The Embeddedness of a North American Snake in the Wildlife Pet Trade and the Production of Assemblage Biogeographies

J. Anthony Stallins* and Lauren Kelley†

*Department of Geography, University of Kentucky
†Department of Geography, Florida State University

The wildlife pet trade has the potential to threaten the viability of free-ranging animal populations. Yet there are potential benefits from the informal biological knowledge produced by breeders and caretakers for these taxa. How the evolution of a species shapes and is shaped by its embeddedness in the unique and changeable spatialities of the pet trade is also of relevance. To convey these points, we invoke materialist approaches from human geography to construct an assemblage biogeography for hognose snakes (*Heterodon* spp.), one of several North American reptiles in the pet trade. Mixed methods delineated what aspects of hognose biology facilitate their trade, what social and economic sites define their commercialization, and how the snake's natural history is dynamically embedded within them. Interviews with breeders, participatory observations at reptile shows, and content analysis of herpetological Web sites indicated that one of three species of *Heterodon*, western hognose (*H. nasicus*), has characteristics desired by breeders and pet owners. Its smaller size, less dramatic displays of bluff aggression, variability in color, and flexible diet make it more suitable than eastern or southern hognose. The contingencies of dispersal and speciation leading to these life history traits for western hognose are embedded within transitory social networks of breeders operating under sharply contrasting state wildlife regulations. Although contextual, these legal asymmetries and situational social arrangements bootstrap the international trade in hognose. They demarcate a self-organizing horizontal assemblage with the potential to crowdsource production of information and skills of value for conserving a growing number of endangered organisms. *Key Words: assemblage, evolution, pets, reptiles, scale, wildlife trade.*

野生动物的宠物交易, 有可能会危及野放动物族群的生存能力。但我们仍有可能受益于饲主及照护者所生产的非正式生物知识。物种的演化, 及其与所镶嵌的独特且可改变的宠物交易空间性之间如何相互影响, 亦同样具有关联性。为了论证上述论点, 我们将诉诸人文地理学中的物质主义方法, 为北美爬虫类宠物交易中的猪鼻蛇 (学名为 *Heterodon* spp.) 建构凑组的生物地理学。涸合方法描绘了促进猪鼻蛇交易的面向、猪鼻蛇商品化的社会及经济场域特性, 以及蛇的自然历史如何动态地镶嵌在猪鼻蛇身上。与饲主的访谈、爬虫动物展的参与式观察, 以及对爬虫学网站的内容分析, 指出三类猪鼻蛇中的西猪鼻蛇 (*H. nasicus*) 具有被饲主与宠物主人喜欢的特质。它体型较小、较少展现虚张声势的夸张侵略行为、色彩斑斓, 以及具有弹性的饮食, 皆使得西猪鼻蛇较东或南猪鼻蛇更适合被饲养。 散佈与物种生成之历史偶合所导致的西猪鼻蛇生命史, 镶嵌在大幅违反国家野生动物规范的瞬息万变的饲主社会网络关係中。儘管是取决于脉络的, 但上述的法律不对称以及情境式的社会安排, 为猪鼻蛇的跨国买卖进行了牵线。它们界定了自行组织的平行凑组关係, 并具有众包 (crowdsource) 保育增加中的濒临绝种物种数量的资讯创造及技术价值之潜能。 *关键词: 凑组, 演化, 宠物, 爬虫类, 尺度, 野生动物买卖。*

El comercio de especies silvestres como mascotas es una amenaza potencial a la viabilidad de poblaciones animales en su estado natural. Se pueden derivar, sin embargo, beneficios potenciales del conocimiento biológico informal generado por criadores y cuidanderos de estos taxa. Es también relevante llegar a comprender la manera como se desenvuelve la evolución de una especie al compenetrarse con la circunstancia única que representa el tráfico de mascotas, y por sus cambiantes espacialidades. Para expresar estos puntos, traemos a cuento los enfoques materialistas de la geografía humana que permitan construir un escenario biogeográfico para las heterodón o serpientes hocico de cerdo (*Heterodon* spp.), uno de los varios reptiles norteamericanos que son objeto del comercio de mascotas. Con métodos mixtos se llegó a precisar los aspectos de la biología de las heterodón que facilitan su comercio, qué escenarios sociales y económicos definen su comercialización, y cómo se involucran dinámicamente estos en la historia natural de la serpiente. Mediante entrevistas con criadores, observación

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participativa en espectáculos de reptiles y análisis de contenido de sitios Web de carácter herpetológico, se pudo establecer que una de las tres especies de este género, la heterodón del oeste (*H. nasicus*), posee las características deseables para criadores y propietarios de este tipo de serpientes. Un tamaño menor, el despliegue menos dramático de su fingida agresividad, la variabilidad de color y dieta flexible, la hacen más apropiada como mascota que las heterodones oriental y sureña. Las contingencias de dispersión y especiación que condujeron a estos rasgos de la historia vital de la heterodón del oeste están inmersos en las redes sociales transitorias de criadores que operan en contraste agudo con las regulaciones estatales de la vida silvestre. Aunque son contextuales, estas asimetrías legales y acomodamientos sociales específicos permean el comercio internacional de las heterodones. Ello demarca un ensamblaje auto-organizador horizontal que tiene el potencial de saturar la fuente de producción de información y habilidades valiosas para ayudar a conservar un creciente número de organismos amenazados.
Palabras clave: ensamblaje, evolución, mascotas, reptiles, escala, comercio de especies silvestres.

In this article, we describe how the biogeography of a genus of native North American snakes, *Heterodon*, shapes and is shaped by the wildlife trade. It is unique as a biogeographical study in that we account for the social as well as the physical mobilization of these snakes from their evolutionary context and into humanized environments. In doing so, we compensate for the individual weaknesses of traditional ecological biogeography and traditional social constructivist human geography to account for the distribution of biota in an intensively humanized world.

Through qualitative and quantitative methods, we also aim to show how the structure and processes of the wildlife pet trade unify some of the theoretical spatialities and dynamics spanning human and physical geographic thought. We invoke materialist geographies to reconceptualize conservation practices and to illustrate how they are relevant to issues regarding the ongoing erosion of biodiversity. By mapping the breeding, trade, and ownership of hognose snakes, we show how the topology and self-organizing propensities of the wildlife pet trade generate biological information and outcomes of potential conservation relevance. We posit that this crowdsourcing of biology that emerges from the wildlife pet trade should not be entirely vilified but recognized as a potential part of a response to biodiversity loss.

Although we have a healthy skepticism about the benefits of markets, we nonetheless maintain that markets and trading define human culture and are not likely to disappear. Unfortunate as it might be, we also advocate a form of "ark" ethics. Humans are not likely to revert to some idealized Edenic state in which zoological breeding programs become superfluous and the trade in animals for pets disappears. To complement conservation in this less than perfect world, we should consider the full range of our proclivities as organisms, notably biophilia, an affinity for life that motivates many of us to have pets. It is not just the more recently arisen institutional arrangements that demarcate science and conservation biology that matter for life on Earth. It is also our deep history of the day-to-day bonds we have with animals in our immediate surroundings, whether they are dogs, cats, or less domesticated forms of wildlife (Haraway 2008).

For better and for worse, humans have a long record of fusing their biogeography with those of other life forms. Yet little of this history is as globally intensive as the present-day trade in wildlife (Rosen and Smith 2010). Revenues from the legal and illegal international trade in wildlife and their products are estimated to range from $5 billion to $20 billion up to more than $300 billion (Hobson 2007; Engler 2008; Wyler and Sheikh 2008). Wildlife commerce is fueled by the potential for profit and the prestige attached with the consumption or ownership of an unusual animal. Scarcity can also fuel the drive to collect. It can ratchet up prices for rare species and lock in population decline (Courchamp et al. 2006; Angulo and Courchamp 2009). This demand and the nature of communications over the Internet make the wildlife trade one of the fastest growing black markets in the world and a threat to biodiversity (Hobson 2007; International Fund for Animal Welfare 2008; Barber-Meyer 2010).

The reptile pet trade is a large component of this market. Although aspects of the reptile pet trade are overtly illegal and hidden from view, much of the commerce operates legally and in the open through reptile shows and retail pet stores. Schlaepfer, Hoover, and Dodd (2005) estimated that of the 49.5 million individual animals exported as pets from the United States between 1998 and 2002, half were reptiles. Their hardiness and small size make reptiles easy to transport long distances. Yet insofar as the reptile trade can be rightly vilified for its removal of rare tropical species and for its cruelty to smuggled stock (Green 2005; Christy 2009), it also promotes a productive and visible industry built around the benefits of captive breeding, the importance of pet stewardship and education, and, for some, the value of a conservation ethic.

