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The Importance of Snake Education on Snake Conservation

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Abstract

Human activities negatively impact snakes around the world, causing populations to decline and threatening hundreds of snake species with extinction. Snakes serve a valuable role, benefitting both humans and their ecosystems as a whole, and widespread snake extinction would cause negative cascading effects on the rest of the biosphere. However, humans typically perceive snakes with fear and disgust, making it difficult to generate support for snake conservation efforts. Snake education programs can help change people's attitudes towards snakes, especially if those programs allow people to physically interact with live snakes. Even people who claimed to be afraid of snakes experienced a decrease in fear and increase in positive emotions. The resulting change in attitude increases people's willingness to conserve snake populations, a shift that will help protect the health of ecosystems around the globe. A snake-centered lesson plan targeted for high school biology teachers to implement in their classrooms can be the start to widespread snake education, enabling the next generation of students to grow up with compassion towards snakes and a willingness to protect them from the impacts of human activities.

Chapter 1: An Overview of Snakes and Snake Conservation

There are over 3,000 species of snakes on Earth, inhabiting every continent except for Antarctica (National Geographic). Snakes are classified into 29 different families under the suborder Serpentes (ITIS 2019), and range in size from a few inches (Rafferty 2016) to well over 20 feet in length (Guinness World Records 2011). Snakes are characterized by their lack of legs, eyelids, and ears, and have overlapping scales (CT DEEP). These scales are not flexible like human skin, so in order to continue growing, the snake needs to shed these scales, which they do all at once to form “snakeskins.” Snakes shed their skin several times per year not only to grow, but to remove parasites and replace worn out skin. To smell, snakes flick out their forked tongues, which pick up particles in the air that they then touch to the Jacobson’s Organ, a specialized organ on the roof of their mouths which indicates to the brain what exactly is being smelled. To hear, snakes feel vibrations in the ground. Some snakes can also sense thermal radiation through heat sensing pits, which help them find and track endothermic prey. To eat, snakes swallow their food whole, often after constricting their prey to death or by injecting it with a fatal dose of venom. In order to physically fit their prey in their mouths, snake jaws not only open from both the top and bottom, but can completely unhinge, enabling them to swallow prey much thicker than their own bodies. Because of this ability to consume massive quantities of food, snakes do not eat regular meals. They instead operate on a “feast and famine” dietary cycle, where their metabolisms are slow during the “famine” stage in order to minimize caloric requirements. During the “feast” stage their metabolisms rapidly skyrocket, allowing them to digest their food and obtain the nutrients they need to last them until their next feast. Despite these adaptations, however, snakes are still susceptible to a variety of conservation threats, and require our attention in order to preserve their well-being.

Conservation issues facing snakes

There are several general conservation threats, both human-caused and not, that have a negative effect on snakes. Arguably the most significant of these threats is habitat loss, which reduces the capacities of a biome to support the species living there (Kareiva and Marvier 2015). Habitat loss occurs when humans destroy natural landscapes so we can use the space for our own residential, commercial, or agricultural developments. Habitat loss affects 92% of all threatened vertebrate species in the United States, including 97% of reptiles (Wilcove et al 1998). China has a similar problem, with 70% of their imperiled vertebrate species affected (Yiming and Wilcove 2005). However, habitat loss does not affect all biomes equally. Biomes such as boreal forests and tundra have almost no land cover converted to serve human activities (Hoekstra et al 2005). Conversely, temperate grasslands/savannas, Mediterranean forests/woodlands, tropical/subtropical dry forests, and temperate broadleaf and mixed forests have all had over 40% of their land area converted. Increased human use of a biome has not correlated with increased human protection of that biome, as the 4 previously-listed high-conversion biomes also have the

4 highest ratios of converted land area to protected land area. Hoekstra et al (2005) subdivided biomes into ecoregions for a closer look at these ratios, and classified some as in "crisis." Many of these "crisis" ecoregions overlap with some of the most biodiverse locations on Earth, many of which also have high concentrations of snake species (Fig 1). Furthermore, these ecoregions represent every major terrestrial biome except for tundra and boreal forest, the two biomes least affected by human development. The areas of Earth that these two biomes cover contain the lowest snake species richness (Figs 1a, 1d, 2). As such, habitat loss may be having a disproportionate impact on snake populations due to the high prevalence of snakes in the world's most threatened areas, and low snake presence in Earth's least degraded areas. This impact is evidenced by the fact that only 3.5% of reptile species' ranges fall within protected areas, whereas those numbers are 6.5% for birds and 6% for mammals (Roll et al 2017).

Another, more specific type of habitat loss is known as habitat fragmentation, which can geographically isolate subsets of a species population and decrease their evolutionary fitness. Habitat fragmentation is defined as "transformation of formerly contiguous habitat into a patchwork of small, isolated habitat remnants" (Kareiva and Marvier 2015). Fragmentation occurs due to competing pressures from environmentalists to preserve land, and from developers to build more and grow the economy. As a result, the protected areas are separated from each other by inhospitable human developments. According to the Equilibrium Theory of Island Biogeography,[1] large habitat patches can support larger populations of each species, which reduces the likelihood of extinction. By fragmenting large habitats into smaller remnants, species populations decline and risk of extinction increases. Furthermore, habitat fragments have larger proportions of edge area than intact habitat. Consequently, increased edge effects on the habitat fragment impact species in different ways, which can alter the species diversity and ecological relationships contained within the fragment. Another negative effect of habitat fragmentation is inbreeding. If populations within each fragment are isolated from each other, they cannot mate with each other, so inbreeding among populations becomes more likely over time. As a result, heterozygosity decreases, and species experience a reduction in evolutionary fitness due to inbreeding depression. Snakes are particularly vulnerable to habitat fragmentation due to their low population densities and poor dispersal abilities (Breininger et al 2012). Furthermore, the increased edge effects of fragmented habitats increase human-snake interactions, resulting in more snakes becoming roadkill or being intentionally killed by humans. Fragmentation also increases the overlap of home ranges for individual snakes, resulting in increased intraspecific competition for resources, an effect that becomes more impactful as fragment size shrinks (Mitrovich et al 2009).

Disease is another threat to the conservation of species, and as populations decline due to other conservation factors, the ability of species to rebound from disease outbreak is reduced.

[1] The Equilibrium Theory of Island Biogeography "postulates that the number of species within a given area is determined by a balance between local colonizations and local extinctions" (Kareiva and Marvier 2015)

The drastic emergence of Ophidiomycosis, or Snake Fungal Disease (SFD), in North America since 2006 has severely threatened small snake populations (Lorch et al 2016). For example, the last remaining population of Timber Rattlesnakes (*Crotalus horridus*) in New Hampshire experienced significant mortality due to an outbreak of SFD (Clark et al 2011). A population of Massasaugas (*Sistrurus catenatus*) in Illinois experienced similar effects (Lorch et al 2016). Consequently, SFD has prompted the United States Fish and Wildlife Service to consider listing eastern populations of *S. catenatus* as a threatened species under the Endangered Species Act, further emphasizing the impact of this disease on snake populations.

Climate change as a whole is also problematic for many species, including snakes. Climate change is occurring as a result of an increase of human-caused greenhouse gases, which trap heat in the Earth's atmosphere and steadily warm the planet (Kareiva and Marvier 2015). The increase in temperature has occurred rapidly on a geologic scale, and consequently has had major ecological impacts across all ecosystems. As temperatures increase, species may shift their ranges to find more suitable environments (Lourenço-de-Moraes et al 2019). These alterations may remove a species from a protected area, further threatening their populations and requiring humans to restructure the provisions of protected areas in order to prevent catastrophe. In oviparous snakes, rising temperatures can also decrease their rate of reproduction due to increased risk of egg desiccation (Lourenço-de-Moraes et al 2019). Increased greenhouse gas emissions also alter weather patterns, which can have negative consequences for species. For instance, the outbreak of SFD among *C. horridus* in New Hampshire was preceded by the wettest year on record in the area, enabling ideal conditions for SFD to spread (Clark et al 2011). With climate variability projected to increase as climate change continues to alter our planet, incidences like these may become more common and severe. Weather pattern changes have also increased the fire risk in many regions (Kareiva and Marvier 2015). More forest fires will not only result in increased destruction of species habitat and therefore species populations, but will also spew more carbon dioxide into the atmosphere, further warming the planet and exacerbating these problems. Increased CO_2 levels also increase the acidity of water, a process known as ocean acidification (Kareiva and Marvier 2015). The carbonic acid causing this acidification degrades calcium carbonate, which is used by corals and other shelled invertebrates. Many species of sea snakes eat such invertebrates, and a decline in food availability will negatively affect sea snake populations (GBRMPA 2012).

