels, ranging from sea level up to approximately 3000 m: *Bothriechis (schlegelii)*, *Bothrocophias (campbelli)*, *hyoprora*, *microphthalmus*, *Bothrops (asper, atrox, bilineata, brazili, lojanus, osbornei, pulcher, punctatus, taeniatus)*, *Lachesis (acrochorda, muta) Porthidium (arcosae, nasutum)* (Table 1) (Torres-Carvajal et al., 2020; Valencia et al., 2016; Alencar et al., 2016). The majority of snakebite accidents in Ecuador are caused by the species *B. asper*, *B. atrox*, *B. bilineata* and *L. muta* (MSP, 2017; WHO, 2010; Yañez-Arenas et al., 2018). Fig. 1B presents the species distribution by geographic region. The species are separated from each other by the Andes and have no contact between them, except *Bothrops lojanus*, which can be found in these three Ecuadorian regions. It is possible that the movement of this species occurs through the Inter-Andean valley of Vilcabamba (Torres-Carvajal et al., 2020; Salazar-Valenzuela et al., 2018; Valencia et al., 2016) (Fig. 1B and Table 1).

In Ecuador, from 2014 to 2019 the average snakebite incident and mortality rates remained constant (average cases: 1506 [range: 1400–1800]; average incidence rate: 9.1 [range: 7.6–11.1] cases per 100.000 inhabitants; mortality rate: 0.07 [range: 0.03–0.10] per 100.000 inhabitants) as compared to the reported cases from Chippaux et al. (2017) from the period between 2014 and 2016 (Fig. 1C y 1E).

The Amazonian region still has the highest number of incident cases (55–78 bites per 100.000 inhabitants) followed by the Coastal (7–11 bites per 100.000 inhabitants) and the Andean (1–4 bites per 100.000 inhabitants) regions. These data highlight that snakebite envenoming is still a neglected condition in Ecuador. We were unable to identify any policy or program aiming to prevent snakebites or to improve the population's knowledge regarding this topic. Incidence rates remained constant over the years in the Andean and Coast regions but dropped since 2017 in the Amazon region. The reasons are still to be elucidated as reported Chippaux et al. (2017a; Chippaux, 2017b).

According to the models generated by Yañez-Arenas et al. (2018), the areas at the highest risk of snake envenoming are located in the central and northern Coastal and Amazonian regions of Ecuador: areas with the highest concentration of rural communities, which in turn, are highly vulnerable to snakebite accidents. Nevertheless, underreporting is a probable concern as a considerable number of rural inhabitants attend private or non-medical resources for emergency events (Eckhardt et al., 2018). In line with this finding, qualitative research has demonstrated how rural snakebite victims opt for traditional healers due to accessibility, cultural issues, and efficacy and access to antivenoms in formal health care centers (Schliodann et al., 2018).

Accidents and deaths per 100,000 inhabitants are much higher in the Amazonian region when compared to the Coastal region. Fig. 1D and F shows how from 2015 until 2017, there was an increase in accidents and

deaths secondary to snakebite envenoming in the Amazonian region. This aspect reinforces the great number of questions that remain unanswered. New research is urgently needed to improve our understanding of human and snake behaviors, as well as the possible seasonal variations that can favor contact between the two populations (Gonzalez-Andrade and Chippaux, 2010).

Unfortunately, antivenoms are not produced in Ecuador; instead, polyvalent antivenoms are imported mostly from the Instituto Clodomiro Picado-University of Costa Rica, and less frequently from Colombia and Argentina (MSP, 2017). Concerning the lethal doses (LD₅₀) of the venoms from the principal species responsible for snakebite accidents in Ecuador (*B. asper* and *B. atrox*), Teran and Lomonte (2016) demonstrated that the Ecuadorian *B. atrox* venom is similar to *B. atrox* from Peru, and the Ecuadorian *B. asper* venom is comparable to that from the same species from Guatemala, Costa Rica, and Colombia.

Laines et al. (2014) analyzed the LD₅₀ of the Ecuadorian *B. atrox* and *B. asper* and verified that the LD₅₀ of these species is much the same. The authors concluded that the polyspecific botropic antivenoms imported from Costa Rica are effective in neutralizing the LD₅₀ and, therefore, hemorrhagic, coagulant, and defibrinogenic effects of the Ecuadorian *B. atrox* and *B. asper*.

