Received: 1 April 2023 | Revised: 6 December 2023 | Accepted: 16 January 2024

DOI: 10.1111/csp2.13092

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

Analysis of 20 years of turtle exports from the US reveals mixed effects of CITES and a need for better monitoring

Tara Easter | **Neil Carter**

School for Environment and Sustainability, University of Michigan, Ann Arbor, Michigan, USA

Correspondence
Tara Easter, School for Environment and Sustainability, University of Michigan, 440 Church Street, Ann Arbor, MI 48109, USA.
Email: tseaster@umich.edu

Funding information
Society for Conservation Biology; National Science Foundation, Grant/Award Number: 2017236939; Horace H. Rackham School of Graduate Studies, University of Michigan

Abstract

The Convention on International Trade of Endangered Species (CITES) is the primary mechanism for controlling international wildlife trade and preventing overexploitation, but measuring its efficacy is difficult, which complicates management efforts. We examined the effects of CITES listings on the trade of freshwater turtles from the US and compared spatiotemporal trends and dynamics of trade across 16 genera using 20 years of export data, triangulated with mixed qualitative data. For each CITES-listed genus, we analyzed the average changes, immediate changes, and changes in trends of export volumes and spatial diversity of trade. Boom-and-bust trends of exports for different taxa were driven by several factors, including CITES listings, but CITES had mixed effects on export volumes for both Appendix II and III species while the diversity of spatial trade networks consistently declined for CITES and non-CITES listed genera. These results point to differences in demand and species' availability from captive breeders, farms, or wild harvest which are important to consider in future listing decisions. However, a lack of reliable data on the source of turtles limited our ability to understand these drivers as well as the efficacy of CITES listings in preventing overexploitation.

KEYWORDS

CITES, conservation, pet trade, reptiles, turtles, wildlife trade

1 | INTRODUCTION

Overexploitation of wildlife for commercial trade poses significant threats to biodiversity worldwide (Fukushima et al., 2020; Morton et al., 2021; Scheffers et al., 2019). Globalized markets and the growth of social media have made international wildlife trade easier and have generated demand for exotic species for a multitude of uses (Bennett et al., 2021; Lavorgna, 2014; Nekaris et al., 2013). For example, consumption markets have driven the serial exploitation of taxa such as sea cucumbers (Anderson et al., 2011), while species' rarity has led to spikes in their demand in specialty hobbyist trades (Chen, 2016; Courchamp et al., 2006).

Outside of domestic legislation, the primary way of regulating international wildlife trade is through the Convention on International Trade in Endangered Species (CITES), which aims to ensure that international trade does not threaten the survival of wild plants and animals. It does so mainly by listing species under one of its three appendices, which have varying degrees of regulations and oversight. Appendix I is the most restrictive;

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2024 The Authors. *Conservation Science and Practice* published by Wiley Periodicals LLC on behalf of Society for Conservation Biology.

species listed under Appendix I are considered threatened with extinction, and international trade of these species for commercial purposes is generally prohibited. Species listed under Appendix II may become threatened with extinction unless trade is controlled. Parties regulate the trade of Appendix II listed species by requiring permits for export after first determining that the trade will not be detrimental to the species' wild population (i.e., the "Non-Detriment Finding" or "NDF") and that the specimens were legally sourced (i.e., the "Legal Acquisition Finding" or "LAF"). Appendix III is meant to assist individual countries in monitoring international trade of those listed species. Export permits and Legal Acquisition Findings are required for Appendix III species, but importantly, Non-Detriment Findings are not required (CITES, 2023).

Despite many criticisms of CITES and its effectiveness (Bowman, 2013; Cooney et al., 2021; Janssen & Krishnasamy, 2018; Phelps et al., 2010), it remains a formative instrument in managing wildlife commerce. Thus, it is important to understand the direct and indirect effects listings have in a variety of contexts to better understand the complex systems of global trade. For example, while several studies have shown a decrease in overall trade volumes following CITES listings of different species, they also document shifts into illegal trade, homogenization of spatial trade networks, spikes in trade in anticipation of listings, real or claimed shifts from wild- to captive-sourced specimens, and mixed effects on national governance and implementation (Booth et al., 2020; Foster et al., 2022; Friedman et al., 2018; Kuo & Vincent, 2018; Miller et al., 2019; Robinson et al., 2015; Shepherd et al., 2020). Having insights into the multitudinous effects of CITES listings can lead to better interdiction efforts and help practitioners avoid adverse and unintended outcomes.