Rather than focus on a tropical reptile in the global trade of wildlife, we characterize the ongoing incorporation of North American hognose snakes (*Heterodon* spp.) in the pet industry. Although tropical species and their transport from Southeast Asia to pet markets in the United States and Europe drive much of the concern over species loss, selecting a native North American snake for study provided more access to the local details about how their trade emerges. Moreover, because North American hognose snakes have entered the pet trade in large numbers only relatively recently, it is a timely opportunity to study the motivations and mechanisms for their adoption. Two other North American snake genera, corn snakes (*Elaphe* spp.) and kingsnakes (*Lampropeltis* spp.), have been intensively collected, bred, and traded for three decades. They are so well established in the trade that it would be daunting to reconstruct the when, where, and why of their emergence in the market. Three species of hognose are found across the United States, although there are several subspecies and active debate as to their taxonomic status (Smith et al. 2003). With distributions ranging as far north as Canada and south into Mexico, these taxa differ in behavior, size, and their capacity for phenotypic variation in color and markings. Such factors, collectively known as *life history traits*, can be as relevant for an animal's incorporation into the pet trade as its rarity (Schlaepfer, Hoover, and Dodd 2005).

In this article, we postulate how the evolutionary history and biological traits of *Heterodon* have shaped its incorporation into the pet trade. This biogeography of *Heterodon* includes the wildlife pet trade itself, however. Individual reptile taxa in the wildlife trade have their own evolutionary history in space and time. They are bounded by biogeographic dimensions that define habitats, breeding populations, and the variability in their characteristics that influence their adoption into the pet trade. But their biogeography is also embedded within an equally complex geometry of legal jurisdictions, digital places, and the human networks comprising wildlife commerce. Our goal in this article is to synthesize a multidimensional or hybrid assemblage biogeography, one informed as much by traditional biogeography as it is by human geography (Whatmore 2002; Campbell 2009).

More theoretically, this article highlights the interaction of relativistic, fluid notions of place and distance with more fixed absolute distances and borders. We invoke material geographies and the concept of assemblages to frame the mixed spatialities and multiple determinations that cohere among the human and nonhuman organisms that make up the trade in hognose snakes (DeLanda 2006; Robbins and Marks 2010; Shaw, Robbins, and Jones 2010; McFarlane and Anderson 2011; Davies 2012). An *assemblage* refers to a collection of contingently arisen heterogeneous elements that retain a distinct material boundedness and an open-ended dynamism that can cohere to produce outcomes or structure. We show how the evolution and present-day biogeography of a reptile genera or species is entangled with—as opposed to being passively incorporated into—the workings of the pet trade. We visualize the "topology" (Whatmore and Thorne 1998; Murdoch 2006; Woodward, Jones, and Marston 2010) of this trade, the form it takes when the scalar logics of traditional biogeography (e.g., Turner, Gardner, and O'Neill 2001) are fused with the more interpenetrating and pluralistic notions of spatialities from human geography (e.g., Leitner, Sheppard, and Sziarto 2008; Kortelainen 2010; Pierce, Martin, and Murphy 2011).

We formally address three questions:

1. How has the natural history of *Heterodon* influenced its incorporation into the pet trade?
2. What types of sites characterize the commodification of hognose?
3. How is the evolutionary history of *Heterodon* mutually embedded in these sites?

We posit that the vertical command and control framework underlying regulation of the wildlife pet trade underutilizes the contingencies of evolution and human sociospatial structures that assemble into the trade of a species. As an assemblage, the trade in wildlife is an amalgam of distances and scales that form a loose but functional aggregate that is more horizontal than purely hierarchical and vertical. It might appear global and seamless by virtue of its final emergent outcome, the procurement and mobilization of animal bodies across international borders. But some of this performativity is embedded within the information accumulated in a reptile's genome and phenome in addition to the human networks, legal jurisdictions, and markets that surround them. Our assemblage approach illuminates a more complex but also a more responsive, if not potentially adaptive, facet of participatory conservation.

Theoretical Background

Embeddedness

Scholars in the social sciences have described the cultural context for how and why some taxa are taken from their historical environments and promoted where

they have not been found previously (Alderman and Alderman 2001; Robbins 2001, 2004; Alderman 2004). Conversely, scholars in the biological sciences have documented the life history traits of species that enhance their likelihood for cultivation and expansion into novel habitats (Hayes and Barry 2008; Fujisaki et al. 2009; van Wilgen et al. 2010). These exchanges and their outcomes allude to the concept of embeddedness.

Embeddedness has several different connotations (Hess 2004). It can imply a tie to a unique location in history or to a physical place. In this usage, embeddedness refers to the legacy of interactions that come to define a site or entity and how they influence subsequent interactions. In contrast, embeddedness in the social network literature characterizes a position within a network irrespective of any actual physical location (Granovetter 1985). Actor network theory (ANT) similarly highlights positionality within an interactive, relational geometry of largely horizontal objects and entities. To comprehend crime patterns, Radil, Flint, and Tita (2010) fused these meanings in their mapping of how the physical locations of gang territories in Los Angeles are embedded within social ties among gang members. Embeddedness in this particular application became a strategy to understand the ways in which different spatialities interact and inform each other. Crime patterns represented an interaction of a spatiality defined by absolute distances demarcating gang territories with a spatiality defined by the social, relative distances among gang members. As we employ it in this article, the description of embeddedness is a way of magnifying or distilling the intensity and context of relationships established through differing spatial representations (Hess 2004; Leitner, Sheppard, and Sziarto 2008).

Some scholars have recognized the mutuality of embeddedness and its inherent link to evolutionary history. *Prunus africana* is a tree that can be repeatedly debarked to produce a drug to treat prostate cancer. In his description of the uses of this plant, Page (2003) argued that looking only at the trees' economic variables misses this key evolutionarily embedded factor that fosters its resilience to extraction. Similarly, for Whatmore and Thorne (1998, 2000) elephant distributions were more than biogeographical. Their distribution also reflected the evolutionarily embedded qualities of elephants that motivate their dispersed representation as digital entities and bodies in zoos. In these two examples, embeddedness denotes a connection to evolutionary history, a reference to the sum or memory of past ecological and environmental interactions. Yet embeddedness is also where this connection is in the present, the place where it unfolds. The embeddedness of *P. africanus* in its evolutionary history contributes to its regrowth of bark, but the tree is also embedded in human networks with their own history and receptivity to ideas and practices of relevance to the sustainability of the tree. Similarly, elephant proximity and place today reflect the evolutionary outcomes that have given this mammal its physicality, its emotional range, and its intelligence. But it is also the context of potential human responses to these qualities that shape elephant distribution in their remaining habitat, in zoos, and in digital media. For the hognose trade, we foreground this mutuality of embeddedness. We describe how the speciation and evolutionary embeddedness of the life history traits of *Heterodon* have shaped its uptake and persistence in the circuits of capital that define its trade. But we also characterize how the hognose moves amid embedded human actors and institutions, with their own ties, histories, informal rules, and wildlife regulatory structures. Our next section highlights the form, or topology, that can arise from this conception of embeddedness.

Assemblages of New Materialism

The social constructivist turn in geography is now more accommodating of material perspectives (Bakker and Bridge 2006; Whatmore 2006; Robbins and Marks 2010). This new materialism circumvents some of the universalizing aspects of the social constructivist turn by allowing nonhuman organisms and the environment more agency. Although this alludes to an affinity with ANT, the intent of new materialism is more descriptive and less inclined to view the interactivity of the world as frictionless flows and placeless, hyperrelational networks (see Bakker and Bridge 2006; Dewsbury 2011; Prytherch 2011).

Materialist geographies have spanned the study of nonhuman organisms such as mosquitoes, bears, elk, and plants and the institutions and individuals among which they are embedded (Bakker and Bridge 2006; Dempsey 2010; Robbins and Marks 2010; Shaw, Robbins, and Jones 2010). Organisms can be mobilized into human spatialities but as active subjects with spatialities of their own. Thus, instead of dissolving all boundaries to conform to a totalizing socially constructed world, new material geographies allow borders to emerge and evolve. Materialist geographies make a place for us to understand the predisposition of life to shape locally distinctive assemblages of entities and

phenomena through their direct agency and through the socially constructed meanings they set in motion. In this light, the production of scale and scalar politics are not activities reserved just for humans (Stallins 2012).