Image removed for copyright purposes For image, see Hoekstra, J. M., T. M. Boucher, T. H. Ricketts, and C. Roberts. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters 8:23-29. Figure 4
Image removed for copyright purposes For image, see Roll, U., A. Feldman, M. Novosolov, A. Allison, A. M. Bauer, R. Bernard, M. Böhm, F. Castro-Herrera, L. Chirio, B. Collen, G. R. Colli, L. Dabool, I. Das, T. M. Doan, L. L. Grismer, M. Hoogmoed, Y. Itescu, F. Kraus, M. LeBreton, A. Lewin, M. Martins, E. Maza, D. Meirte, Z. T. Nagy, C. de C. Nogueira, O. S. G. Pauwels, D. Pincheira-Donoso, G. D. Powney, R. Sindaco, O. J. S. Tallowin, O. Torres-Carvajal, J.-F. Trape, E. Vidan, P. Uetz, P. Wagner, Y. Wang, C. D. L. Orme, R. Grenyer, and S. Meiri. 2017. The global distribution of tetrapods reveals a need for targeted reptile conservation. Nature Ecology & Evolution 1:1677-1682. Figure 1a
Image removed for copyright purposes For image, see Roll, U., A. Feldman, M. Novosolov, A. Allison, A. M. Bauer, R. Bernard, M. Böhm, F. Castro-Herrera, L. Chirio, B. Collen, G. R. Colli, L. Dabool, I. Das, T. M. Doan, L. L. Grismer, M. Hoogmoed, Y. Itescu, F. Kraus, M. LeBreton, A. Lewin, M. Martins, E. Maza, D. Meirte, Z. T. Nagy, C. de C. Nogueira, O. S. G. Pauwels, D. Pincheira-Donoso, G. D. Powney, R. Sindaco, O. J. S. Tallowin, O. Torres-Carvajal, J.-F. Trape, E. Vidan, P. Uetz, P. Wagner, Y. Wang, C. D. L. Orme, R. Grenyer, and S. Meiri. 2017. The global distribution of tetrapods reveals a need for targeted reptile conservation. Nature Ecology & Evolution 1:1677-1682. Figure 1d
Figure 1. Global map of crisis ecoregions (top) compared to species richness of terrestrial tetrapods (reptiles, amphibians, birds, and mammals) (a) and species richness of snakes (d). (a) and (d) from Roll et al 2017, top image from Hoekstra et al 2005

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For image, see Trimble, M., and R. van Aarde. 2012. Geographical and taxonomic biases in research on biodiversity in human-modified landscapes. Ecosphere 3:art119.
Figure 2

Figure 2. Map of Earth's 14 major terrestrial biomes, from Trimble and van Aarde 2012

IUCN listing of threats to snakes

The International Union for Conservation of Nature (IUCN) has gathered extensive data on many species worldwide, and compiled these data into their "red list," a detailed listing of all species they have examined and the conservation status and threats posed to those species.[2] Of the 2348 snake species currently evaluated by the IUCN, 370 (15.8%) are threatened or near-threatened. Many of the threats posed to snakes are widespread, and warranted extra attention from the IUCN (Table 1). The IUCN does not quantify the severity of each threat with regards to individual species, nor is there a stated severity threshold that must be reached in order for a threat to apply to a given species.

Table 1: threats to snakes listed by the IUCN and the number of species each threat affects

Threat	**Number of species affected**
Residential & commercial development: housing & urban areas	287

[2] https://www.iucnredlist.org/

Hunting & trapping terrestrial animals: intentional use (species is the target)	255
Agriculture & aquaculture: annual & perennial non-timber crops: small-holder farming	230
Hunting & trapping terrestrial animals: persecution/control	220
Agriculture & aquaculture: annual & perennial non-timber crops: agro-industry farming	170
Agriculture & aquaculture: annual & perennial non-timber crops: scale unknown/unrecorded	155
Transportation & service corridors: roads & railroads	115
Agriculture & aquaculture: livestock farming & ranching: small-holder grazing, ranching, or farming	100
Residential & commercial development: tourism & recreation areas	98
Energy production & mining: mining & quarrying	92

Residential and commercial development of housing and urban areas consists of "human cities, towns, and settlements including non-housing development typically integrated with housing." As such, this category includes not just homes and apartment complexes, but shopping areas, offices, schools, hospitals, and other structures. Such development results in widespread habitat loss and fragmentation, which may affect many species in an area. For species with smaller ranges, the destruction of habitat due to development affects disproportionately large areas of suitable land for that species, driving the remaining individuals into a smaller area with fewer resources available. For example, Lataste's Viper (*Vipera latastei*) is native to Spain and North Africa, but populations are becoming rarer and more fragmented due, in part, to urbanization of coastal areas throughout its range (Miras et al 2009). *V. latastei* populations are now primarily found in mountains, having been exiled from their preferred flat, coastal habitat by human development (Santos et al 2006).

Intentional use of hunting or trapping terrestrial animals entails "killing or trapping terrestrial wild animals or animal products for commercial, recreation, subsistence, research or cultural purposes." Intentional use designates the species as the target of these activities, as opposed to unintentional use in which the species is being affected as a result of actions targeted towards a different species. One species particularly impacted by this threat is the King Cobra (*Ophiophagus hannah*), which is harvested by humans for skin, food, and traditional Chinese medicine, and is also taken from the wild by people wanting them as pets (Stuart et al 2012). In

China, over 60 snake species are hunted and sold for these purposes, and all but 4 are listed in the China Red Data Book, the comprehensive list of threatened Chinese species (Zhou and Jiang 2004). In Australia, the one of the few remaining Broad-headed Snake (*Hoplocephalus bungaroides*) populations lost 85% of its adult females in 1997 due to poachers collecting them for sale in the pet trade (Webb et al 2002). Snake wine is also a popular drink in Vietnam and other countries in Southeast Asia, although the number of snakes, including endangered species, that are killed to make this drink are unknown (Somaweera and Somaweera 2010).

Persecution or control of terrestrial animals is defined as "killing or trapping terrestrial wild animals or animal products… for control/persecution reasons." Snakes all over the world are killed by humans merely for the crime of being snakes, as people will kill snakes on sight because they perceive them to be dangerous, regardless of whether or not they are actually venomous. Given that humans killing snakes they encounter generally goes unreported, exact data quantifying this threat are unobtainable. However, using fake decoys of both turtles and snakes, one study found that 2.7% of drivers will swerve to intentionally hit reptiles while driving (Ashley et al 2007). These results illustrate people's willingness to go out of their way to kill snakes, even if the snakes pose no threat and could easily be left alone.

Agriculture and aquaculture of annual and perennial non-timber crops pose "threats from farming and ranching as a result of agricultural expansion and intensification," and encompass all crops that are not woody. These activities threaten snakes on both the small and industrial scales. Ashe's Bush Viper (*Atheris desaixi*) is one notable victim of agricultural growth, as its native habitat is being rapidly destroyed to make room for crop fields, grazing areas, and illegal marijuana plantations (Spawls and Malonza 2019). The conversion of native habitat to farmland destroys and fragments large areas of many species' ranges. Pesticides used in agriculture also negatively impact snakes, with even very low concentrations reducing liver and kidney function by up to 67% (Khan 2003). Furthermore, agricultural machinery may pose a threat to snakes due to physical crushing or destruction of burrows and potential suffocation if the snake is inside, although the magnitude of these effects are unknown because they are poorly studied. (Fischer and Lamey 2018). Fertilizers used in agriculture also contribute to nutrient runoff, which can cause harmful algal blooms in nearby aquatic ecosystems. Such blooms are shown to increase physiological stress in Northern Watersnakes (*Nerodia sipedon*), which is not fatal but can negatively impact immune function, bodily health, and reproduction (Refsnider et al 2021).

Roads and railroads threaten snakes not only from the vehicles that travel on these corridors, but also from the roads and railroads themselves. The roads and railroads fragment habitats, while the vehicles can run over snakes that attempt to cross. For example, the recent development of a system of paved roads has increased roadkill mortalities of the Cave Racer (*Elaphe taeniura*) in Eastern Asia, threatening populations that may be evolutionarily distinct subspecies and would therefore need even more extensive protection (Li et al 2021).

Furthermore, an estimated 2.7x more snakes are actually killed on roadways than are found by observers due to scavengers removing carcasses, observers missing carcasses, and maimed snakes slithering off the road and out of sight before perishing (Winton et al 2018). This discrepancy makes calculating the exact impact of roadkill mortality difficult, and special care must be taken to avoid underestimating the potential ramifications for snake populations.

Livestock farming and ranching includes "domestic terrestrial animals raised in one location on farmed or nonlocal resources (farming); also domestic or semi-domesticated animals allowed to roam in the wild and supported by natural habitats (ranching)." The major threats to snakes occur when such activities are done on a small-holder (non-industrial) scale. Smaller farms pose a greater threat to snakes than larger farms because in many areas of the world, poor, rural farmers are highly dependent on their livestock and must take stricter anti-snake measures in order to protect their livelihoods (Babo Martins et al 2019). However, such farms also have an impact on snakes beyond their livestock-protection strategies. For example, the Meridia Coral Snake (*Micrurus meridensis*) occupies a small range in Venezuela, where its habitat is being degraded by the overgrazing of goats owned by local farmers (Rivas and Schargel 2019). Such degradation is particularly impactful to *M. meridensis* because of its limited dispersal.