Measuring these varied effects of CITES listings or other trade regulations is challenging, however, because before and after trade data are often lacking, as there are few datasets on the trade of species not listed under CITES that can act as a control against which to compare the effects of CITES listings (Booth et al., 2020; Janssen & Shepherd, 2018; Robinson & Sinovas, 2018; Watters et al., 2022). The drivers of changes in trade can also be elusive, especially if the limitations of trade data are not fully understood (Booth et al., 2020; Challender et al., 2022; Robinson & Sinovas, 2018). For example, the use of flawed reports on the source of traded animals can lead to misinterpretations of shifts in trade (Hinsley & Roberts, 2018; Schlaepfer et al., 2005). Triangulating multiple data sources (e.g., market surveys, stakeholder interviews, trend analyses) can aid researchers in overcoming these limitations and discerning causal links in wildlife trade, as several studies have demonstrated (Booth et al., 2020; Cardeñosa et al., 2018; Challender et al., 2015; Davies et al., 2022; Friedman et al., 2018; Lam et al., 2016; Miller et al., 2019).

In this study, we utilize the US Fish and Wildlife Service's (FWS) Law Enforcement Management Information System (LEMIS) and mixed qualitative research to add to the evidence base for the effects of CITES. LEMIS tracks US imports and exports of all flora and fauna which provides an opportunity not only to measure changes in the trade of species listed under CITES but to also take a wider view in understanding shifts in trade among similar, unlisted taxa. Such an approach has both practical and theoretical implications, as such information can aid managers in making listing decisions on a species-by-species basis. For example, some assert that if demand is elastic to price changes, demand may shift to similar, unlisted taxa; whereas if it is inelastic, trade bans or restrictions may exacerbate illegal trade (Challender, Hinsley, et al., 2019). Furthermore, whereas previous studies tend to focus on single species or regions, comparing case studies across taxa, geographic areas, or governing regimes can better measure the efficacy of CITES as a whole.

We use the commercial trade of freshwater turtles as a case study to investigate the dynamics of wildlife trade and effects of CITES listings. Turtle life history traits (i.e., low annual fecundity, delayed maturity, high adult survivorship and longevity) make them especially vulnerable to overexploitation, and researchers now consider this to be one of the main threats to wild turtle populations (Stanford et al., 2020). Turtles are sought after globally for a variety of experiential, social, functional, financial, and spiritual reasons (Thomas-Walters et al., 2021), but many are broadly destined for pet/hobbyist trades and consumption markets (Lovich et al., 2018; Sigouin et al., 2017). They are collected from the wild, farmed, and bred in captivity at ranging scales, again depending on the species, its purpose, and location. Over half of recognized turtle species are threatened with extinction, so understanding turtle trade dynamics is vital to prevent further declines (Lovich et al., 2018; Stanford et al., 2020).

We specifically focus on the exports of US-native turtles for three reasons. First, the US has one of the richest assemblages of freshwater turtles in the world that have varying conservation statuses (Buhlmann et al., 2009; Mittermeier et al., 2015). This allows us to examine shifts in demand among many taxa which has important implications for the conservation of turtles, globally. Second, the US plays a significant role in international trade dynamics as one of the top exporters of turtles for pet and consumption trades due to large aquaculture and

hobbyist communities (Collis & Fenili, 2011; Hughes, 1999; Moll & Moll, 2004). Third, as trade has globalized and moved from brick-and-mortar shops to online commerce, researchers have observed boom and bust patterns in the commercial trade of turtles across the globe, where a species or area is in high demand and heavily traded, then the market shifts to a new species or area (CITES, 2011; Klemens, 2000; van Dijk et al., 2000). Experts suggest that the "bust" in trade of several turtle species in Asia—due to regulatory restrictions and/or population declines—led to the rise of turtle exports from the US to meet continued demand (CITES, 2011; Colteaux & Johnson, 2017; Mali et al., 2014; Reed & Gibbons, 2003). This, combined with a heightened awareness of the plight of turtles in international trade, led to an increase in US turtle listings under CITES, allowing for before-after analyses and underscoring the need to understand the outcomes of listing decisions.