New materialist geographies examine aspects of the world "not to see how it might fit an already known solution, but to see how it is situated as a singular changing field whose activities mark the dynamics as well as the limits of its describability" (Woodward, Jones, and Marston 2010, 272). New material geographies describe configurations of entities that arise contingently, reinforce particular interactions, and then might resolve into other structures or disappear. These assemblages are the "dynamic structure[s] applied to semi-stable socionature configurations and geographies that emerge over time and space" (Robbins and Marks 2010, 181). They are "site ontologies," an "immanent (self-organizing) event space that is differentiated and differentiating, but whose emergent properties also include congealments and blockages" (Woodward, Jones, and Marston 2010, 272). There are no transcendent organizing principles other than the propensity for interaction and to settle into semipermanent domains of transitory meaning and configuration.

Because the material has been reinserted into the more intangible distances and geometries that characterized the social turn, there is a potential for visualization (Simonsen 2004). The assemblages of new materialism can be mapped by evaluating the relative position of entities or sites and their geographic configuration. One can critically trace out these configurations or topologies to explore what makes the actors the way they are and what produces the contingent character of the objects and agents involved. In so doing, the implication of these particular configurations in terms of the range of outcomes might become more visible (Robbins and Marks 2010). The diverse perspectives on scale and spatialities (Marston, Jones, and Woodward 2005; Jones, Woodward, and Marston 2007; Stallins 2012) potentially embedded in an assemblage, however, suggest that a suitable visualization method would have to be able to accommodate a variety of data types (Allen 2011).

Although a visualization of another animal taxon in the pet trade would likely identify similar sites and how they are related, there should also be singularities worthy of description by focusing only on *Heterodon*. Our goal is to articulate these irreproducible contingencies surrounding the incorporation of hognose snakes in the pet trade. At the same time, we also want to distill some of the structural propensities of assemblages that might inform other issues related to wildlife conservation.

Biological Background

The Evolutionary History of *Heterodon*

For many years, herpetologists have disagreed on the phylogenetic and systematic arrangement of genus *Heterodon*. *Heterodon*, along with five other North American snake taxa, are now considered "relict" to emphasize their lack of closely related living relatives in North America (Pinou et al. 2004). Recent genetic analyses support an Asian origin for *Heterodon* (Holman 2000; Vidal et al. 2000). *Heterodon* is postulated to have entered North America via a Beringian land bridge at least 10 to 16 million years ago during the Pliocene and subsequently dispersed throughout North and Central America.

Three species comprise the genus *Heterodon* (Figure 1). Their high intraspecific variation, broad geographic distribution, and correspondence of taxonomic discontinuities with dispersal barriers like the Rio Grande and Mississippi River are supportive of a complex, deep history of speciation for relict North American snakes (Holman 2000). The fossil record indicates that ancestral groups for the western hognose and for the eastern hognose were present in North America during the Pliocene. However, by the end of the Pleistocene, all three present-day species of *Heterodon* were in place, suggesting that North American glaciations played a key role in their origin. The present-day distribution of eastern, western, and southern hognose has affinities to those for other animals impacted by Pleistocene glaciations (Auffenberg and Milstead 1965; Soltis et al. 2006; Fontanella and Siddall 2010).

The sequence of events leading to the present-day distribution of western, eastern, and southern hognose has been synthesized by Eckerman (1996). Southern hognose are thought to be derived from western hognose. During more xeric (glacial) conditions in the Pleistocene, western hognose might have dispersed eastward along the Gulf Coast. Subsequent warming and return of a moist interglacial climate likely isolated these individuals in peninsular Florida and adjacent coastal plain lowlands, where they subsequently underwent allopatric speciation to become southern hognose. Current distributions and the reproductive traits among *Heterodon* species support the idea that southern and western hognose are more evolutionarily proximate to

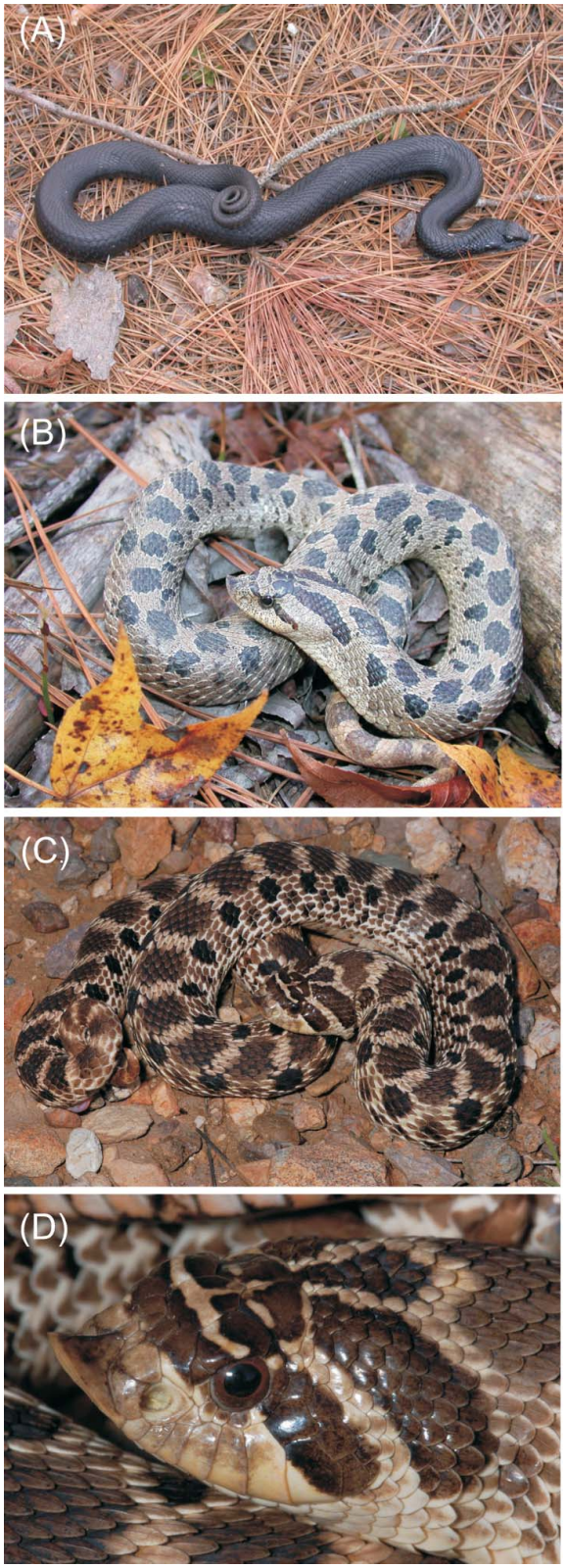

Figure 1. The genus *Heterodon*. (A) Eastern hognose (*H. platirhinos* Latreille). (B) Southern hognose (*H. simus* L.). Photo courtesy of J. D. Willson, University of Georgia Savannah River Ecology Laboratory. (C and D) Western hognose (*H. nasicus* Baird and Girard). Photo courtesy of Troy Hibbetts (http://thehibbitts.net/troy/ and http://blackbeltreptiles.com). (Color figure available online.)

each other than they are to the eastern hognose (Edgren 1961; Platt 1969; Holman 2000).

There are several other distinctive evolutionary characteristics of North American hognose snakes. *Heterodon* are rear-fanged. Rear fangs are used to hold and subdue prey. Although some reactions can be severe, their bite is not considered dangerous (Weinstein and Keyler 2009). Bites are also rare because *Heterodon* have a mild disposition. Yet when threatened, *Heterodon* bluffs aggression and puts on a death-feigning display (Edgren 1955; Gehlbach 1970).

Western hognose are found from interior Canada to central Mexico (Figure 2A). As many as three subspecies of western hognose have been proposed, although their taxonomic distinctiveness is questioned (Smith et al. 2003). The western hognose is listed by the International Union for Conservation of Nature and Natural Resources (IUCN) as a species of least concern, with a widespread and stable population (Hammerson 2007a), although some North American herpetologists have expressed concern over reductions in its former abundance and distribution (Durso 2011). The southern hognose snake (*H. simus*) is also a relatively small terrestrial snake. It has dramatically declined over much of its former range (Figure 2B; Gibbons et al. 2000; Tuberville et al. 2000; Enge and Wood 2002). The IUCN classifies this species as vulnerable (Hammerson 2007b) and it is considered by the U.S. Fish and Wildlife Service (USFWS) to be a species of concern (USFWS 2011). The eastern hognose snake (*H. platirhinos*) ranges over eastern North America (Figure 3). It is the largest of the three species of *Heterodon*. They are not listed by the International Union for Conservation of Nature and Natural Resources, USFWS, or the IUCN, but they have experienced declines, particularly in the Northeast, where habitats have become urbanized.