Residential and commercial development of tourism and recreation areas encompasses "tourism and recreation sites with a substantial footprint" such as ski areas, golf courses, resorts, and other large developments. The effects of this development on snakes are similar to that of housing and urban development listed above, in that the habitat destruction and fragmentation caused by these structures evicts snake species from large portions of their native habitat. For example, the Keeled Vine Snake (*Proahaetulla antiqua*) occupies a small range in India where religious tourism and pilgrimages are common, and threaten what little habitat *P. antiqua* occupies (Ganesh and Achyushan 2021).

Mining and quarrying entails "Exploring for, developing, and producing minerals and rocks," and occurs at coal strip mines, gold mines, rock quarries, and other locations. This resource extraction can result in noise and air pollution from explosive blasts and the dust it creates, water pollution, and habitat destruction (Lameed and Ayodele 2010). For instance, the Greek Meadow Viper (*Vipera graeca*) lives exclusively in mountains, some of which have mines that are actively destroying the isolated areas on which *V. graeca* can survive (Mizsei et al 2018).

<u>Why snake conservation is important</u>

Snake conservation is a worthwhile endeavor because preserving snake biodiversity is critical to maintaining balance in the ecosystems snakes occupy. Snakes are carnivores, consuming rodents, other smaller mammals, lizards, birds, amphibians, and even other snakes. However, snakes are also prey to many animals, including birds of prey, kingsnakes, raccoons, badgers, crocodilians, and more. Snake eggs are also subject to predation, and juveniles are more susceptible to predators due to their smaller size and weaker bodies. All of these interactions are valuable to the health of the ecosystem, helping it remain stable and intact for us to experience and learn from.

Snakes help provide balance to their ecosystems in a variety of ways in addition to their standard predator-prey interactions. One substantial, yet relatively unexamined function of snakes is their role as secondary seed dispersers (Reiserer et al 2018). Snakes, however, are unique in that when they consume a rodent that has eaten seeds, the seed can actually start to germinate inside the snake's digestive tract because snakes typically take a long time to digest their meals. Furthermore, the seeds are less likely to be damaged given that snakes do not chew their food, and the broad individual ranges of some snake species allow for widespread dispersal of seeds. Another function of snakes is that different species occupying the same area often have considerable overlap in type of prey consumed, but will distribute prey species consumed so as to minimize interspecific competition for a food source (i.e. several snake species in an area eat frogs as part of their diet, but one snake species will eat mostly wood frogs, another will eat mostly leopard frogs, etc) (Carter 2015). This distribution helps ensure that populations of all prey species are kept in check, while simultaneously avoiding overconsumption of any one particular species.

Snakes also provide valuable ecosystem services to humans, of which the primary service is pest control. For many snakes, the majority of their diet consists of rodents, which we humans view as undesirable vermin. A healthy snake population will not only keep rodent numbers in check, but will do so without humans needing to use chemicals, which can spread throughout the ecosystem and result in poisoning of other wildlife and accidental ingestion by children and pets (Williams 2013). Rodent control has major benefits to humans, as an estimated $20 million in damage is done every year by house mice (*Mus musculus*) in Nebraska alone (Vantassel et al 2012). Furthermore, rodents and other small mammals often give ticks Lyme Disease, and those ticks in turn affect larger mammals like deer and humans (Levi et al 2012). However, predators of small mammals, including snakes, can remove those ticks from the environment when they eat small mammals with ticks attached to them. The presence of these predators, such as Timber Rattlesnakes (*Crotalus horridus*) is correlated with reduced prevalence of Lyme Disease, whereas areas without these predators experience steep increases in disease rates (Levi et al 2012, ESA 2013). *C. horridus* populations are capable of removing 2500-4500 ticks per site per year, preventing them from spreading Lyme Disease and benefiting humans as a result (ESA 2013).

In summary, human activities both directly and indirectly threaten snakes in a plethora of ways. Without proper action, snake populations will continue to decrease and the ecosystem services and stability that snakes provide will be lost. In order to promote such action, however, people first need to be informed of the conservation issues facing snakes. In the next chapter I will discuss several methods of snake education, and how such education can encourage people to take action towards supporting snake conservation.

Chapter 2: Snake Education and its Effect on Conservation

<u>The effects of existing snake and environmental education programs on people</u>

In order for the general public to be aware of the conservation issues facing snakes, and why conserving snakes is ecologically important, educational programs must be implemented to provide people with the information necessary to develop an understanding of the issue. There is a precedent for this type of environmental education, as programs around the world have sought to increase the level of human connection to wildlife and local ecosystems in order to cultivate a love and respect for nature. These educational initiatives have taken many forms, occurring in classrooms, nature centers, parks, and more, and involved people of all ages and backgrounds. There is no one right way to conduct an educational program, as everyone learns differently, but certain tactics can not only enable the learner to more effectively retain knowledge, but also increase one's emotional investment and therefore care for the environment, wildlife, and snakes in particular.

The primary objective of conventional education is to increase knowledge of the subject matter, and environmental, snake, and other wildlife education accomplishes this goal. Zoo visitors, who often don't do more than read informational signs and view animals in enclosures from a distance, leave the zoo with a greater knowledge and understanding of the species they saw (Luebke and Matiasek 2013). One-day-long school field trips to various ecosystems also significantly increased students' knowledge of those ecosystems, as well as the ecological relationships and trophic interactions contained within (Prokop et al 2007, Manzanal et al 1999). This effect was even more noticeable when compared with the students in the control group who did not participate in the field trip, and instead only received biology lectures from their teachers. The students who participated in the field work performed significantly better on their post-tests taken after the field trip than they did on their pre-tests taken before, whereas the control group students showed no change in test scores. The hands-on, real world application of class concepts enabled the students to solidify their understanding, and simple day-long field trips are relatively easy to incorporate into course curricula. Such trips also increase knowledge of students about the environment and the impact humans have on the natural world (Bogner 1998). The age at which field trips can increase knowledge is not limited to just older students. A study of fourth and fifth graders found that their drawings of food chains using a snake as the secondary consumer were significantly more detailed and accurate after a field trip than they were previously (Conkey and Green 2018). This shift indicates the effectiveness of supplementing classroom learning with field experience. The field trip allowed the students to connect what they learned with the real world, providing them with context surrounding their newfound knowledge. Additionally, first and second graders were able to use crafts to learn ecological facts about conventionally disliked animals (such as snakes), including why the attributes humans dislike are important for those animals in the wild (Rule and Zhbanova 2012). These crafts allowed the young children to stay engaged while still effectively learning, and illustrate how education can take many forms and still be productive.

Not only does environmental education increase knowledge, it also has the capacity to change people's attitudes towards nature, and snakes in particular. The aforementioned first and second graders who conducted crafts experienced a decrease in their previously-held negative emotions towards generally disliked animals, showing caution when first learning about the species but over time approaching the lessons with enthusiasm (Rule and Zhbanova 2012). When asked to rate animals on a 1 (hate) to 10 (love) scale, students who partook in the crafts rated animals significantly higher on their post-test than pre-test, whereas control group students who did not partake in the crafts showed no change in ratings. An increase in information about snakes has also been shown to increase positive attitudes towards them (Morgan 1992, Luebke and Matiasek 2013). One possible explanation for this improvement is that information can debunk myths and misconceptions, both of which are prevalent regarding snakes and can influence a person's opinion before ever interacting with a snake (da Silva et al 2021). This effect is illustrated in the case study, where the individual believed snakes to be vicious without ever having interacted with one (see Case Study box).

Class field trips have a particularly powerful effect on attitude improvement because in addition to supplying information, they have been shown to cause students to develop an emotional affinity for the ecosystems they visit (Manzanal et al 1999, Sousa et al 2016). The beauty of the area, and even some particular organisms, were strong factors in developing this response, which was noticeably absent from groups that got a classroom lesson instead of a field trip and thus did not experience the aesthetic pleasure of natural surroundings (Manzanal et al 1999). Field trips also improved students' attitudes towards biology classes and nature in general, regardless of student gender or whether the students were from an urban or rural area (Prokop et al 2007). If a field trip has a specific focus regarding a species, attitudes towards that species in particular are improved accordingly (Sousa et al 2016, Ballouard et al 2012). This correlation can enable perceptions of snakes to improve as more people obtain field experience with snakes. One instance of this effect occurs from the previously mentioned students who had to draw food chains; they were able to observe live rattlesnakes on their field trip, and even though handling was impossible for safety reasons, the students were still able to see the importance of snakes in their local ecosystem and develop an appreciation for them that had not previously existed (Conkey and Green 2018). Observing animals in zoo enclosures also increased visitors' emotional connections with both the animals and nature as a whole (Luebke and Matiasek 2013). Zoos are largely self guided experiences, occurring with a physical barrier between oneself and the animals. If such affective responses can occur at a zoo, where no physical contact occurs, there is promising potential for environmental education that involves hands-on learning and animal interaction.