Several studies have provided overviews of the trade in turtles and tortoises in different ways, finding that the trade in turtles from the US rapidly increased in the 1990s, began to decline overall in the 2000s, and that the species traded in the highest volumes shifted from sliders (*Trachemys* spp.) and cooters (*Pseudemys* spp.) to snapping turtles (*Chelydra serpentina*) from the 1990s to 2010s (AFWA, 2020; Luiselli et al., 2016; Mali et al., 2014; Reed & Gibbons, 2003). Our study seeks to build on these findings by taking a closer look at spatial and temporal trade dynamics between taxa and following CITES listings. Specifically, our objectives were to examine: (1) the spatiotemporal trends in trade over 20 years; (2) how the average, immediate, and trend in exports of turtles from the US changed following their listings under CITES; and (3) the shifts in international demand of US-native turtles. Revealing finer-scale patterns of trade will deepen our understanding of global trade patterns, which has important implications for the conservation of turtles and utility of CITES.

2 | METHODS

We acquired LEMIS trade data for all turtles and tortoises (Order Testudines) for 1999–2018 used by Stringham et al. (2021). We removed records of marine turtles and filtered the remaining data to only include numbers of live animals (Wildlife Description = "LIV" or "EGL", Unit = "NO"), shipped for commercial purposes (Purpose = "T"). We restricted our analysis to live turtles because that is how they are most frequently traded and because using the number of individuals is a more reliable and consistent unit of measure than weights (e.g., "kg") or reported numbers of body parts (e.g., shells, bones). We also removed records of seized shipments (Disp. = "S") and re-exports (Action = "R") and any that were missing information on whether the shipment was imported or exported (~600 records of ~50,000). Although these criteria may result in a slight underestimation of trade, the remaining number of rows accounted for approximately 92% of the total number of rows in the original dataset. This dataset did not have shipment IDs for all records, so we relied on the raw number of individuals reportedly traded in the Quantity column with the aforementioned filters. We did not separate or filter exports based on the reported sources of the animals (i.e., wild, captive-bred, ranched, or farmed) because these source codes in LEMIS and CITES data are often misreported and misleading (AFWA, 2020; Hinsley & Roberts, 2018; Mali et al., 2014; Schlaepfer et al., 2005). Therefore, we summed the total number of individuals exported, regardless of their sources, to not obscure trends in the commercial trade of different species. We also corrected outdated taxonomy or misspelled species names where appropriate (See supplementary material, Appendix 1). All analyses were conducted at the genus level due to the lack of specificity of records for certain species. However, several turtle genera are monotypic (e.g., *Macrochelys*, see Table 1).

In the timeframe that the LEMIS data were recorded (1999–2018), several turtle species were newly listed under CITES, while others were listed or up-listed before or after these data were recorded or have not ever been listed (Table 1). To evaluate changes in trade before and after a CITES listing, we used export records of five US-native genera listed under CITES Appendices II and III in 2013 and 2006, respectively, for there to be enough years post-listing for analysis. Note that four of these five genera are monotypic or only have one extant species (Table 1). First, we examined how listings affected the number of exported turtles per year using generalized linear models with a negative binomial distribution and log-link function. We tested three aspects of temporal trends using two models, following Wauchope et al. (2021). The first model (Equation (1) evaluates the *average change* in export volume before and after listing, where Y is the number of individuals exported per year (i) and genus (j) and is predicted by a binary Before-After (BA) variable set to 0 for each year before listing, and 1 for each year after listing (2006 or 2013 depending on the genus). The second model (Equation (2)) evaluates *immediate change* and the *change in trend* after listing by adding variables for year (Time) and an interaction term (BA*Time), where Time represents one time step for each year of trade, centered around 0, with 0 being the first year after listing. To check the robustness of this model, we removed the BA term (Equation (3) and compared AIC scores of the two models (Wauchope et al., 2021).