The Reptile Pet Trade

The trade in snakes for pets is driven by novelty. Breeders seek to produce "morphs" that express novel colors and markings. Rarity of physical appearance is highly prized and some newly bred or recently discovered morphs can sell for thousands of dollars (Tapley, Griffiths, and Bride 2011). Prices drop as morphs become more common and new morphs appear. Breeders work to tease out unusual patterns and colors and create captive bloodlines that they can use to produce a desired morph. The offspring are either sold for profit or traded for other snakes to further the bloodline. Place specificity, the look or vigor of individual reptiles from

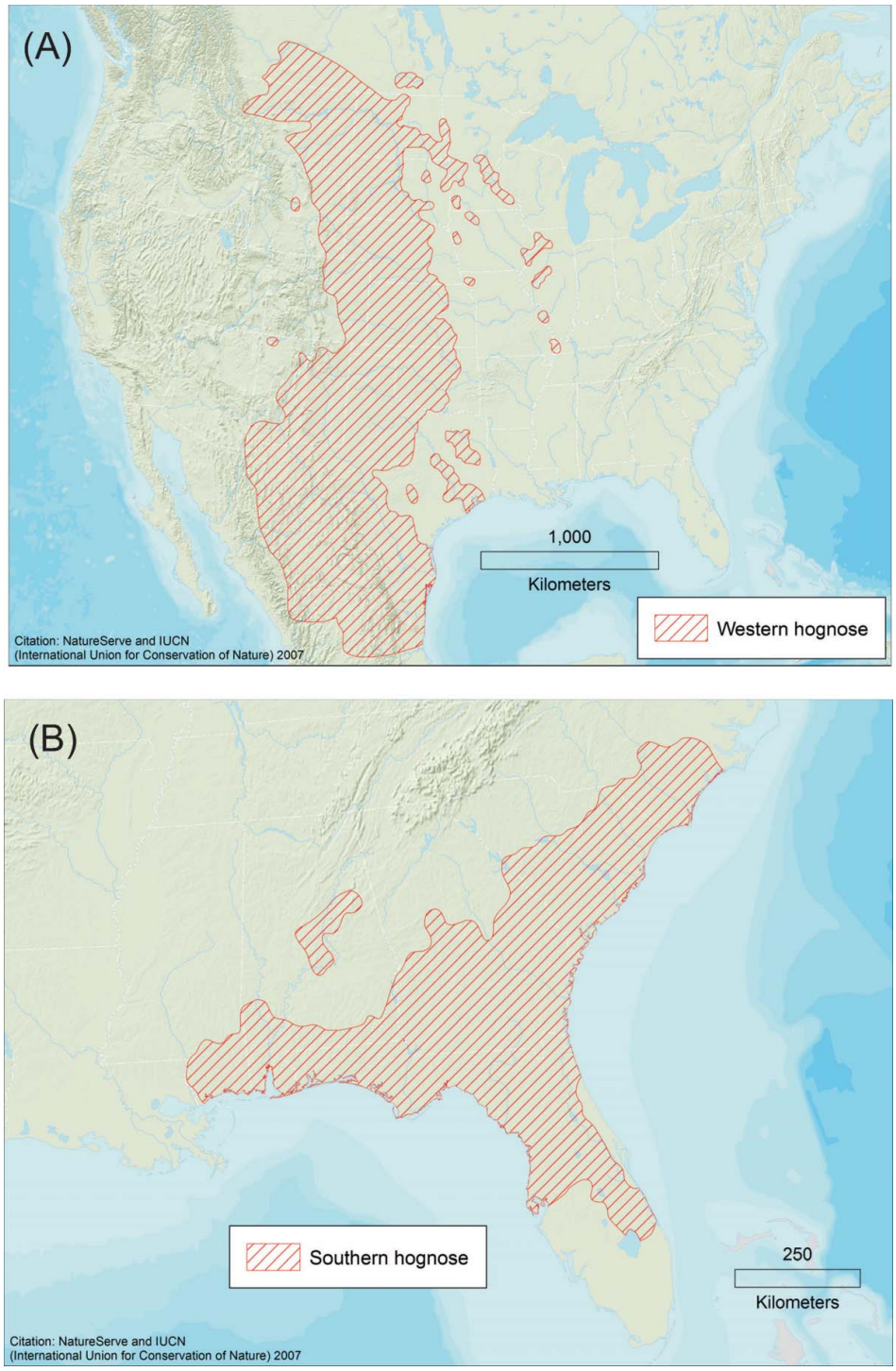

Figure 2. Distribution of (A) western and (B) southern hognose snakes. (Color figure available online.)

specific locations, can attain cult status among breeders and collectors.

Breeders are dependent on the life history traits of their stock. Phenotypic diversity, the propensity to express a range of colors and geometries of markings, is desired. The presence of multiple species and subspecies in a genus enhances this potential. Snakes taken into the trade must also be "easy feeders" that adapt to captivity. Temperament is also important. Contrary to many assumptions about snakes, different species have different "personalities." "High-strung" species that bite readily are often undesirable.

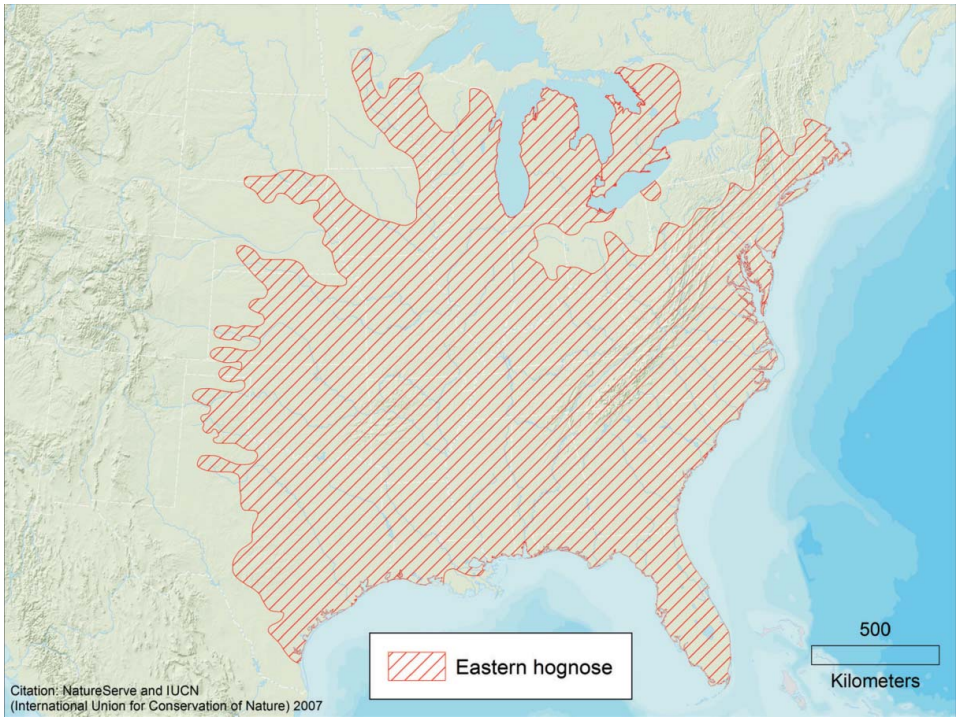

Figure 3. Distribution of eastern hognose snakes. (Color figure available online.)

Methods

To characterize motivations for investing in hognose snakes and to identify the sites of their conversion to pets, participatory observations and interviews were initiated at reptile shows. One of the world's two largest shows occurs in Florida each year, the Reptile Breeder Expo in Daytona, Florida. This is an international show that serves professional reptile breeders and collectors. We attended this show as well as several smaller, retail-oriented shows held in Florida for the general public.

Because *Heterodon* vendors at shows have limited time, phone interviews and e-mail communications were used to gain more detail from respondents and to cross-check information. Because commercial activity also unfolds over the Internet, we employed content analysis of herpetological Web sites that offered insights into the motivations for bringing hognose into the pet trade. Thirty breeders were interviewed. Close to seventy online sites breed or sell hognose in the United States, suggesting that our interviews canvassed roughly half of the entire domestic trade. Many of our interviewees were knowledgeable, influential professional breeders with a long history (thirty years in one case) of working with hognose.

The list of sites in the hognose trade provided a framework for the construction of a data set amenable to quantitative visualization. Our visualization alludes to Whatmore and Thorne's (1998) description of a topology of wildlife, as well as the assemblage topologies referenced by Murdoch (2006) and Woodward, Jones, and Marston (2010). Here, however, we deploy quantitative methods. Using the sites identified in interviews as a guide, we codified the biogeographical, regulatory, and commercial facets of the trade in *Heterodon* for each of the lower 48 states (Table 1). Once assembled, this data set was visualized using a nonparametric ordination technique, nonmetric multidimensional scaling (nMDS).