Field trip participation is neither the only nor the most significant contributor to changing attitudes towards snakes, however. A study by Dos Santos et al (2020) showed that wildlife interactions with various species can stimulate emotion, and that most participants exhibited positive emotions when interacting with wildlife. As such, physical interaction with animals, including snakes, can develop a powerful emotional connection, and the authors concluded that educators should use live animals as teaching tools. Such a connection with animals only deepens the more in-depth the first-hand experience is, as simply viewing snakes provides far less of a bond than personally holding a snake (Morgan 1992). This effect is illustrated by the fact that as the level of involvement with snakes increased, students' orientations towards the animals became more emotionally based. Handling a snake produces a "wow" factor that is difficult to quantify, but has a large impact on developing positive attitudes towards snakes (see Case Study box). For example, a simple, one-day school field trip centered around snakes was enough to get kids to develop positive attitudes towards snakes, and the students shared that their hands-on interaction with the animals was their favorite part (Ballouard et al 2012). Even among students who liked snakes both before and after the field trip, their reasons for doing so became more emotion-based, indicating that hands-on interaction can change people's feelings in a way that lectures cannot. Not only is handling snakes enjoyable, research shows that it has the largest impact on the improvement in attitude towards snakes (da Silva et al 2021). When quantifying four factors that reduced aversion to snakes, the effect of previously handling snakes had quadruple the effect of recognizing the snake species, triple the effect of believing the snake to be ecologically important, and double the impact of having previously visited animal educational exhibits. These results indicate that live animal interactions not only have the potential to increase positive emotions, but are also highly effective at reducing fear, both among college students (da Silva et al 2021) and school-aged children (Ballouard et al 2012). Fear is a powerful emotion and source of motivation (Andreasen 2016), one that must be reduced or eliminated in order to generate support for snakes and snake conservation initiatives. As shown in the case study, once the fear of snakes evaporated, a willingness to protect snakes developed as a result of the change in attitude towards them (see Case Study box).

The benefits of interacting with snakes is not just limited to students, however, as handling live animals also has a positive impact on the emotions of educators (Fuhrman and Rubenstein 2017). When undergraduate students used live animals when educating both their peers and children, they self-reported feeling more confident, less nervous, more adaptable to unforeseen circumstances in the presentation, and perceived the audience as being more engaged. These benefits may be due to their indication that having a live animal to handle while speaking takes attention away from potential awkwardness or speaking mistakes, decreasing self-consciousness. They also reported feeling more enthusiastic while presenting, and instructor enthusiasm is shown to increase audience engagement and facilitate a better learning environment, which enables material to be better retained.

Case Study

An individual with a self-described fear-based perception of snakes visited a reptile park at the encouragement of a friend who was a park employee. Prior to visiting the park, the individual did not understand why anyone would want a snake as a pet or how anyone could emotionally connect with snakes like humans typically connect with dogs or cats. He viewed snakes as vicious animals that laid in the grass and bit people, and would never have considered supporting snake conservation causes.

During his visit to the park, the individual held several snake species that are commonly found as pets, viewed several more species of snakes and other reptiles, and attended an educational show conducted by park staff. When asked to describe his encounters with the snakes, he shared that he expected the snakes to be slimy and was surprised when they weren't. He also shared that the intimate physical contact broke down a mental wall he had against snakes, and learned a lot about snake demeanor and attitudes towards humans.

After his experience at the park, he has a positive attitude towards snakes and even wants one as a pet. He described going to the pet store to pick up dog food, and going out of his way to view the snakes on display. He stated that the most influential factors of this perspective shift was the physical contact and handling of live snakes, which he said not only allowed him to realize for himself that snakes are not vicious and out to bite people, but gave him a "wow" moment that did not occur when simply observing snakes in their enclosures. When posed a question about his current willingness to support snake conservation efforts, he expressed that he would definitely be open to the possibility if he were provided with more specific information surrounding the particular cause. Furthermore, he shared that he is no longer hesitant of his child's interest in snakes, and has been actively sharing in the enthusiasm towards snakes and encouraging his child to continue learning about them.

The effects of education on snake conservation

Understanding what motivates people to engage in conservation efforts will enable methods of educating the public about snakes to have a tangible impact on snake conservation. Potential impacts can manifest themselves in multiple ways, both in terms of financially donating to causes and in the environmentally-friendly actions people can incorporate into their daily lives. Given how negatively viewed and persecuted snakes are, generating such motivation is particularly difficult. However, there are several sources of motivation that snake education can draw upon in order to promote action. Monroe (2003) established that a specific behavior is a product of opportunity and intent, and intent is a combination of knowledge and attitude. In order to have intent, one must have a positive outlook on the perceived outcome of their action and believe they are able to perform that behavior, which requires knowledge of the situation and the factors involved. A simple way to increase both of these factors is to target public awareness of conservation efforts to local audiences, as people are more likely to monetarily support conservation in their area than those that are far away (Martin-Lopez et al 2007). The authors quantified respondents' willingness to pay for conservation, and this factor decreased as geographic distance increased. Increased awareness of nearby issues is the most likely reason for this correlation, as information about local issues is more accessible to the general population (Johnson et al 2001). Personal gain is another motivating factor, as evidenced by the fact that people are much more likely to support conservation of a species that provides a useful service to them than a species that offers no discernible utility (Martin-Lopez et al 2007). A third way to motivate people is by increasing perceived connection between people and nature, as this perception increases the likelihood of action (Schultz 2011). This correlation is illustrated by the fact that emotional affinity towards nature, interest in nature, and indignation about insufficient protection of nature are all powerful predictors of environmentally friendly action (Kals et al 1999). Survey responses showed that almost 50% of those feelings towards nature are a result of people's personal experiences in nature, emphasizing their importance in encouraging eco-friendly actions.

Environmental education can play a significant role in establishing those personal experiences in nature, which could provide the influence and motivation to get people to support snake conservation efforts. However, education alone typically does not result in behavioral change; as mentioned above, people need motivation in order to act. The strategies educators must employ to motivate people to act must be simple, specific, and achievable in order to increase the likelihood of success. "Broad pleas to 'protect the environment' or 'save the planet' are generally ineffective at changing specific behaviors," as are long lists of tasks to start performing (Schultz 2011).

The increase in positive emotions towards nature and snakes described in the previous section bodes well for promoting pro-environmental behavior through education. School field trips have been shown to increase the number of children who chose to protect snakes when asked to choose just a few from a list of species to protect (Ballouard et al 2012). If the field trip is more thorough and lasts several days, students are more likely to engage in pro-environmental behaviors (Bogner 1998). Additionally, people who feel connected to nature have increased concern for nature, and are not only less likely to harm it, but more likely to actively participate in eco-friendly behavior (Mayer and Frantz 2004). Environmental education programs play a major role in motivating volunteers in urban areas to become more engaged in conservation efforts, despite people in urban areas being more disconnected from the natural environment

(Miles 2021). These results show that a connection to nature can be developed fairly quickly and easily, and that conservation is not restricted to just those in rural areas or “outdoorsy” people. However, those who feel connected to nature have been shown to have a greater personal well-being than the average citizen, regardless of potential confounding variables such as affluence or education (Mayer and Frantz 2004). Furthermore, the magnitude of the increase in personal well-being due to nature connectedness was comparable to the magnitude shown by factors such as marriage, education, and income, all of which are more traditionally associated with happiness. Proving to people that their well-being is likely to be improved if they develop a connection with nature could possibly motivate them to start caring about the environment, even if that motivation is due to their own self interest of wanting to be happier, rather than altruism. Additionally, people who developed nature programs were the biggest supporters of species that typically cause phobias, such as snakes and spiders, possibly due to their usefulness when making such programs (Martin-Lopez et al 2007). Even though the selfish motive is not ideal, achieving the end result of garnering support for snake conservation is the most important factor.

If education about snakes can give people more knowledge, not only about snakes themselves but also about how they benefit their ecosystems and (both directly and indirectly) humans, that may increase people’s willingness to monetarily support snake conservation. A study by Pinheiro et al (2016) established that serpentarium visitors who had prior interactions with snakes were less likely to be afraid of snakes and have negative perceptions of them. Negative perceptions were correlated with fear of snakes and viewing snake conservation as unimportant. Furthermore, people with higher levels of education were less likely to have negative attitudes towards snakes, possibly due to higher-educated people having more information about snake biology and not believing folklore or hyperboles that vilify snakes in popular culture. The widely misunderstood ecology and demeanor of snakes allows misconceptions to permeate their way into our dialogue surrounding snakes. By increasing our understanding of these animals, we open the door for us to care more about their well-being, and support for their conservation can follow.