TABLE 1 CITES listings of US freshwater turtles.

Year effective	App.	Genus	Species	Generic name
1992	I	*Glyptemys*	*G. muhlenbergii*	Bog turtle
	II	*Glyptemys*	*G. insculpta*	Wood turtle
1995	II	*Terrapene*	*T. carolina, T. nelsoni, T. ornata*	Box turtles
2006[a]	III	*Graptemys*	*G. barbouri, G. caglei, G. ernsti, G. flavimaculata, G. geographica, G. gibbonsi, G. nigrinoda, G. oculifera, G. ouachitensis, G. pearlensis, G., pseudogeographica, G. pulchra, G. versa*	Map turtles
	III	*Macrochelys*	*M. temminckii*	Alligator snapping turtle
2013[a]	II	*Clemmys*	*C. guttata*	Spotted turtle
	II	*Emydoidea*	*E. blandingii*	Blanding's turtle
	II	*Malaclemys*	*M. terrapin*	Diamondback terrapin
2016	III	*Apalone*	*A. spinifera, A. mutica, A. ferox*	Softshell turtles
	III	*Chelydra*	*C. serpentina*	Common snapping turtle
2023	II[b]	*Apalone*	*A. spinifera, A. mutica, A. ferox*	Softshell turtles
	II[b]	*Chelydra*	*C. serpentina*	Common snapping turtle
	II[b]	*Graptemys*	*G. barbouri, G. ernsti, G. gibbonsi, G. pearlensis, G. pulchra*	Map turtles
	II[b]	*Macrochelys*	*M. temminckii*	Alligator snapping turtle
	II	*Kinosternon*	*K. baurii, K. flavescens, K. hirtipes, K. sonoriense, K. steindachneri, K. stejnegeri, K. subrubrum*	Mud turtles
	II	*Sternotherus*	*S. carinatus, S. depressus, S. minor, S. odoratus*	Musk turtles

Note: Nomenclature follows taxonomy as listed by CITES proposals. Only species native to the US are listed under each genus as these are what we filtered for in our analyses.

[a]CITES listings that were included in the before-after analysis of trends.

[b]Species were up-listed from Appendix III to Appendix II.

Second, we calculated the Shannon Diversity Index (H) of exporting port-importing country pairs per year for each genus to analyze how listings affected the spatial complexity of trade (following Miller et al., 2019). We chose this index because it accounts for rare occurrences (i.e., port-country trade pairs where a smaller relative number of turtles were traded) better than other indices such as the Simpson Index. An H of 0 means that all individuals of a given genus were exported from one port and imported into one country. Using this index as the response variable, we ran linear regressions with the same model structure (Equations (1)–(3)). We checked for normality using Shapiro–Wilk tests.

$$Y_{ij} = \beta_0 + \beta_1 \mathrm{BA}_{ij} \quad (1)$$

$$Y_{ij} = \beta_0 + \beta_2 \mathrm{BA}_{ij} + \beta_3 \left(\mathrm{BA}_{ij} \mathrm{Time}_{ij}\right) + \beta_4 \mathrm{Time}_{ij} \quad (2)$$

$$Y_{ij} = \beta_0 + \beta_5 \mathrm{Time}_{ij} \quad (3)$$

To visualize spatial and temporal trends across all US, CITES-listed genera, we mapped trade flows using Sankey diagrams across four time periods with R package *networkD3* (Allaire et al., 2017). The scale of exports in some genera and to some countries are orders of magnitude higher than for others (e.g., *Trachemys* spp. to China). Therefore, to simplify the visualization of trends while incorporating differences across taxa, all figures of trade flows show individual genera and the geographic subregions that corresponding importing or exporting countries belong to, following the United Nation's geoscheme (UN, 2023).