In nMDS, these state data were first converted to a matrix of similarity distances. Once in this format, state-to-state comparisons can be made even though their similarity is derived from absolute measures (the presence or absence of western hognose or the annual count of reptile shows) as well as more relative criteria and distance (the ranking of the harshness of laws governing native reptiles). Subsequently, states might be far apart in terms of absolute geographic distances but close to each other in terms of their multivariate similarity distance. The next step in the nMDS algorithm is to rank paired state similarity distances. They are then iteratively shuffled in a Cartesian coordinate system until their graphical distances correspond to the rank order of their similarity distances. The final output is a graphical visualization of the observational units (states) where distance between them defines similarity in variables describing the hognose trade. Bray–Curtis distance was used as the similarity distance metric.

Table 1. Nonmetric multidimensional scaling variables defined for each state

Variable	Data type, coding, and sources
Reptile shows	Counts based on 2011 online reptile show calendars
Number of breeders	Counts based on tally of seller and breeder Web pages
Law severity	Categorization of laws governing hognose based on online legal sites (1 = least restrictive, 4 = very restrictive)
List protection	Presence or absence of listing on state threatened or endangered species inventories
Blanket ban	Categorization based on severity of blanket ban affecting reptile pet trade (1 = least severe, 3 = most severe)
Collection sites	Presence or absence of any collection locations for western hognose based on respondent information
Heterodon species	Presence or absence of eastern, western, and southern hognose (three separate variables)

A final best solution is a function of dimensionality and stress. Stress is a measure of the disagreement between similarity distances and graphical distances. High-dimensional solutions might minimize stress but lose visual interpretability with a high number of axes. Low-dimensional solutions might be easier to interpret, but stress reduction might not be minimized. The software used for this technique, PC-Ord (McCune and Mefford 2011), performs multiple runs of nMDS to select an optimal solution. Scree plots and Monte Carlo randomizations were also employed to gauge whether stress reduction was significantly different from values obtained from randomization of the analysis data. The final nMDS solution was rotated using a varimax rotation. This maximized the variance in the data along the first and succeeding orthogonal axes and allowed us to interpret axes based on nonparametric correlations of site axis scores with the original state-level variables.

Our nMDS visualization mapped descriptors for the hognose trade to facilitate interpretation of its dynamics and structure in relation to the contingencies in state laws and the evolutionarily constrained geographic distribution of *Heterodon*. It reduced the dimensionality of univariate descriptors of the pet trade (Table 1) to better discern the similarities and differences among states. Our nMDS output was also useful for cross-checking the information communicated by respondents in interviews.

Results

Evolutionary Embeddedness of *Heterodon* and the Reptile Trade

Respondents identified several characteristics of hognose snakes that make them attractive to the reptile pet trade. First, many hognose snakes will readily and frequently breed in captivity. They are docile and will not bite, but their individual bluff displays of aggression give them distinct personalities. *Heterodon*'s relictual rear fang anatomy added an element of danger, however slight. Their relatively small size compared to other snakes in the reptile pet trade makes hognose easier to care for and ship. Because of their large north–south latitudinal distribution in the wild (Canada to Mexico), hognoses can tolerate cold weather shipping conditions better than many reptiles.

All three species of *Heterodon* were encountered at reptile shows and on online reptile sites, but the western hognose was far more abundant in the trade than any other hognose species. Respondents emphasized the appeal of the more strongly upturned snout of westerns as compared to the eastern hognose. Western hognose are also the smallest of the native North American species, almost toy-like. One respondent suggested that the diminutive, jewel-like size of western hognose makes them a "snake for women." Nicknames such as hogs and hoggies underscore this appeal.

Yet according to breeders, the major factor as to why western hognose comprise almost the entire hognose market relates to feeding behavior. Toads, frogs, and other amphibians are the dominant food source for eastern and southern hognose in the wild. As these cold-blooded prey are not going to be readily available as food year-round in many locations, they would have to be bred or purchased from specialized biological supply companies, thus increasing the cost of owning a hognose. By contrast, western hognose are flexible feeders. Breeders discovered that western hognose in captivity can be trained to eat mice readily purchased from pet stores instead of toads. Western hognose will feed on amphibians opportunistically in their arid home range, but their main prey items can also include small mammals. By contrast, eastern hognose are less likely to take to a diet of mice. According to several breeders, they might even develop a liver disease when conditioned to take a mouse diet.

The variability in color and markings within the subspecies of western hognose was also a quality highly desired by breeders, as this enhances the potential of

discovering new morphs. Although lacking formal subspecies designations, eastern hognose have perhaps an even larger amount of diversity in colors and skin patterns than western hognose. But the larger adult size of eastern hognose and their less flexible feeding requirements make the western species more workable as a breeder and more suitable for the pet trade.

The Sites of Embeddedness for Hognose

Respondents identified six key sites in the event space of the hognose: collection locations, phylogeographic networks, reptile shows, Web sites, the social networks among breeders, and legal jurisdictions. These are the locations where the evolutionarily derived characteristics of hognose species become embedded in the assemblage of contextual relationships, communications, and exchanges in the reptile pet trade.

Collection Sites. Interviewees identified Texas, New Mexico, Colorado, and Minnesota as states where western hognose were common and available for collection in the wild. Starting in the early 1990s, 1,000 to 2,000 western hognose were collected from specific locations in these states and sold for about ten years. This collection seeded the trade in hognose and allowed the market to take hold and sustain itself. Collection sites also provide a genetic source for novel morphs. By crossing established lines in captivity with unusual morphs collected in the wild, breeders can produce hognose with new colors and skin patterns.

Phylogeographic Networks. Breeders track the lineage of their snakes based on physical appearance, or phenotype. Once inferred, breeding can be strategized to enhance the numbers of a morph or to try to produce a morph new to the market. These phlyogeographic networks are a second site of relevance for the hognose trade. As a spatiality, phylogeographic networks delimit the lineage of what morphs appeared where, when, and under what circumstances. Compared to the neat hierarchical mappings that typify phylogeographic maps in historical biogeography, biological relatedness in the hognose pet trade is more of an amorphous, discontinuous network. Contingencies where snakes are shipped, in the genetics of individual snakes, and in the practices of breeders and buyers defies any crisp dichotomous mappings of phylogeographic descent. Hognose breeding operates simultaneously among different breeders and in relative privacy to keep the development of a new morph a trade secret. Strategies adopted by breeders could change suddenly depending on the outcomes of other breeders. Morphs might be in demand one year, only to be overly abundant the next.

Table 2. Spearman's rank correlation coefficients for nonmetric multidimensional scaling coordinates with state-level descriptors from Table 1

State descriptors	Axis 1 (x)	Axis 2 (y)
H. nasicus native	**–0.72****	–0.09
H. platirhinos native	0.35*	–0.05
H. simus native	0.39 **	–0.17
Reptile shows in 2011	**0.76****	**–0.62****
Number of breeders	**0.53****	**–0.80****
Law severity class	–0.35*	–0.29*
List protections	**–0.61****	–0.14
Blanket ban	0.04	0.19
Known collection sites	–0.26	–0.29*

Note: Informative correlations highlighted in bold.
*$p \leq 0.05$.
**$p \leq 0.01$.

Consequently, a timeline best represented phylogeographic relationships in the hognose trade (Table 2). All of the predominant commercial morphs to date were developed in the western hognose. Their morphs entered the market through wild-caught individuals, often coming from Texas. Many morphs were also captive bred. One of these new western hognose morphs emerged in Germany from captive stock originally from North America. Yet even with the supposedly controlled environment of targeted breeding, surprises are common. Morphs are not always easy to identify in newly hatched snakes. Happenstance encounters between breeders and people who find unusual-looking snakes in the wild were another avenue by which new morphs have entered the trade.

Breeder Social Networks. Because they need to be certain of the genetic potential and legal background of snakes they acquire from other individuals, breeders rely heavily on their social networks. Trust is a key element defining membership in a network. One respondent identified close contacts with breeders in seven states scattered across the United States and that "it's important to have really good friends that you trust in the trade so that you know the genetics of the animals you get from them. . . . Reputation is everything." Although many of the larger breeders alluded to their own carefully kept records, there is concern in the breeding community that if careful records are not kept, strategic breeding might not be possible. But with a tightly knit word-of-mouth network, breeders are able to

self-police and marginalize "sloppy breeders." There is also a low tolerance for illegal activity or fraudulent sales over the Internet: "If someone is known to be doing bad business, it can get hard for them to work with people within the network, they can be ostracized." Additionally, there are online forums for rating reptile vendors such that "the reptile community polices itself to prevent bad business and illegal activity that makes them all look bad. Word gets out when you're bad business." Nonetheless, these social networks can be exclusionary and challenging to access. Secrecy can increase profits with the introduction of a new morph. These social networks also evolve and change over time and might even include individuals from law enforcement and zoological centers.