Flagship species are animals that are typically used by conservation organizations as figureheads for garnering support for their environmental causes. Threatened species that gain the most attention and support for protection are ones that people find most aesthetically pleasing (Knight 2008). When survey respondents were asked to rank 10 species, the three (a bat, a spider, and a snake) that scored the lowest in aesthetic value also scored the lowest in support for their protection. In other words, people tend to believe that cute and cuddly animals deserve more protection than ugly ones. For example, the giant panda (*Ailuropoda melanoleuca*), a species humans typically deem adorable, provides the mascot for the World Wildlife Fund. In a study of mammals depicted on beer and cider cans and bottles worldwide, rodents and bats were significantly underrepresented relative to the proportion of mammal species that they encompass (Feldhamer et al 2002). Conversely, carnivorous mammals were the most frequently shown, despite comprising a significantly smaller proportion of all mammals than rodents and bats. The authors point out that carnivores are commonly associated with strength and power, whereas rodents and bats are associated with disgust, fear, and disease, possibly explaining the disparity in prevalence on cans and bottles. Similarly, another study found that conservation and nature magazines in the US predominantly featured large mammalian carnivores and birds on their covers, representing the flagship species of that magazine issue (Clucas et al 2008). Mammals and birds were featured on over half of covers, whereas reptiles were on fewer than 4% of covers. The over-representation of large carnivorous mammals and birds is likely “because the western public is most familiar and therefore most sympathetic to birds and mammals; that they are thrilled by the act of predation and traits that predators possess; that they have seen more large species than small ones, particularly on television programs and in zoos; and they are moved by rarity.” Put more simply, large animals are familiar, and familiarity induces sympathy. If the animal is powerful, that is thrilling, and if it’s rare, the novelty is attractive.

If education can make snakes familiar to the general public, sympathy for snakes can follow. These positive emotions can be maximized by using live snakes as educational tools. People have to know and care about the snakes in order to take action. Emotions influence such action, and hands-on interactions can stimulate these emotions (Dos Santos et al 2020). Education can also show people that the power of snakes isn’t targeted at humans. Even though many large snakes are strong enough to constrict humans and many venomous species are toxic enough to be fatal, snakes don’t hunt people, and only pose a threat to humans when the snake itself feels threatened. By being able to see the power of snakes without being afraid for their own lives, people will then have emotional room to be thrilled by snakes, as opposed to having fear be the dominant feeling. Educating people on endangered snakes can also attract people to the novelty of a rare animal, and increased knowledge and appreciation of the ecology of snakes could help people see the beauty in them. It may help to show images of vibrant snakes such as the eyelash viper (*Bothriechis schlegelii*) in order to appeal to people’s aesthetics, as visually appealing images evoke our attractiveness bias (Langlois et al 2000).

The potential for snake education to encourage and motivate people to actively participate in snake conservation is high, and the wide range of possible avenues with which to educate the public provides for lots of flexibility for educators. However, establishing the appropriate methods for particular audiences and targeting local species and conservation concerns in the educational program is imperative in order to maximize the effectiveness of environmental education initiatives.

Chapter 3: Putting Snake Education into Practice

In chapter 2, instances of snake and environmental education were discussed, as were their effects on improving knowledge of and attitudes towards snakes, and how that might translate to increased conservation actions to help protect snakes in the future. However, these educational programs or events were relatively isolated, existing as part of a study with no mechanisms in place to continue such education in subsequent years, which would allow more students to reap the benefits of proper environmental education. This chapter will outline a lesson plan that can be implemented by high school biology teachers who wish to incorporate snake education into their curricula, and will subsequently provide scientific justification for why elements of the lesson plan were included. The establishment of lesson plans such as this may enable the benefits shown in chapter 2 to be realized by a broader audience, and hopefully result in greater support for and success of snake conservation.

<u>Lesson plan</u>

At the start of the lesson, ask the students to compile a list of what they think they know about snakes. This will be a collaborative list, so write their responses up on the board for all to see. If any answers from students are inaccurate, write those in a separate list to address later, as recognizing misconceptions is an important first step to remedying them. This activity should take roughly 5 minutes.

After your list is complete, give a standard classroom lecture to your students. This lecture should include basic snake characteristics, their role in ecosystems, and common misconceptions about snakes. You can refer to any ideas from the list your students generated, both correct and incorrect, as you go along. Conservation threats to snakes should also be covered, and will allow students to apply this knowledge to real-world issues. Be sure to include pictures, diagrams, videos, and other forms of multimedia in your lecture in addition to just words on slides. For instance, when discussing rattlesnakes and their rattles, you can describe the function and importance of the rattle, show a diagram of a rattle and how its interlocking buttons function, and play a video (with sound) of a rattlesnake rattling. Another example may be to explain the process of snakes shedding their skin, accompanied by a video of it occurring. If you have a snake as a class pet, or a student is willing to bring in their pet snake, having a live animal as a part of your lecture is ideal, although biofacts such as skins or skeletons provide a decent substitute. Supplementing the material you cover with videos from celebrity wildlife and conservation experts such as Steve Irwin or Coyote Peterson may help inject excitement into the classroom, and may also encourage students to find videos on their own time to learn more about wildlife conservation. Where applicable during the lecture, localize the topics covered to snakes in your area. See the Appendix for a description of the snake families native to the United States, as well as 12 “featured” snake species that may be native to your particular area. Also in the

Appendix is Table 2, which has a listing of the number of snake species, number of venomous snake species, snake families, and "featured" species present in every state. This lecture should take roughly 20 minutes, or whatever duration of time brings you to slightly before the halfway point of the class period.

After the lecture, place students into groups of 3-5 and assign them a group project to begin working on. There are several options for what this project could entail. One possibility is to have the students choose a misconception about snakes, and make a slideshow or video public service announcement targeted at the general public as to why their chosen misconception is logically unsound. Another option could be to choose a snake species and create an infographic or poster detailing its characteristics and information. A third type of project could be to choose one aspect of snake anatomy, ecology, or behavior, and create a presentation explaining why that aspect is important for snake survival. In all of these cases, students can begin working on their project during class and finish it for homework, and have all projects due in a week or so and then presented in class or posted on a class website for other students to view. While students are working, the live snake and/or snake biofacts (if available) can be brought around to student groups, giving them physical references for topics they are covering in their projects and also enabling them to share the excitement of such personal animal interactions with their peers. This portion of class should run until about 5 or 10 minutes remain in the class period.

For the final 5 or 10 minutes of class, have students individually reflect on new information they learned about snakes and snake conservation, and how that knowledge either differed from what they previously believed or filled in a gap in their understanding. They can also elaborate on what part(s) of the lesson was most enjoyable or impactful on how they view snakes, and how the lesson as a whole either reinforced their perception of snakes or changed their minds in some way. Have students submit those reflections to you.

<u>Justifications and considerations for the lesson plan</u>

In an ideal world, this classroom lesson would supplement a field trip, given the benefits associated with hands-on experience outlined in chapter 2. However, recognizing the financial and time constraints of some school districts, students, or curricula, this lesson was created with the ability to stand alone if necessary. There are alternatives to field trips that can be implemented instead, such as educational programs that come to the classroom. Some nature centers and other environmental organizations offer this service, and can bring both animals and occupational expertise into a classroom setting to provide students with the opportunity to personally interact with snakes and learn about the environment from professionals. A lesson of this sort would allow students to experience some of the benefits of a field trip without incurring as much cost or taking as much time as a standard off-site field trip.

The motive behind student learning must be considered when implementing this lesson, and how different motives can affect retention of material and effectiveness of the lesson. In the typical classroom, students are graded on an A-F scale, yet such a grading system does not motivate students to learn; instead, students are merely motivated not to receive bad grades (Schinske and Tanner 2014).

> "Grades appear to play on students' fears of punishment or shame, or their desires to outcompete peers, as opposed to stimulating interest and enjoyment in learning tasks. Grades can dampen existing intrinsic motivation, give rise to extrinsic motivation, enhance fear of failure, reduce interest, decrease enjoyment in class work, increase anxiety, hamper performance on follow-up tasks, stimulate avoidance of challenging tasks, and heighten competitiveness." (Schinske and Tanner 2014)

However, including effort as part of a grade encourages students to learn and improve. Instructor feedback without a grade also enhances learning, showing that educational goals can be achieved without assigning a letter or number grade to students based solely on their knowledge of a subject. By adopting a grading system based on completion and effort rather than knowledge and accuracy, students become more interested in improvement, practice more, participate more in class, and avoid the negative effects of our current grading system. Based on these findings, any snake education program would be most effective if ungraded, or graded solely on participation and effort. Establishing this condition with students at the beginning of the lesson is recommended, so that they will never feel pressured to know everything and can instead focus on learning for enjoyment.

Having students list what they think they know about snakes will encourage active classroom discussion, but will also give you, the teacher, an idea of what students know and don't know. Having this knowledge can allow you to build on accurate information and fill in gaps where prior knowledge is lacking or incomplete (Ambrose et al 2010). This exercise will also give you the opportunity to address any misconceptions immediately, so throughout the lesson the truth can be reinforced rather than the student realizing halfway through that what they thought earlier was wrong, and having to reconnect the information they just learned to a new mental construct. Combatting misconceptions is a particularly relevant consideration of this lesson plan, given that misconceptions surrounding snakes are prevalent in today's society. Misconceptions are typically difficult to correct because they've generally been reinforced over time and in multiple contexts, and often include some accurate components in addition to the inaccuracies (Ambrose et al 2010). Furthermore, consciously overriding misconceptions is harder than sticking with what's familiar, and because people prefer ease, they do not devote time and energy towards amending their beliefs. However, minimizing distractions and eliminating the pressure associated with time constraints can make students more likely to think rationally, and therefore more likely to avoid misconceptions. Asking students to justify their reasoning can expose contradictions that inaccurate information contains, which also helps eliminate misconceptions.