Finally, we drew from qualitative data collected as part of a larger project on the legal and illegal trade of turtles in the US to triangulate our findings. The purpose of this data collection was not solely to investigate the effects of CITES listings; however, trade dynamics revealed through these sources provided valuable nuance that would have been otherwise missed or unaccounted for in quantitative models. Sources included semi-structured interviews and informal conversations with key informants, participation in two multi-stakeholder workshops to combat the illegal trade in turtles in the US, and document review conducted from March 2021–November 2022. Twenty-three semi-

structured interviews were conducted in total, including with scientific, management, and law enforcement personnel from state and federal agencies ($n = 15$), hobbyists and commercial turtle dealers ($n = 5$), and turtle scientists from non-governmental organizations ($n = 3$). Interviews were recorded and transcribed verbatim with permission. In some cases, interviews were not recorded due to the sensitivity of the discussion, and detailed notes were taken instead and typed out immediately following the conversation. Informal conversations were held with other FWS staff and NGO-affiliated scientists and advocates involved in CITES implementation for turtles. Finally, CITES listing proposals of US turtle species from 1995 to 2022 and working group documents related to legal and illegal turtle trade were reviewed. Trade dynamics, drivers, and trends for all US species discussed in interview transcripts, workshop notes, and documents were collated using NVivo (QSR International Pty Ltd., 2020). The University of Michigan Institutional Review Board Health Sciences determined this study is no more than minimal risk and exempt from ongoing oversight.

3 | RESULTS

3.1 | Export volumes

From 1999 to 2018, over 192 million live turtles were exported from the US for commercial purposes. Of those, over 99.8% were of species native to the US and 88% were of *Trachemys* or *Pseudemys* species. Records indicated that most *Trachemys* exports were of pond sliders, likely red-eared sliders (*Trachemys scripta* and *T. s. elegans*) while 94% of *Pseudemys* exports were simply labeled *Pseudemys* "species." Aside from those two genera, the volume of exports varies widely by species and time frame, ranging from less than 100 per year (*Glyptemys*, *Terrapene*, and *Actinemys* spp.) to over a million per year (*Chelydra*). Taking all genera together, the total volume of exports appears to decrease over these 20 years, but this is largely driven by the decrease in exports of *Trachemys* and *Pseudemys* spp. (Figure 1). Trends of export volumes varied by genera as well, with some clearly increasing over most of the 20 years (e.g., *Chelydra*, *Sternotherus*, *Kinosternon*, and *Glyptemys* spp., Figure 2), while others followed nonlinear patterns. Of those genera with multiple species where records were available at the species level, export volumes were typically dominated by the more common species with relatively large ranges in the southeast (e.g., *Graptemys pseudogeographica*, *Sternotherus odoratus*, *Kinosternon subrubrum*, etc.).

3.2 | Importers of US turtles

Turtles were exported from the US to 108 countries in 19 regions, but only 19 countries in 8 regions account for over 95% of all exported turtles. The top five importers, making up 72% of exports were, in order: Hong Kong SAR, China, Mexico, Singapore, and Taiwan. However, top importers varied by genus, with *Graptemys* spp. being the most notable exception which were mostly destined for Portugal, Spain, Italy, Czech Republic, and Germany (Figure 2).

3.3 | Ports of export for US turtles

Turtles were exported from 22 US ports (note that domestic transport prior to export is not documented in LEMIS