Relative to the snakes' conservation state, the Elapidae family species in danger of extinction are similarly distributed in the Coastal (five species) and Amazonian regions (four species). However, the majority of Viperidae species in danger of extinction (except *B. asper*) are distributed in the Coastal region, where the majority of the Ecuadorian human population is concentrated. The high growth population rate leads human beings to invade natural environments and to kill snakes in an attempt to avoid snakebites. In fact, among the eight Viperidae species living in the Coastal region, seven are critically endangered (Fig. 1B). On the contrary, in the Amazonian Region, where only 5% of the national population lives, only one species is in grave danger of extinction (*B. pulcher*), and two are in a vulnerable state (*B. microphthalmus* and *L. Muta*) (Fig. 1B) (Birskis-Barros, 2019; Carrillo et al., 2005). From a geographical perspective, the Coastal region is a highly limited strip of land in an east-west direction between the Pacific Ocean and the Andes. Therefore, both humans and snakes tend to move in the north-south direction, which increases the possibilities of interactions between them.

On the other hand, this geographic restriction observed in the Coastal region is absent in the Amazonian region. The only restriction that exists in the Ecuadorian Amazon is the Andes that limits it on the west side. Thus, both human and snake populations have greater freedom and can disperse to the Peruvian, Colombian, and Brazilian Amazon, decreasing the likelihood of contact. In the Amazonian environment, the multi-environmental complexity might protect biodiversity in general, including snake populations (Antonelli et al., 2018; Rittler et al., 2018).

Ecuador is extremely rich in biodiversity; thus, it must be treated with extreme care to avoid the loss of this valuable heritage, including snake environments. Nevertheless, a crucial aspect to consider is the species' conservation in the context of essential economic activities. Therefore, behavioral, ecological, and environmental research is needed to understand the population's dynamics to support the actions of environmental management without impacting economic growth. In this sense, this study offers an insight of the accidents and deaths caused by snakebites in Ecuador. Still, several questions remain unanswered. Future research should identify the real impact of snakebite envenoming in rural communities, and the perceptions of victims about health care access and pertinence. Programs are urgently needed to: (i) improve the national surveillance system reporting, by avoiding inconsistencies and providing a more detailed description (i.e., species involved), (ii) implement programs aimed at educating the population concerning the importance of snake conservation, (iii) evaluate the diagnosis and treatments provided by primary health care practitioners, and (iv) develop appropriate interventions to prevent snakebite accidents. The Ecuadorian Ministry of Health should invest in improving primary





Table 1

Viperidae family species in Ecuador and their geographic location (see Fig. 1A) (Torres-Carvajal et al., 2020; Valencia et al., 2016).

Genus	Species	Photo	Common Names	Province localizations (See Fig. 1A)
<i>Bothriechis</i>	<i>schlegelii</i>		Eyelash palm-pit vipers; Cushili; Víbora papagayo; Zampiña; Campanita.	1; 2; 3; 4; 5; 7; 9; 10; 11; 15; 16
<i>Bothrocophias</i>	<i>campbelli</i>	Photo by Omar Torres-Carvajal 	Ecuadorian toad headed pit vipers; Boca de sapo; Curruncha.	1; 2; 9; 10; 11; 13; 14
	<i>hyoprora</i>	Photo by David Valenzuela-Salazar 	Amazonian toad headed pit vipers; Nariz de Puerco; Cabeza de candado; Ushuali.	18; 19; 20; 21; 22; 23
<i>Microphthalmus</i>	<i>microphthalmus</i>	Photo by Wolfgang Wuster 	Small-eyed toad headed pit vipers; Hoja podrida; Macanchilla; Núkamp; Pushlio.	12; 19; 21; 22; 23
	<i>Bothrops</i>	<i>asper</i>	Photo by Museo de Zoología QCAZ 	American Lancehead; Cuatronarices; Equis; Pudridora; Macanchi mariposa.
<i>Bothrops</i>	<i>atrox</i>	Photo by Wolfgang Wuster 	South American lanceheads; Equis negra; Shishi; Macanchi.	18; 19; 20; 21; 22; 23
	<i>bilineata</i>	Photo by Museo de Zoología QCAZ 	Two-striped forest-pitvipers; Lorito; Palo verde; Nukam; Tobenaka.	18; 19; 20; 21; 22





(continued on next page)

Table 1 (continued)