Reptile Shows. In 2011, there were nearly 200 reptile shows in the United States. Reptile shows were deemed important sites by breeders and sellers because of their potential for profits. Small and frequent shows target end-of-the-line buyers. These are pet owners who will not breed their purchases. Breeders might be indirectly dependent on these shows, however, as it is here that a large volume of their snakes can be sold. These could be morphs that are no longer fetching a high price and would require upkeep when resources could be directed toward breeding a new line. Then there are large shows that do not focus on the novice reptile owner, like the annual National Reptile Breeder's Expo in Daytona Beach, Florida. The public attends these shows, but the commerce here revolves around professional breeders and international collectors in a trade show environment. Arrangements for large-volume purchases are often made at these venues.

Herpetological Web Sites. Many respondents identified the critical role of the Internet in the reptile pet trade. Web sites allow breeders to reach more customers without the costs of transportation to a show. The Web also serves as a forum where breeders exchange information and arrange private purchases. Before the Internet, people became learned about reptiles and captive breeding face-to-face through herpetological society meetings. Now, the Internet, according to one breeder, "has done wonders for reptiles that were little known; it educates the public that the animal exists." Breeders, however, vary in their dependence on the Internet. One respondent noted that 95 percent of his hognoses are sold over the Internet. Others reported a more equitable split between online sales and reptile shows. Some respondents reported that they use Web sites solely for networking and do direct sales to interested parties using carefully vetted personal e-mail lists. The Internet can also allow breeders and buyers to sidestep state-to-state permitting requirements. The geographic location of breeders is in some cases unavailable from their Web site. Online sellers often require out-of-state buyers to assume all responsibility for rules and regulations governing shipments of their purchases.

Legal Jurisdictions. Each state has its own laws applying to the collection, breeding, and sale of certain reptiles. Some states have no hognose-pertinent regulations, whereas in others the collection, possession, and sale of hognoses are highly restricted. Colorado, for instance, strictly regulates the number of western hognose that can be collected from the wild. Sale and transportation across state lines is prohibited. In other states, it is easier to do business. Texas was identified as having the most lenient captive reptile laws. To collect from the wild or to sell or barter legal reptiles in Texas, proper nongame permits must be obtained and certain recordkeeping practices must be practiced. As long as permits and licensing are maintained and collection numbers are documented each year, breeders can conduct business from this state.

Respondents were unified in their recognition of the many gray areas regarding which states allow possession, sale, and transport of certain reptile species. It was widely asserted that there is a lack of clarity as to the laws that exist on paper and the regularity of their enforcement. Although federal and state laws can be found online, and Web sites compile this information specifically for the reptile pet trade, how to work across different states and remain legal can be ambiguous and challenging to decipher. At the same time, some breeders and sellers have learned to navigate these legal jurisdictions. They know where the laws are enforced and not enforced and what paperwork needs to be done to stay legal. These individuals are able to exploit the legal asymmetry among states to leverage an advantage in the conduct of business.

nMDS Visualization of the Hognose Trade

Two nMDS dimensions, or axes, were selected as optimal. Stress reduction was significantly greater than stress reduction for randomized ordinations of the data ($p = 0.04$, $n = 249$ Monte Carlo permutations). The first axis, the horizontal *x*-axis, was significantly correlated with whether or not *H. nasicus* was native in each state (Table 3). The number of hognose breeders and

Table 3. Western hognose phylogeographic morph timeline (all dates approximate)

Year	Morph
Mid-1990s	Pink pastel morph found near Tokio, Texas
	Orange albino found in New Mexico
	Hypo albino hatched in captivity from wild-caught gravid female
	First line of jungle morph from wild-caught gravid female
	Tigers or banded patterns appear through captive breeding
	Leucistics develop from wild-caught gravid female
	Axanthics originate with unknown hobbyist from captive-bred clutch sold to breeder
2004	First Anaconda, captive breeding
	Snows, captive breeding
	Caramel albino, captive breeding
	Toffeebelly, captive breeding in Germany
	Supercondas, captive breeding
	Mocha morph, wild-collected juvenile
	Spider morph, wild-caught gravid female
	Second line of banded morph appears as result of captive breeding
	Lavenders, captive breeding
2008–2009	True hypos, including smoke hypo, captive breeding
2010	Bengals emerge as codominant morph, captive breeding
	Jungle morphs, another line of axanthic

the degree of legal protection of *H. nasicus* were also significantly correlated. In the nMDS scatterplot, states farther to the right along the *x*-axis do not have western hognose as a native species. Those to the left have native populations of western hognoses. Conversely, laws become more lenient to the right of the first axis and more stringent to the left. The second axis in the vertical *y* dimension expressed significant correlations with the number of breeders and the number of shows.

The relative distances among states in the nMDS scatterplot as well as information from interviews and Web sites suggested that the states formed six clusters (Figure 4). The cluster of states in the left center of the scatterplot were considered locations well suited for potential collection. They correspond to where *H. nasicus* is native and where there is some legal protection in place, although it does not entirely limit breeders and shows. A second cluster of states was positioned along the center of the *x*-axis. Western hognose are not abundant in these states. These have a range of legal protections but with overall little commercial activity of *H. nasicus*. States having a large number of reptile shows formed several clusters. Because of higher counts of breeders and trade-oriented reptile shows, a high commercial activity cluster was demarcated in the lower middle right of the scatterplot. Florida, California, and New York fall in this group and likely represent gateway states to international trade. Texas can be considered a part of this group but, given its importance as a collection center and the leniency of its laws regarding commerce in reptiles, it is more of an outlier and designated as a single-member cluster. Two states, Kentucky and Ohio, stood out for their high number of retail trade shows that sell mainly to pet owners. According to one interviewee, these states have active state and local herpetology societies that support end-of-the-line retail shows for the general public. Lastly, Colorado and Montana were repeatedly identified by respondents for their strict regulation of western hognose. They stood apart in the nMDS scatterplot and formed their own cluster.

Discussion

Taken as a whole, the state clusters and their positions within the final nMDS scatterplot represent the embeddedness of *Heterodon* in its evolutionary history and within the contingent array of sites that define its trade. It is a quantitative encapsulation of an assemblage geography, a topology of the trade in *Heterodon* at the state level. Our qualitative descriptions of the trade in *Heterodon* provided narratives that confirmed the geometry of this topology. They provided a grounded explanation for the final arrangement of states in their hognose trade space. For example, Colorado and Montana were repeatedly identified by respondents as having strict regulation of western hognose. These two states subsequently appear close together in the nMDS scatterplot. Respondents also communicated the importance of gateway states that have a large number of breeders and large, trade-oriented reptile shows. A high commercial activity cluster of three states (Florida, California, and New York) emerged in the nMDS scatterplot. These states are bridges to the international trade in hognose. Texas could be considered a part of this cluster but, given the respondents' repeated identification of important collection centers in the state as well as the leniency of its laws regarding commerce in reptiles, we designated Texas as an outlier and our only single-state cluster.

The characteristics of *Heterodon* that breeders and vendors identified as relevant to its success in the pet trade had plausible linkages to evolutionary and

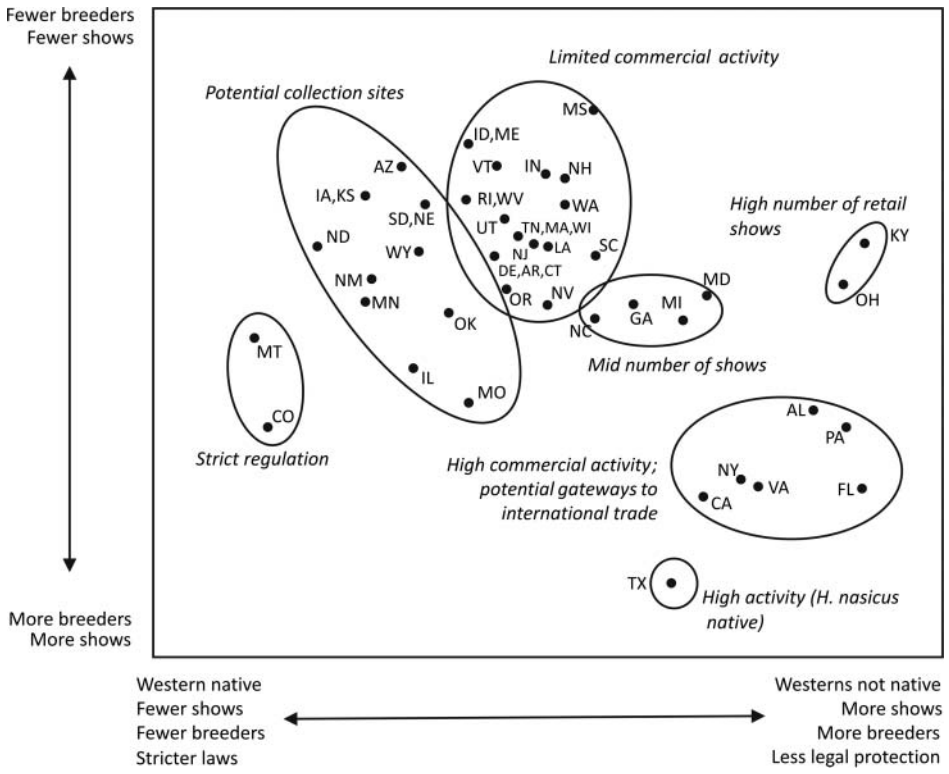

Figure 4. Nonmetric multidimensional scaling scatterplot of U.S. states based on data in Table 1.