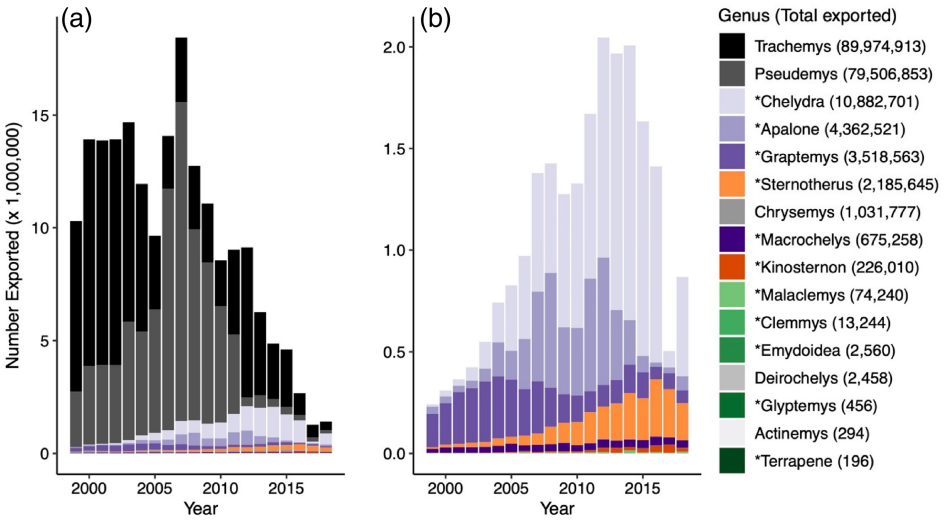


FIGURE 1 Total US export volumes of all live, US-native genera for commercial purposes from 1999 to 2018 (A) and only CITES-listed genera (B). Asterisks denote all CITES-listed genera. Genera export volumes are stacked in descending order from the most to fewest individuals exported in total from 1999 to 2018. Genera not listed under CITES are colored in black/gray. Appendix III species (prior to 2022) are colored in purple. Appendix II species are colored in green, and genera that were newly listed in 2022 are colored in orange.

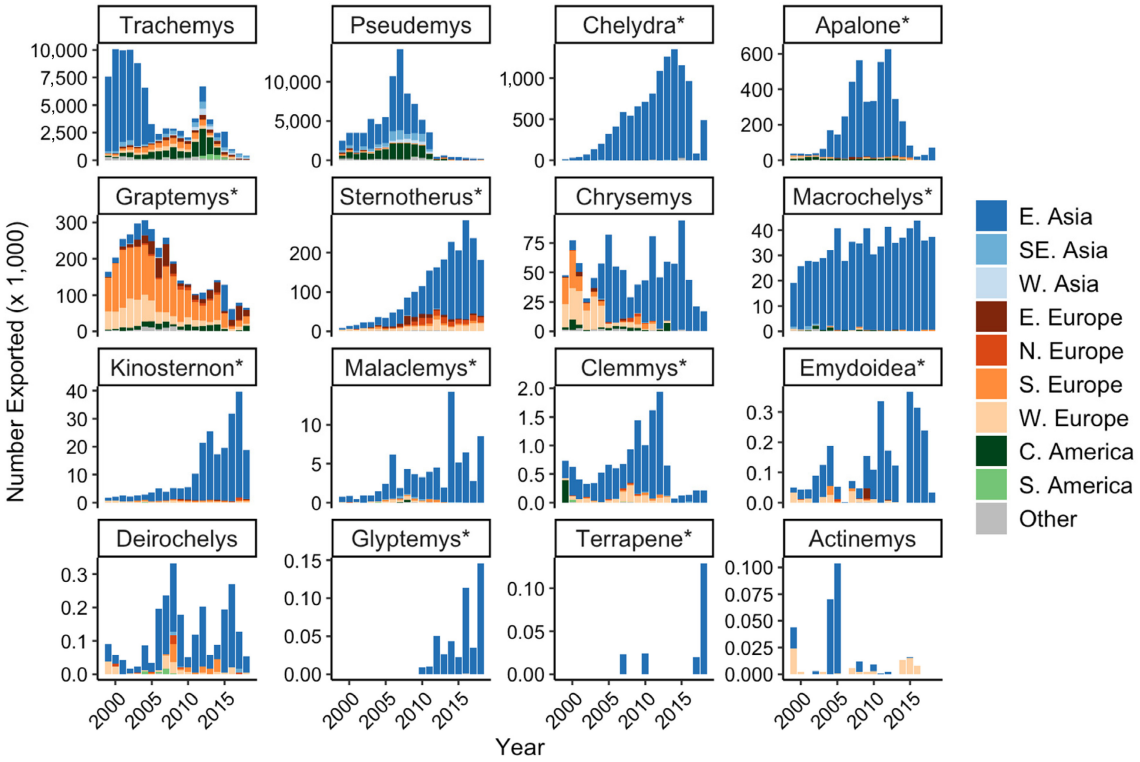


FIGURE 2 Number of live turtles exported from the US from 1999 to 2018. Export volumes are color-coded by the subregion of the importing countries which accounted for 95% of total exports of each genus, each year. The "Other" region sums all the countries that accounted for <5% of exports.