Genus	Species	Photo	Common Names	Province localizations (See Fig. 1A)
		 <p data-bbox="560 697 831 719">Photo by Museo de Zoología QCAZ</p>		
<i>brazili</i>		 <p data-bbox="424 1076 608 1108">© W. Wüster</p> <p data-bbox="592 1123 799 1144">Photo by Wolfgang Wüster</p>	Brazil's lanceheads; Equis de Brazil; Pitala; Kara napi; Yawayawaa.	18; 20; 21; 22; 23
<i>lojanus</i>		 <p data-bbox="560 1410 831 1432">Photo by Museo de Zoología QCAZ</p>	Lojan lanceheads; Macanchi; Macucho.	7; 16; 17; 23
<i>osbornei</i>		 <p data-bbox="560 1698 831 1719">Photo by Museo de Zoología QCAZ</p>	Osborne's lanceheads; Llucti negra.	10; 11; 14
<i>pulcher</i>			Andean forest-pitvipers; Culebra tigre; Lorito; Loro mashaco; Yaku pitalala.	12; 17; 19; 20; 21; 22; 23




(continued on next page)

Table 1 (continued)

Genus	Species	Photo	Common Names	Province localizations (See Fig. 1A)
		 <p data-bbox="560 527 829 549">Photo by Museo de Zoología QCAZ</p>		
	<i>punctatus</i>	 <p data-bbox="603 793 786 815">Photo by Andrés Calero</p>	Chocoan lanceheads; Equis de árbol; Equis manchada; Granita de oro	1; 2; 8; 10
	<i>taeniatus</i>	 <p data-bbox="560 1261 829 1283">Photo by Museo de Zoología QCAZ</p>	Speckled forest pit vipers; Orito palo; Gunjintsin; Shishink; Wascapitalala.	14; 18; 19; 20; 21; 22; 23
<i>Lachesis</i>	<i>acrochorda</i>	 <p data-bbox="560 1719 829 1740">Photo by David Valenzuela-Salazar</p>	Chocoan bushmasters; Guacama; Verrugosa	1; 2; 3; 10
	<i>muta</i>		Amazon bushmasters; Verrugosa; Sol; Motolo; Cofase.	18; 19; 20; 21; 22; 23

(continued on next page)

Table 1 (continued)

Genus	Species	Photo	Common Names	Province localizations (See Fig. 1A)
<i>Porthidium</i>	<i>arcosae</i>	 <p data-bbox="560 772 831 793">Photo by Museo de Zoología QCAZ</p>	Manabí hog nosed pit vipers; Sabanera	3
	<i>nasutum</i>	 <p data-bbox="592 1240 799 1261">Photo by Wolfgang Wuster</p>	Rainforest hognosed pit viper; Guardacaminos; Vivora.	1; 2; 3; 9; 10
		 <p data-bbox="560 1478 831 1500">Photo by Museo de Zoología QCAZ</p>		

health care services and provide high-quality training to health professionals and community members.

Ethical statement

International ethical guidelines for scientific papers were followed in the preparation of this manuscript.

Declaration of competing interest

The authors declare that they have no competing interests.

CRedit authorship contribution statement

Angélica Ochoa-Avilés: Conceptualization, Formal analysis,

Investigation, Methodology, Project administration, Writing - original draft, Writing - review & editing. **Odalys S. Heredia-Andino:** Formal analysis. **Samuel A. Escandón:** Formal analysis. **Cristopher A. Celorio-Carvajal:** Investigation, Methodology. **María C. Arias-Peláez:** Investigation, Methodology. **Fausto Zaruma-Torres:** Investigation, Methodology. **Cleópatra A. da S. Caldeira:** Investigation, Methodology. **Andreimar M. Soares:** Investigation, Methodology. **Saulo L. Da Silva:** Conceptualization, Investigation, Methodology, Project administration, Writing - original draft, Writing - review & editing.

References

Alencar, L.R.V., et al., 2016. Diversification in vipers: phylogenetic relationships, time of divergence and shifts in speciation rates. *Mol. Phylogenet. Evol.* 105, 50–62.