ecological mechanisms. The small, "cute," nonthreatening body size of the western hognose was one reason for its desirability over other hognose species. Reptiles have a strong capacity for morphological plasticity. Changes in climate can lead to the selection of new body size (Millien et al. 2006; Canale and Henry 2010). The diminutive size of the western hognose could be derived from its evolutionary exposure to the more arid and continental climates of its interior North America distribution. Unlike the trend for mammals, warmer temperatures and greater moisture levels like those that prevail in the eastern United States have been associated with increasing body sizes in North American snakes, although there are likely to be more complex ecological or biotic controls for individual genera and species (Mousseau 1997; Ashton and Feldman 2003; Olalla-Tárraga, Rodriguez, and Hawkins 2006). Because there are some questions about the applicability of general body size–climate rules to reptiles (Watt and Salewski 2011), food availability might actually play a greater role than climate in shaping body size (Boback 2003; Jessop et al. 2006).

Although the feigned displays of aggression contribute to the popularity of hognose in the pet trade, this behavior differs in intensity among hognose species, an observation made by *Heterodon* breeders as well as a long line of herpetologists (Edgren 1955; Durso 2011). The western hognose puts on a less elaborate display when threatened than does its eastern relative. Eastern hognose have a very dramatic repertoire of flattening their head like a cobra, opening their mouth, hissing loudly, defecating or regurgitating food, and then playing dead. These behaviors are so pronounced in eastern hognose that their owners might feel revulsion and fear. Reasons for these interspecies contrasts in bluffing are not well understood (Gerald 2008). A diet rich in toads might have coevolved with bluff displays in *Heterodon*, however (Gehlbach 1970; Durso 2011). *Heterodon* have acquired tolerance to bufotoxins, a variety of chemicals that occur in the skin glands of toads. These toxins function as stress hormones that might latently activate displays of bluff aggression and death feigning. Consequently, *Heterodon* with predominantly toad diets like the eastern hognose might have more vigorous displays, although the physiological mechanism has yet to be elucidated (Durso 2011).

The strongest evidence for the embeddedness of evolution in the hognose pet trade relates to feeding preferences, however. The drier climates experienced by western hognose in the central and southwestern United States might have predisposed it to feed on small mammals, ground lizards, and prey other than amphibians. Food availability in general would be less consistently abundant where drier conditions and

longer intervals of time could elapse between rainfalls. This dietary flexibility would have also facilitated the eastward dispersal of the ancestral western hognose population that underwent allopatric speciation to become southern hognose.

In sum, although eastern and western hognose each have considerable variability in coloration and patterning, the evolutionary selection of body size, bluffing behaviors, and feeding plasticity in western hognose has allowed them to become the market species of choice. Had not a western species and subspecies of *Heterodon* evolved these particular traits, the trade in hognose might not have otherwise developed as it has. Yet as Lorimer (2010) has similarly described for humans and elephants, the hognose has a far larger biogeography than what might be mapped from this evolutionary point of view. Western hognose are embedded in a contingent array of reptile shows, social networks, digital information, and legal landscapes. They are distributed and remade through the embeddedness of breeders in a social network, whose livelihoods depend strongly on the structure and coherency of these networks. "In reptile breeding, the network is everything," observed one respondent. Breeding programs are also embedded in a legal framework where the interstitial spaces formed from the differences in state laws matter as much as any single state code. We postulate that this dynamism, or productivity, of the hognose trade resides in its mash-up of spatialities. These spatialities originate out of present-day hognose biogeographic distributions and the evolutionary distances demarcating taxonomic relatedness and behavioral contrasts among hognose species. They also emerge out of the access and connectedness contained in social networks, as well as the relative distances socially constructed through the qualities perceived in the hognose. Yet within such a heterogeneous assemblage, there is a coherency, a propensity for tasks related to hognose breeding and selling to unfold with a degree of predictability.

On the other hand, this assemblage of embedded spatialities also has a transitional, contingent character. Change is the norm. Embeddedness is not static, either for the human networks or for the genetic and phenotypic character of individual hognose snakes. For example, a respondent noted that in the early days of the trade the reptile network was small and navigable because there were fewer people involved and they all knew each other. But because of the Internet, the trade has "spread out." With more interest in breeding and the ready availability of animals, the trade has expanded to include novices who might not engage in some of the informal rules that guide breeding. Consequently, as more and more breeding takes place, the biogeographic embeddedness of the western hognose might become obscured. Relationships between a snake's evolutionary past—its occurrence in a particular habitat and geographic location—and its present-day appearances and meanings can diverge. For example, the Okeetee corn snake was once the name given to distinctively patterned corn snakes that could only be collected around the Okeetee Hunt Club in South Carolina, the site where they were first found. With intensive, undocumented breeding over a period of years, an Okeetee became less a place and more a generic color pattern as its morph became popular (Love and Love 2005). Such an outcome could occur with hognoses as the trade matures, and there is already discussion about how to maintain the integrity of breeding lines to retain their place specificity.

Contingency was also implicit in the hognose trade in that new morphs can pop up at random or simply appear on the doorstep of a breeder in the form of a wild-caught individual. They are not always the outcome of a long and targeted breeding effort. Self-governance in the reptile trade also has a contingent, self-organizing propensity. The informal rules of good business among participants in the reptile pet trade were not taken from a prefabricated guidebook on snake breeding. Instead, they were improvised and arose from unique contingencies and will continue to evolve as laws change, morphs emerge, and biotechnology and Internet communications modify the context of their work.

Our characterization of this assemblage biogeography for hognose snakes evokes ones described by Shaw, Robbins, and Jones (2010) and Robbins, Farnsworth, and Jones (2008) for mosquito abatement practices in Phoenix and in Tucson. Each practice evolved out of the mosquito's material engagement with the world around it. Abatement practices in Tucson sought out the mosquitoes' breeding places, the locations holding water to support eggs and larvae. Although there is contingency in where eggs are actually deposited, they are contained with the propensities of an evolutionary trajectory, genetic potentials, and the life history strategies of the mosquito. Abatement becomes more of a horizontal process. It tries to see the world on the level of the mosquito. The abatement practice in Phoenix was more vertical. It sought to suffocate the insect by blanketing all surfaces with chemicals, both in homes and from the sky, as a command and control attempt to eliminate the mosquito.

The trade in *Heterodon* has analogous horizontal and vertical counterparts (Jones, Woodward, and Marston 2007). The vertical one is top-down conservation regulation. It is driven by representations fixed to market economics, international trafficking, and command and control approaches to conservation enforcement. The assemblage we have described for *Heterodon* is more horizontal. It is more inclusive of context, self-organization, and the mutual embeddedness of evolutionary history within human practices and their spatialities. As we consider next, this horizontal assemblage can potentially inform the frameworks that attempt to regulate them. It could also have implications for the viability of the organisms that constitute them.

The Production of Conservation via Biogeographic Assemblages

One of the criticisms of material assemblage geographies is that the emphasis on the contingency of their character will amount to endless description and an unfortunate reawakening of the idiographic impulse to catalog (Robbins and Marks 2010; Allen 2011). We posit, however, that the details of their description allude to the contextual, adaptive, but nonteleological properties they possess. As an example, the contingent and transitional arrangements comprising the social networks of breeders and collectors might actually be conducive for developing new morphs. The contingent, if not unstable, arrangement or topology of sites in the reptile trade acts as a diversity "roulette" by multiplying the range of possible scenarios for breeding new morph colors as well as the permissible geometries of the trade itself. It is because of the heterogeneity in state legal contexts and in the permutations of communication and exchange that can develop through the Internet that the reptile pet trade acquires the self-organizing, "immanent" properties that define material assemblages.