The lecture portion of the lesson serves several purposes. The first function is to increase students' knowledge of snakes and snake conservation. As discussed in chapter 2, snake and environmental education programs achieve this goal. For example, zoos increase the knowledge of visitors who walk through their gates, and viewing the animals is the most influential component of zoo education despite contact being prohibited with almost all zoo animals (Luebke and Matiasek 2013). Chapter 1 contains information about snakes and snake conservation, and can be used as a resource when forming your presentation. The lecture also creates space for individual learning, which allows students to get more problem-solving practice to help solidify concepts and develop proficiency in relevant procedures (Mullins et al 2011). There are ways to give students problem-solving practice without having to grade them on anything other than completion, such as having students fill in diagrams of how humans are adversely affecting various ecosystems and how snakes are impacted from those processes.

The second function of the lecture is to connect students to snakes and snake conservation in as many ways as possible. People have different ways in which they prefer to gather and process information, and these styles fit into four categories of sensory modalities: visual(V), aural (A), read/write (R), and kinesthetic (K) (Prithishkumar & Michael 2014). Together, these modes make up the VARK learning style model. Evidence suggests that large percentages of students are multimodal in their preferred learning style, with one study finding that 87% of undergraduate medical students are multimodal (Prithishkumar & Michael 2014), and another finding 26% of business students are as well (Espinoza-Poves et al 2019). Given these data, finding ways to incorporate several modalities into a lesson will not only be beneficial to multimodal learning students, but also accommodate the varying preferences of unimodal students. Using multimedia and a live snake or snake biofacts will help cover all four sensory modalities, and therefore enable students to more effectively comprehend the concepts discussed in the lesson. Snake skins are the most easily accessible of snake biofacts, as all you need to do is ask a snake owner for a shed skin, but other animal artifacts such as fangs, rattles, and skeletons are available as well. These can be passed around during the lecture or group portion of the lesson, allowing students to observe and feel them up close.

As established in chapter 2, people need to develop an emotional connection with snakes in order to care about snakes’ well-being, which then lends itself to a willingness to act on conserving snakes. Snake education can succeed in this aspect, especially when students can observe and handle live snakes. Even though this lesson does not include a field trip, the benefits shown in chapter 2 can still be gained if an emotional connection is developed. Handling snakes is the single most influential factor when improving attitudes towards snakes, and not only increases positive emotions but decreases fear of snakes as well (da Silva et al 2021). Physical encounters with snakes are not absolutely necessary to form a connection, however, as simply providing information about snakes has been proven to increase positive attitudes towards them

(Morgan 1992, Luebke and Matiasek 2013). Biofacts are good alternatives when live snakes are not an option, as they not only appeal to the kinesthetic (K) learning style but can also act as a replacement for generating some of the positive emotions that people typically get from handling live snakes (Dos Santos et al 2020). Another benefit of the use of biofacts is that they are less likely to instill fear in people with ophidiophobia, also known as fear of snakes. Inanimate objects cannot move or flick out their tongues and it is impossible for them to bite, and these assurances may generate enough confidence in an ophidiophobic individual to touch the biofacts and start forming a physical connection with snakes. Presenter enthusiasm can also indirectly help form a connection, as students recall much more information from an enthusiastic teacher than from an unenthusiastic one (Moè et al 2021). This discrepancy can at least partially be explained by the difference in attentiveness, with students paying significantly more attention to instructors with high enthusiasm. Incorporating Steve Irwin or Coyote Peterson videos may help reap the benefits of excitement in the classroom, and will also appeal to the visual (V) and aural (A) sensory modalities.

A third purpose of the lecture is to make the addressed topics relevant to the local area, which may increase student engagement with the lesson as people are much more likely to care about and subsequently act on issues that are closer to home (Martin-Lopez et al 2007). Localizing the material will allow students to form connections between what they learn and what they've seen outside in their own backyards, and may inspire some to explore more and deepen their understanding of their local ecosystems and wildlife. The Appendix provides a starting point for information regarding snakes in the United States, including state-by-state information and resources.

Allowing students to participate in group work draws upon the benefits of collaborative learning, which provides multiple benefits to students. Collaborative learning not only necessitates that students explain concepts to each other, therefore reinforcing the material, but also facilitates the collective construction of new ideas and the critical evaluation of those ideas (Hausmann et al 2004). Furthermore, the interactive aspect of group learning can fulfill social goals for students, which in turn can increase motivation and desire to do the task at hand (Olsen et al 2017). Collaborative learning also works well for finding problems with erroneous information, as well as the critical evaluation of ideas, both of which can help reinforce correct knowledge and further debunk misconceptions (Olsen et al 2017, Hausmann et al 2004, Ambrose et al 2010). Giving students time to complete a group project at home will enable these benefits to continue beyond just the class period, allowing for deeper engagement with the material. When collaborative learning is applied in addition to the individual learning discussed above regarding the lecture portion, the combination is more effective than either one alone, as it allows the instructor to align each part of the lesson with the strengths of the two methods of learning (Olsen et al 2017).

Having students individually reflect at the end of the lesson can help solidify concepts discussed in class, without the distractions that collaborative work can cause (Mullins et al 2011). Not grading these reflections will also encourage students to be more open and honest about any misconceptions they may have had, which can help to continue overriding those misconceptions with correct information. Lastly, collecting the reflections will allow for student feedback on how to most effectively educate people about snakes and snake conservation in the future.

One final consideration before implementing this lesson are the potential obstacles impeding its progress. In this case, there are several possible challenges to the implementation of a snake education program. While this paper as a whole aims to establish the importance of snake education, which will hopefully alleviate any skepticism about the necessity of the endeavor, implementation of the lesson itself may meet resistance. For starters, the number of school days in a year is finite, and if high school biology curricula in some school districts are less flexible, teachers and administrators may be disinclined to make room for snakes. Additionally, half the population experiences some form of anxiety regarding snakes, and 2.6% of people meet the criteria for ophidiophobia, or fear of snakes (Polák et al 2016). While more educated people are less likely to fear snakes due to reduced susceptibility to folklore or hyperbole (Pinheiro et al 2016), the possibility exists of ophidiophobic administrators objecting to teachers implementing a snake education program in their classrooms. Parents of students may also object, a problem Dos Santos et al (2020) encountered in their study. When parents found out that snakes were the program's "animal of the week," many had negative reactions and only half of the registered participants attended that week's program. However, 70% of children who were present handled and interacted with the live snakes, indicating that children may be less snake-averse than parents, who are unilaterally deciding to avoid snakes without giving their children a chance to form opinions for themselves. Furthermore, some may raise ethical concerns with using live animals as teaching tools. One objection is that because pet animals are technically property, they are denied rights, and by using them we are exploiting beings without rights (Francione 1996). Another potential concern is that of speciesism, where we view the needs and interests of nonhuman animals as less important than that of humans, which enables us to mistreat animals under the premise that human interest outweighs animal interest (Singer 1975). If ethical concerns such as these prove to be too off-putting, biofacts such as snake skins, fangs, and skeletons can provide an alternative that has been proven to evoke positive emotions and be highly engaging for audiences (Dos Santos et al 2020). Considering these potential obstacles is important when preparing to implement this lesson, but they can all be worked around in order to successfully educate students about snakes and snake conservation.

<u>Conclusion</u>

Implementing a lesson on snakes and snake conservation and incorporating strategies such as the ones listed above will not only educate students about snakes and their place on our planet, but help students develop an emotional affinity for snakes and therefore be more likely to take action to protect and conserve them. Snakes need our help, and given the plethora of issues human activities have created that are threatening snake survival around the world, it is our obligation to conserve them. Snakes are some of the most feared and misunderstood animals in the world, so the road to generating support for snake conservation begins with education. Education programs can change the minds and hearts of people, which increases the likelihood of action. If snake education can grow and become widespread enough, misconceptions and fear of snakes will start to dissipate, allowing conservation initiatives to have the support and funding needed to protect these animals which provide so much to their ecosystems and the world.

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Appendix

The purpose of this appendix is to provide educators with a starting point for state-specific information to include in their lesson plans. The “snake families of the United States” section offers general characteristics of the five native snake families found in the US. Table 2 is an alphabetical listing of each state and general snake data for that state, designed to provide easy access to locally relevant information about snakes. As mentioned in Chapter 2, people are more likely to care about and support issues close to home than ones that are far away, so tailoring the lesson to your local environment should help it resonate more with students. I included a list of a dozen “featured species” at the end to help give examples of snakes you and your students might find in local backyards or parks, with the goal of students being able to connect what they learned in the lesson to what they have seen in their environment. Invasive species are not included in this appendix, and in cases where multiple subspecies of the same species were present in the same state, they were grouped together and counted as one species.

Snake families of the United States

Boidae (boas)

Boas are nonvenomous constrictor snakes, and include the largest snakes on Earth such as the 550lb Green Anaconda (*Eunectes murinus*) and the extinct 2500lb Titanoboa (*Titanoboa cerrejonensis*) (61, 70). The term “Boa constrictor” has been used as a general term for boas, but is actually the scientific name for the Red-tailed Boa and its subspecies, which are native to Central and South America. Two species of boa are native to the United States, the Rubber Boa (*Charina bottae*) and Rosy Boa (*Charina trivirgata*), both of which are small in size and inhabit western states.