- Almeida, J.R., et al., 2020. Assessing the stability of historical and desiccated snake venoms from a medically important Ecuadorian collection. *Comp. Biochem. Physiol. C Toxicol. Pharmacol.* 230, 108702.
- Antonelli, A., et al., 2018. Amazonia is the primary source of Neotropical biodiversity. *Proc. Natl. Acad. Sci. U.S.A.* 115, 6034–6039.
- Birskis-Barros, I., et al., 2019. Ecological and conservation conservation of rarity in new world pitvipers. *Diversity* 11, 147–162.
- Carrillo, E., et al., 2005. Lista roja de los reptiles del Ecuador. Fundación Novum Milenium, UICN-Sur, UICN-Comité Ecuatoriano, Ministerio de Educación y Cultura. Quito Ecuador.
- Chippaux, J.-P., 2017a. Incidence and mortality due to snakebite in the Americas. *PLoS Neglected Trop. Dis.* 11 (6), e0005662.
- Chippaux, J.-P., 2017b. Snakebite envenomation turns again into a neglected tropical disease! *J. Venom. Anim. Toxins Incl. Trop. Dis.* 23, 38.
- Derrotero, 2005. De la Costa Continental e Insular del Ecuador. Quito Ecuador. Instituto Oceanografico de la Armada INOCAR Retrieved from.
- Eckhardt, M., et al., 2018. Universal health coverage in rural Ecuador: a cross-sectional study of perceived emergencies. *West. J. Emerg. Med.* 19 (5), 889–900.
- Esquerre, D., et al., 2019. How mountains shape biodiversity: the role of the Andes in biogeography, diversification, and reproductive biology in South America's most species-rich lizard radiation (Squamata: Liolaemidae). *Evolution* 73, 214–230.
- G, EE. Gaceta epidemiológica Ecuador (SIVE-ALERTA). (n.d.). Ministerio de Salud Pública. from. <https://www.salud.gob.ec/gaceta-epidemiologica-ecuador-sive-alerta/>. (Accessed 5 February 2020).
- Gutierrez, J.M., et al., 2017. Preclinical evaluation of the efficacy of antivenoms for snakebite envenoming: state-of-the-art and challenges ahead. *Toxins* 9.
- INEC (Instituto Nacional de Estadística y Censos). (n.d.). Proyecciones poblacionales. Instituto nacional de Estadística Y censos. from. <https://www.ecuadorencifras.gob.ec/proyecciones-poblacionales/>. (Accessed 6 February 2020).
- Laines, J., et al., 2014. Toxicity of Bothrops sp snake venoms from Ecuador and preclinical assessment of the neutralizing efficacy of a polyspecific antivenom from Costa Rica. *Toxicon* 88, 34–37.
- Marcussi, S., et al., 2011. Evaluation of the genotoxicity of *Crotalus durissus terrificus* snake venom and its isolated toxins on human lymphocytes. *Mutat. Res. Genet. Toxicol. Environ. Mutagen* 274, 59–63.
- Moura, A.A., et al., 2014. Purification and biochemical characterization of three myotoxins from *Bothrops mattogrossensis* snake venom with toxicity against *Leishmania* and tumor cells. *BioMed Res. Int.* Article number 195356.
- MSP (Ministerio de Salud Pública), 2017. Manejo clínico del envenenamiento por mordeduras de serpientes venenosas y picaduras de escorpiones. Protocolo basado en evidencia. <https://www.coursehero.com/file/41672301/Manejo-clinico-del-envenenamiento1pdf/>.
- Perry, G., Lacy, M., Das, I., 2020. Snakes, snakebites, and humans. In: Angelici, F.M., Rossi, L. (Eds.), *Problematic Wildlife II: New Conservation and Management Challenges in the Human-Wildlife Interactions*. Springer International Publishing, pp. 561–580.
- Rittler, C.D., et al., 2018. Locality or habitat? Exploring predictors of biodiversity in Amazonia. *Ecography* 42, 321–333.
- Salazar-Valenzuela, D., et al., 2018. Divergence of tropical pitvipers promoted by independent colonization events of dry montane Andean habitats. *J. Biogeogr.* 46, 1826–1840.
- Schioldann, E., et al., 2018. Why snakebite patients in Myanmar seek traditional healers despite availability of biomedical care at hospitals? Community perspectives on reasons. *PLoS Neglected Trop. Dis.* 12 (2), e0006299.
- Teran, M.C., Lomonte, B., 2016. Actividad letal de seis venenos de serpientes de importancia médica en el Ecuador. *Rev. Ecuat. Med. Cienc. Biol.* 37, 25–30.
- Torres-Carvajal, O., et al., 2020. Reptiles del Ecuador from. <https://bioweb.bio/faunaweb/reptiliaweb/ListaEspeciesPorFamilia/115>. (Accessed 6 February 2020).
- Valencia, J.H., et al., 2016. Serpientes Venenosas del Ecuador Fundación Herpetológica Gustavo Orcés. Universidad de Texas Quito Ecuador.
- WHO (World Health Organization), 2010. Guide Lines for the Production Control and Regulation of Snake Antivenom Immunoglobulins, pp. 1–134.
- Yanez-Arenas, C., et al., 2018. Estimating geographic patterns of ophidism risk in Ecuador. *Neotropical Biodiversity* 4, 55–61.