data). The top five exporting locations by volume were New Orleans, Los Angeles, San Francisco, Miami, and Dallas-Fort Worth (Figures 3, S1). Given the concentration of turtle farms in Louisiana and their production, it is unsurprising that New Orleans alone accounted for 60% of all exports. Los Angeles exports account for 32% of the total, likely due to air transport routes and the availability of direct flights from Los Angeles to Asia. Exports from California likely include a mixture of turtles taken from the wild, farmed and/or bred from other states since most of these species do not naturally occur in California. Again, there are notable differences by genera, with *Glyptemys*, *Clemmys, Emydoidea*, and *Terrapene* turtles exported mostly out of Miami (Figure 3, **S1**). Florida is home to many hobbyist and commercial collectors and breeders of turtles, so this may partially explain a higher number of exports in these species which are more highly valued in the pet trade and are generally protected from commercial collection in their range states. Overall, trade networks (exporting port-importing country pairs) decreased in diversity over time ($F(1, 285) = 38.74$, $p < .001$, Figures 3 and 4). In 1999, there were 127 total port-country pairs (13 ports, 52 countries); that decreased to 56 pairs in 2018 (6 ports, 35 countries).

3.4 | Before-after trends of CITES-listed species

CITES-listings under both Appendix II and III for US genera had mixed effects, which we measured in three ways: average change, immediate change, and change in trend before and after a genus was listed (Table 2, Figure 5). *Clemmys* exports decreased on average and immediately following CITES listing, and the trend in export volumes switched from positive to negative after listing. There was not a statistically significant change in the average, immediate or trend of *Emydoidea* exports after listing, and the best-fitting model was Equation (3), without before-after interaction terms. *Malaclemys* exports increased on average, but immediate changes and changes in trend after listing were not statistically significant. Equation (3) was also the best fitting model for *Malaclemys* exports, further indicating that there was not a significant change in exports from before to after listing (Figure 5).

Results also differed for *Graptemys* and *Macrochelys* export numbers (Table 2, Figure 5). *Graptemys* exports decreased on average and immediately following listing, and the trend in export volumes switched from positive to negative after listing in 2006. *Macrochelys* exports