Colubridae (colubrids)

Colubrids are the largest snake family in the world, and encompass roughly 84% of US species (57). The appearance and ecology of colubrids varies greatly, and they inhabit every state except Alaska and Hawaii. Most species have solid teeth, but some have grooved fangs in the rear of their upper jaws.

Elapidae (elapids)

The elapids are a family of venomous snakes, renowned for being among the most toxic in the world (57). Elapids have neurotoxic venom, which disrupts the functioning of our nervous systems, and do not have triangular heads like vipers (60). Iconic species such as the king cobra and black mamba are members of the elapid family. Our only terrestrial elapids in the United States are coral snakes, of which we have three species: the Eastern, Texas, and Sonoran (aka Arizona) Coral Snake (58). There is also one species of sea snake, the Yellow-bellied Sea Snake (*Hydrophis platurus*), that inhabits US waters off of California and Hawaii, although it is rarely seen (56).

Viperidae (vipers)

Vipers are a family of venomous snakes, and all vipers in the United States belong to the subfamily Crotalinae, or Pit Vipers (57). This subfamily gets its name from the heat-sensing pits located on each side of the head, between the nostril and eye. These pits aid the snake in sensing and accurately striking warm-blooded prey. Other characteristics of Pit Vipers are their large triangular heads, vertically elliptical pupils, and the single row of scales on the underside of the tail. Copperheads, Cottonmouths, and Rattlesnakes form the three groups of Pit Vipers in the United States, and at least one species can be found in every state except for Alaska, Hawaii, Maine, and Rhode Island. Pit Viper venom is mostly hemotoxic (affecting the blood), cytotoxic (affecting the cells), or myotoxic (affecting the muscles) (64). However, the Mojave Rattlesnake (*Crotalus scutulatus*), Timber Rattlesnake (*Crotalus horridus*), and Southern Pacific Rattlesnake (*Crotalus oreganus helleri*) also have neurotoxic (affecting the nervous system) venom.

Leptotyphlopidae (slender blind snakes)

Slender Blind Snakes are small, burrowing, wormlike snakes that, as the name suggests, are blind (57). They do possess vestigial eyes, which allows the observer to distinguish the head from the tail, as the tail of these snakes appears very blunt. The tails of Slender Blind Snakes are very short, but end in a tiny spine. The belly scales of these snakes are the same size as the dorsal scales, which is unique among US snakes. The two members of this family in the United States are present in the Southwest.

Table 2: general data for snakes in each US state, listed alphabetically. For more information about the snake families, see the "Snake Families of the United States" section above. For a description of each featured species, see the "Featured Species" section below. Information was gathered from the sources listed by number in parentheses, see the "Appendix References" section below for further reading

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
Alabama (1, 58)	49	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Alaska (2)	0	0	N/A	N/A
Arizona (3, 4, 58)	52	14	Boidae, Colubridae, Elapidae, Viperidae, Leptotyphlopidae	Western Diamondback Rattlesnake, Prairie Rattlesnake, California Kingsnake, Gopher Snake, Western Hognose Snake
Arkansas (5, 58)	38	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
California (6, 58)	73	9	Boidae, Colubridae, Elapidae, Viperidae	Western Diamondback Rattlesnake, Garter Snake, California Kingsnake, Gopher Snake
Colorado (7, 8)	29	4	Boidae, Colubridae, Viperidae, Leptotyphlopidae	Prairie Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake, California Kingsnake, Gopher Snake
Connecticut (9)	14	2	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake
Delaware (10)	19	1	Colubridae, Viperidae	Copperhead, Northern Watersnake, Garter

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
				Snake, Milk Snake
Florida (11, 12, 58)	44	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Plain-bellied Watersnake, Garter Snake
Georgia (13, 58)	46	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Hawaii[3] (14, 56)	1	1	Elapidae	none
Idaho (15)	12	2	Boidae, Colubridae, Viperidae	Prairie Rattlesnake, Garter Snake, Gopher Snake
Illinois (16)	38	4	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Indiana (17)	32	4	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Gopher Snake
Iowa (18)	28	4	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern

[3] Hawaii has no terrestrial snakes. The Yellow-bellied Sea Snake, a member of the Elapidae family, is a sea snake occasionally seen off the coast of Hawaii. A description of the Yellow-bellied Sea Snake can be found in reference 56.

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
				Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Western Hognose Snake
Kansas (19)	42	6	Colubridae, Viperidae, Leptotyphlopidae	Copperhead, Cottonmouth, Timber Rattlesnake, Prairie Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Kentucky (20)	32	4	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Louisiana (21, 58)	37	7	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Maine (22)	9	0	Colubridae	Garter Snake, Northern Watersnake, Milk Snake
Maryland (23)	27	2	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Massachusetts (24)	14	2	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
Michigan (25)	18	1	Colubridae, Viperidae	Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Minnesota (26)	17	2	Colubridae, Viperidae	Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake, Gopher Snake
Mississippi (27, 57, 58)	55	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Missouri (28)	47	5	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Montana (29)	10	1	Boidae, Colubridae, Viperidae	Prairie Rattlesnake, Garter Snake, Milk Snake, Gopher Snake
Nebraska (30)	29	4	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Prairie Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Nevada (31, 32)	27	6	Boidae, Colubridae, Viperidae, Leptotyphlopidae	Western Diamondback Rattlesnake, Garter Snake, Milk Snake, California Kingsnake, Gopher Snake

State	**Total # of snake species**	**# of venomous species (59)**	**Snake families present**	**Featured species present**
New Hampshire (33)	11	1	Colubridae, Viperidae	Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake
New Jersey (34)	22	2	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake
New Mexico (35, 36, 58)	46	11	Colubridae, Elapidae, Viperidae, Leptotyphlopidae	Western Diamondback Rattlesnake, Prairie Rattlesnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, California Kingsnake, Gopher Snake, Western Hognose Snake
New York (37)	17	3	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Water Snake, Garter Snake, Milk Snake
North Carolina (38, 58)	38	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
North Dakota (39)	10	1	Colubridae, Viperidae	Prairie Rattlesnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Ohio (40)	26	3	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Oklahoma (41)	44	7	Colubridae, Viperidae,	Copperhead,

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
			Leptotyphlopidae	Cottonmouth, Timber Rattlesnake, Western Diamondback Rattlesnake, Prairie Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Oregon (42)	15	1	Boidae, Colubridae, Viperidae	Prairie Rattlesnake, Garter Snake, California Kingsnake, Gopher Snake
Pennsylvania (43)	21	3	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake
Rhode Island (44)	12	0	Colubridae	Northern Watersnake, Garter Snake, Milk Snake
South Carolina (45, 58)	38	6	Colubridae, Elapidae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
South Dakota (46)	16	1	Colubridae, Viperidae	Prairie Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Tennessee (47)	32	4	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
				Snake, Milk Snake
Texas (48, 57, 58)	76	11	Colubridae, Elapidae, Viperidae, Leptotyphlopidae	Copperhead, Cottonmouth, Timber Rattlesnake, Western Diamondback Rattlesnake, Prairie Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake
Utah (49)	24	4	Boidae, Colubridae, Viperidae, Leptotyphlopidae	Garter Snake, Milk Snake, Gopher Snake
Vermont (50)	12	1	Colubridae, Viperidae	Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake
Virginia (51)	34	3	Colubridae, Viperidae	Copperhead, Cottonmouth, Timber Rattlesnake, Northern Watersnake, Plain-bellied Watersnake, Garter Snake, Milk Snake
Washington (52)	12	2	Boidae, Colubridae, Viperidae	Prairie Rattlesnake, Garter Snake, Gopher Snake
West Virginia (53)	20	2	Colubridae, Viperidae	Copperhead, Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake
Wisconsin (54)	21	2	Colubridae, Viperidae	Timber Rattlesnake, Northern Watersnake, Garter Snake, Milk Snake, Gopher Snake

State	Total # of snake species	# of venomous species (59)	Snake families present	Featured species present
Wyoming (55)	13	2	Boidae, Colubridae, Viperidae	Prairie Rattlesnake, Garter Snake, Milk Snake, Gopher Snake, Western Hognose Snake

Featured Species

The goal of this section is to provide examples of common snakes around the US that can be included in a lesson, so that students can connect what they learned in school to what they have seen in their own backyards. These featured species were chosen based on their distribution, popularity/name recognition, prevalence in the pet trade, and/or unique characteristics, with the goal of at least one of these species being present in all lower 48 states. Prevalence of the snake was also a factor, and all of these species are fairly common and therefore observable in at least parts of their native ranges and habitats. Table 2 has a listing of which of these featured species can be found in your state. The "Snake families of the United States" section has general information about characteristics of the families to which each of these snakes belong.