Breeders are well aware of these assemblage properties and their potential productivity. From their point of view, policies and laws regulating the wildlife pet trade should become more participatory or generative (i.e., horizontal) instead of the top-down vertical implementation of conservation enforcement. Several respondents noted that breeders participating in the herpetological pet trade are often the first to develop and disseminate highly refined modes of husbandry. Even details about the care and breeding for common species, like the hognose, were unavailable until pet hobbyists incorporated these species into their networks. Breeders might also be the best experts for information about the numbers of species in captivity and estimates of how many are being removed from the wild (Schlaepfer, Hoover, and Dodd 2005).

Another argument made by breeders as to the productive value of a more horizontal, participatory approach to conservation centers around their opinions about zoos. In their perspective, zoos might not have the resources or the distributed responsiveness to breed the diversity of species that are faced with extinction in the wild and to strengthen these numbers to ensure effective assurance colonies for the future. As an example, the market for turtles as food in parts of Asia led to concern about a worldwide collapse of turtle abundance and diversity. It forced professional conservationists to rely on serious hobbyists for assistance in providing homes to turtles in need of protection (IUCN 2009). Experienced pet keepers have also been called on to house and breed rare invertebrates, birds, amphibians, and fishes in cooperation with zoo, government, and museum-sponsored conservation initiatives. Yet this rarity is a basis for another criticism of zoos made by reptile breeders. One interviewee put forth that "Zoos won't breed captive rare or endangered species because they only want to keep their zoo population stable, not growing. Rarity is important to get people in the zoo door." Indeed, birth control and euthanasia are practiced at zoos (Kaufman 2012). Thus, diversity in the motivations for breeding might be desired, if not necessary, to maintain larger, safer, viable populations and to meet the demand for knowledge about organisms that might soon become endangered.

In a sense, breeders and participants in the reptile pet trade enact a form of citizen conservation whereby conservation work becomes distributed and horizontal as well as vertical and top-down. Such horizontality is a locally emergent, experimental process that might not be possible to emulate solely by decree or regulation. An entirely vertical, cops-and-robbers outlook on the wildlife pet trade—although it certainly has necessary and beneficial components—might not be sensitive to the material structures and practices that allow these horizontal conditions to flourish and thus obscures solutions to the very problems addressed (Hobson 2007; Robbins et al. 2009). Yet breeders and owners of animals in these horizontal assemblages would need to adhere to stricter standards because indiscriminant collection of wild-caught organisms can indeed deplete a species (Belzer and Steisslinger 1999; Webb, Brook, and Shine 2002). Horizontal participatory elements of

conservation would require a much more systematic recordkeeping system. Findings and outcomes would need to be publicly communicated to potentially produce greater conservation impact. Yet this systemization could, by its very nature, instill a more vertical structure to the trade and eliminate the contingent horizontality that motivates network formation and the enthusiasm to produce and exchange information.

The production of conservation can have an ethical component as well. From an animal welfare perspective, horizontal assemblages might reduce some of the undesirable impacts of large box retail pet stores. For example, the success of a few reptiles sold in large quantities in pet stores makes it appear as though such creatures are easily maintained in captivity, when in actuality their upkeep might be highly complex. Green iguanas grew in popularity because large pet stores gave the impression that their upkeep was simple and that they would grow to large, impressive sizes quickly. Consequently, animals that actually require considerable skill to maintain were purchased by people who were not qualified to care for them. Green iguana rearing, however, eventually came to be informally guided by the knowledge of dedicated breeders and owners who had less of a financial stake in the high-volume sale of a species. In a similar example of a more humane, horizontal approach to the trade in pets, many large retailers now sell foster dogs and cats procured through ties to local community animal shelters (PetSmart 2011). They no longer sell dogs and cats bought from unreliable sources or from breeders who are increasing the abundance of animals without regard for their welfare. Through a transitory but persistent horizontal assemblage of retailers, shelters, and foster parents, veterinarian-certified neutered dogs and cats are given to owners who undergo an informal screening process and postadoption follow-up.

In sum, the details of the hognose pet trade distilled in this article provide a template for characterizing the assemblage biogeographies of other organisms. Life forms have a biogeographical topology arising out of interactions across ecological, economic, and social sites. Moreover, characterization of these sites and their topology through qualitative and quantitative methods can permit one to assess or visualize relationships among the entities under study and to potentially make policy recommendations. For example, our nMDS topology of the hognose trade identified a cluster of potential collection states, locations where western hognose might occur and where regulations governing *Heterodon* are less strict. Because these states could harbor new morphs, small or isolated populations of hognose in these states might be more readily threatened by collection and local extinction in the wild.

Our assemblage biogeography for *Heterodon* also illustrated how organisms that travel through commodity chains invoke social constructions over what locally defines whether or not they belong or have value. A more novel consideration, though, is that these constructions are shaped by an organism's evolutionary history and their capacity to thrive in different environments. Invasive species and the assemblages they form with humans exemplify this embeddedness. An assemblage biogeography for an invasive species would include not only its evolutionary history and its genotypic and phenotypic plasticity down to the level of individual organisms but also the simultaneity of sites that promote invasion or seek to eliminate or restrict this species.

Finally, our findings convey that the cartographies of the Internet and social networks are relevant for the biogeography of many organisms. Analogous to dispersal, dissemination and access to information about an organism is what gives it ontological status and the identity associated with its local occurrence. Organisms are not only just out there in the wild; they are also realized via human ecologies of knowledge. Pathogens such as flu viruses or the bacteria that cause cholera come to mind as examples that might apply here. Their detection by our various technologies, the institutionalization and communication of warnings, and the routes of exposure extend traditional biogeographies of pathogens well beyond their ecological, nonhuman reservoirs.

These generalities go beyond the truism that humans and the nonhuman living world are not independent. Indeed, there is something commonsensical in the observation that an organism's biology, evolutional history, and life history traits shape its incorporation into human networks. That networked people are acting on the evolution of species, even while the evolved characteristics of the species are acting on the network, is also somewhat self-evident. As we have detailed for the hognose, however, there are many contingencies associated with the evolution and distribution of any organism brought into the human circuits. There are also contingencies with how humans encounter these organisms and with what extrinsic and intrinsic values they are assigned. Biology and life, inclusive of humans, operate via this radical contingency. Any general dynamics or principles we imagine for them will always have a narrative that can be extended and given more detail simply because its participants are alive and adapting.

Conclusion

Except for a few generalist species, reptiles are undergoing global declines (Gibbons et al. 2000; Reading et al. 2010). For some species, collection for food and for the pet trade are to blame. In other cases, hunting, habitat decline, and introduced species play a greater role. For our study, what remains contested is the degree to which the hognose trade is dependent on wild-caught individuals. Some breeders are adamant that breeding prevents collection in the wild: "It's not lucrative to go out and waste gas when you can buy [western hognose] for $40 a baby." Moreover, the practice of breeding hognose, as well as the breeding and collecting of animals for pets in general, is not without its own ethical criticisms, which we have not addressed here (Green 2005). There is also a continuum of positions to consider on the ethics of keeping wild animals in captivity (Bride 1998; Fox 2006). Explicit, situated political ecologies of wildlife ranching and breeding (e.g., Brooks, Allison, et al. 2010; Brooks, Kebede, et al. 2010) and formal characterization of the economics of wildlife pet markets (e.g., Robinson 2001; Damania and Bulte 2007) could similarly expand critical interpretations of our study.

In summary, we took a biogeographical framework and fused it with theory and methods from human geography. Our goal was to open up "the spaces of wildlife from the cordon of exteriority to the multiple spaces and fluid ecologies of performative networks" (Whatmore and Thorne 1998, 451). Our assemblage biogeography for the hognose pet trade folded in different conceptions of space, place, and distance to yield a broader geography for this native North American snake. Although its function does not preclude actions or practices that might be detrimental to hognose snakes, we have highlighted its potential to self-police, to generate information useful for conservation practices, and to cultivate a better appreciation of nonhuman organisms and their complexity.

As far as the work of traditional ecological biogeography goes, its more typical inventorying of population numbers, the cataloging of areas of available or degraded habitat, and emphases on predictive modeling are good sound practices. Alone, however, these practices have the effect of turning the hognose and its enthusiasts into isolated, uninformative actors and representational motifs under the influence of generic regulations. Conversely, human geography can overlook biological and evolutionary factors in the interest of the justifiably necessary work of theorizing power, politics, and agency. Material perspectives recognize these tensions and have the potential to put them into practice simultaneously.

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Correspondence: Department of Geography, University of Kentucky, 817 Patterson Office Tower, Lexington, KY 40506-0027, e-mail: ja.stallins@uky.edu (Stallins); Department of Geography, Florida State University, Room 323 Bellamy Building, Tallahassee, FL 32306-2190, e-mail: Lg_kelley@yahoo.com (Kelley).