Copperhead (*Agkistrodon contortrix*), family Viperidae

These Pit Vipers are named for their distinctive coppery-red heads (57). Five subspecies are currently recognized, and inhabit most of the Eastern United States. Copperheads generally grow 2-3 feet in length, and have dark hourglass-shaped (wide on the sides, narrow around the spine) crossbands along their back. In some subspecies, these hourglasses are broken in the middle. These snakes camouflage extremely well, but may also vibrate their tail against leaves or the ground to mimic a rattlesnake in an attempt to ward off predators. Copperheads primarily eat mice, but also consume small birds, lizards, small snakes, amphibians, and insects. Juveniles are paler in color, but have bright yellow tail tips, which they use to lure prey (62). These snakes are primarily nocturnal during warmer months, but may be found during the day as well. Copperhead venom is relatively weak and almost never results in death. Many nonvenomous snakes are mistaken for Copperheads and are killed. Do not attempt to harass or kill these snakes, as this is how most bites occur.

Cottonmouth (*Agkistrodon piscivorus*), family Viperidae

Cottonmouths get their name from the white interior of its mouth, which it will open when attempting to scare off predators (57). Also known as Water Moccasins, these snakes are generally 2.5-4 feet in length, and have a very dark coloration with dark crossbands. The crossbands fade as they get older, with the oldest adults potentially losing them completely.

Juveniles have more distinct patterning, as well as a yellow tail tip to lure prey. As the name "Water Moccasin" suggests, they are semiaquatic and primarily eat fish, but will consume anything they can swallow. Three subspecies are currently recognized, and they inhabit most of the Southeastern United States. Many nonvenomous water snakes closely resemble the Cottonmouth. Aside from the Pit Viper characteristics, Cottonmouths can be distinguished from other water snakes by their propensity to slowly crawl away or stand their ground, rear up their head, and gape their mouth open when threatened, whereas nonvenomous water snakes will quickly try to escape. Cottonmouth venom is believed to be more dangerous than Copperheads, but less toxic than that of most rattlesnakes (63).

<u>Timber Rattlesnake (*Crotalus horridus*), family Viperidae</u>

Also known as the Canebrake Rattlesnake, these large (3-5 feet) rattlesnakes inhabit nearly the entire Eastern half of the United States (57). These snakes are generally pale yellow, tan, or light brown, with dark V-shaped crossbands. Some Northeastern individuals are mostly black, however, and Southern populations tend to have a rust-colored stripe running along the spine down the length of the body. Timber Rattlesnake tails are solid black, and their diet consists primarily of rodents (65). Many populations in the Northeast have been extirpated from their historical ranges, and as a result are protected in several Northern States.

<u>Western Diamondback Rattlesnake (*Crotalus atrox*), family Viperidae</u>

Arguably the most famous snake in the United States, the Western Diamondback Rattlesnake ranges from 2.5-6 feet long and is native to the arid climates of the Southwest (57). These snakes are generally brown or gray, but may have red or yellow hues. The diamond-shaped patterning on the back is not clear-cut, and the tail has thick black and white banding. The face has two light, diagonal stripes on both sides of the head, one on either side of each eye. Their diet consists mainly of small mammals such as rabbits and rodents, including gophers. The Western Diamondback is responsible for more human deaths than any other snake in North America, and as such these snakes should be treated with extreme caution and respect.

<u>Prairie Rattlesnake (*Crotalus viridis*), family Viperidae</u>

The two currently recognized subspecies of the Prairie Rattlesnake reach 3-4 feet in length, and together they inhabit nearly the entire Western United States (57). The coloration of these snakes range from greenish-gray to olive-green to greenish-brown, and can even be light brown or yellowish. Darker blotches with a very thin ring of white run down nearly the entire back, but near the tail those blotches join with the side markings to form crossbands on the tail. The heads have two light stripes, with the back stripe running from the back corner of the eye down and above the corner of the mouth. These snakes prefer to live in grassy plains, and may even live at elevations up to 8000 feet. In addition to rodents, Prairie Rattlesnakes also feast upon young prairie dogs and burrowing owls.

Northern Watersnake (*Nerodia sipedon*), family Colubridae

The four subspecies of the Northern Watersnake occupy most of the Eastern United States (57). As the name suggests, these nonvenomous, semiaquatic snakes can inhabit any freshwater body within its range, although they prefer slower-moving water to fast streams and rivers. Reaching 2-4ft in length, Northern Watersnakes exhibit a variety of patterns, which are highly visible on juveniles but become obscured in adults, which often appear pure black or dark brown. Their diet consists mostly of food caught in and around the water, including amphibians, fish, and crayfish. Their first form of defense is to flee, but if caught, these snakes will excrete a foul musk from glands located near the base of the tail.

Plain-bellied Watersnake (*Nerodia erythrogaster*), family Colubridae

Plain-bellied Watersnakes, of which there are 4 subspecies in the United States, are native to most of the Southeast (57). These snakes reach 2.5-4 feet in length, and are generally gray to brown to black. The belly color varies with subspecies, ranging from red to copper to yellow. Juveniles have more distinct patterning than adults, although the patterns are still visible in adults. Like the Northern Watersnake, the Plain-bellied Watersnake's diet is primarily amphibians, fish, and crayfish. These snakes prefer to occupy larger, more permanent bodies of water such as swamps and lakes, but can be found in many different types of aquatic habitats. However, they often travel long distances away from water in hot, humid weather.

Garter Snake (*Thamnophis sirtalis*), family Colubridae

Garter Snakes and their 12 subspecies are one of the most common and widely distributed snakes in the United States (68). There are even more species and subspecies of snakes called "Garter Snakes," but since they are taxonomically different from *T. sirtalis* and its subspecies they will not be included here (57). However, many of the characteristics of *T. sirtalis* are applicable to these other species. Garter snakes are smaller snakes, ranging from 1.5-2.5 feet in length. Given their small size, amphibians are their primary food source, but can also eat fish, worms, leeches, and small mammals and birds. These snakes are generally dark in color, with a longitudinal stripe on each side, and some have a stripe running down the length of the spine. They generally have alternating rows of black spots, but in some subspecies these spots merge to form crossbars, and in some cases those crossbars are red, not black. Like the nonvenomous watersnakes, Garter Snakes will also musk when captured.

Milk Snake (*Lampropeltis triangulum*), family Colubridae

Strangely, Milk snakes get their name from an old wives' tale claiming that snakes milk cows (57). These slender snakes are generally 1.5-3 feet in length, and are often tricolored, with red or brown, black, and white or yellow rings. When threatened, these snakes will vibrate their tails, hiss, and strike. There are 8 currently recognized subspecies in the United States, and they inhabit most of the Midwest and all of the East (69). Mice are their primary food source, but lizards and other snakes are also on the menu (57). Their scales often appear shiny to the observer. While Milk Snakes are harmless, several Southern subspecies mimic the highly venomous Eastern Coral Snake. The difference between the two can be remembered through the rhyme “red touch yellow, kill a fellow, red touch black, friend of Jack.”

California Kingsnake (*Lampropeltis getula californiae*), family Colubridae

The California Kingsnake is a subspecies of other Kingsnakes, *L. getula*. Reaching 2.5-4 feet in length, these snakes are known for their ability to eat other snakes, including venomous ones, and are able to do so due to their immunity to the snake venom of other native species (67). Snakes are not their only food, as small mammals, lizards, amphibians, birds, and eggs are all consumed by this species. Kingsnakes themselves are nonvenomous, instead killing their prey via constriction, but will vibrate their tails in an attempt to mimic rattlesnakes and ward off predators. California Kingsnakes generally have alternating bands of brown or black and white or yellow. However, many naturally occurring morphs can be found that alter the banding pattern, but the color scheme remains the same throughout. As the name suggests, this species is native to California, but also occupies portions of the surrounding states, including at elevations over 7000 feet.

Gopher Snake (*Pituophis catenifer*), family Colubridae

There are 7 currently recognized subspecies of the Gopher Snake, and they occupy most of the Western United States (66). Gopher snakes are fairly large, ranging from 3-6 feet in length, and can be quite aggressive, both by striking and by vibrating their tails in an attempt to mimic rattlesnakes (57). The base color is yellowish, with black, brown, or reddish brown blotches on the back. The head generally appears too small for its body. Gopher Snakes are adept burrowers, and will inhabit plains, prairies, or deserts depending on the subspecies. Their primary food source is small mammals, but they will also eat birds and their eggs, and juveniles will consume lizards.

Western Hognose Snake (*Heterodon nasicus*), family Colubridae

Western Hognose Snakes are small, measuring only 1-2 feet in length (57). 3 subspecies are currently recognized, and they occupy the Western portion of the Midwestern United States, with the Rocky Mountains serving as an approximate Western border of their range. These snakes get their name from their sharply upturned snout, and have a light tan coloration with dark blotches on their back. The belly is jet black, with white or yellow blotches. They prefer to inhabit dry prairie areas, with sandier prairies being their favorite. Their diet consists mostly of amphibians and lizards. When threatened, Western Hognose Snakes will flatten their heads, inflate their bodies with air, and hiss loudly, attempting to show hostility and scare off any predators. If this performance doesn’t work, the snake will play dead by rolling on its back, opening its mouth, briefly convulsing, and then lying still.

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