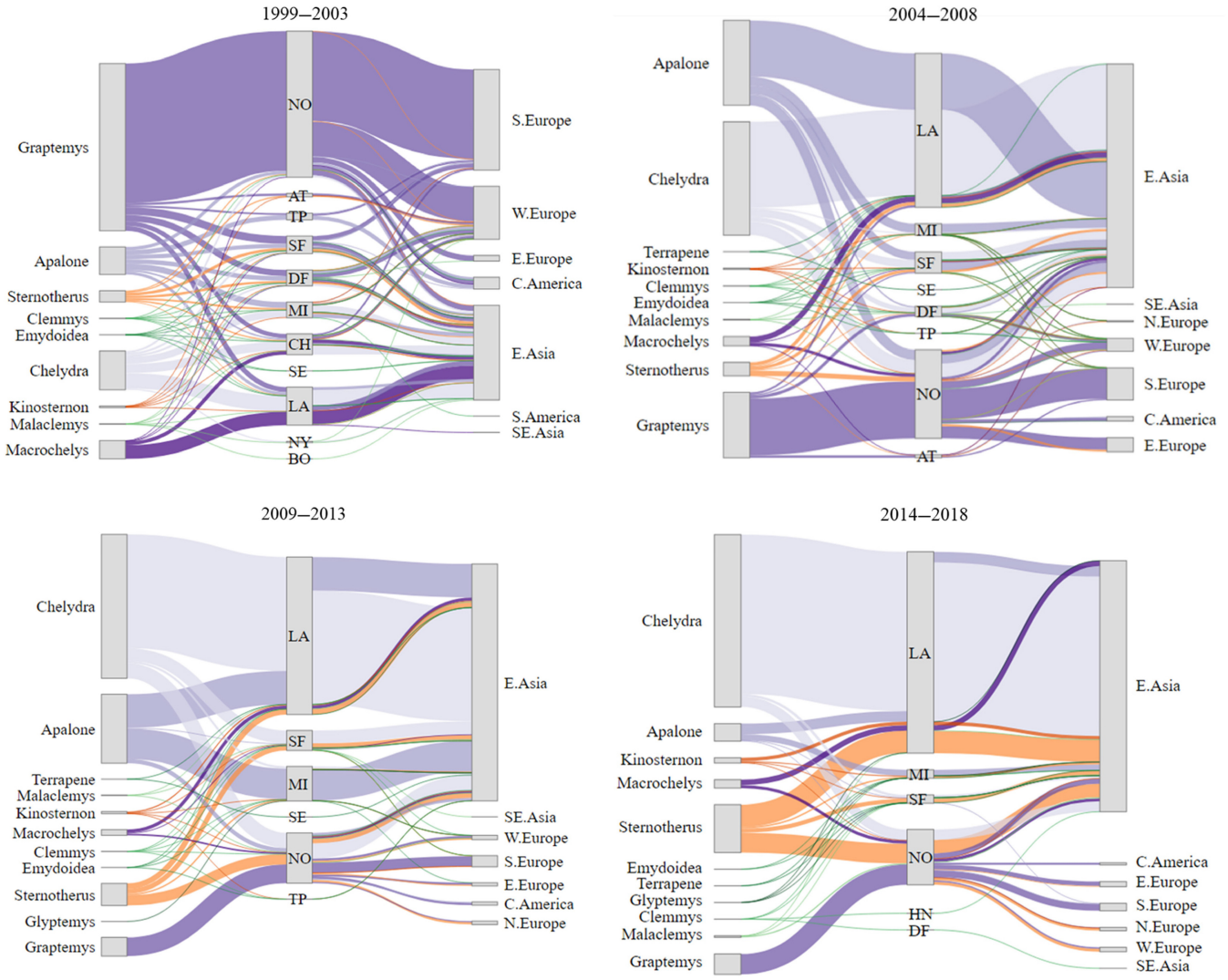


FIGURE 3 Sankey diagrams showing export flows of turtles by genus through their ports of export and to their regional destinations over four, even time periods. Flows of genera listed under Appendix III of CITES are shown in different shades of purple (from lighter to darker: *Chelydra*, *Apalone, Graptemys, Macrochelys*). Flows of genera that were listed under Appendix II at CoP19 are shown in different shades of orange (lighter: *Sternotherus*, darker: *Kinosternon*), and flows of genera listed under Appendix II are shown in different shades of green (from lighter to darker: *Malaclemys, Clemmys, Emydoidea, Terrapene, Glyptemys*). Flows of turtle exports which made up less than 1% of the total exports per genus and per year were removed for better visualization of major trends.

increased on average after listing, but there was an immediate decrease following listing. Although the trend in *Macrochelys* remained positive, the rate of increase was slower from 2007 to 2018.

Trends in spatial complexity (measured using the Shannon Diversity Index, H) differed by genus in relation to CITES listings as well (Table 2, Figures 3 and 6). The diversity of ports and destination countries for *Clemmys* turtles decreased on average and immediately following listing, but there was not a significant change in trend (Figure 6). *Emydoidea* exports decreased in spatial complexity on average after listing. Residuals from the *Emydoidea* model for Equation (2) were non-normal (Shapiro–Wilk $p < .05$), so results from this model are not shown. The diversity of ports and destination countries also decreased on average and immediately following listing in 2013 for *Malaclemys* exports, and changes in trend were not significant (Figure 6). *Graptemys* turtle trade decreased in spatial complexity on average and immediately following listing and had a negative trend from 2006 to 2018. However, results were non-significant for all three tests for *Macrochelys* (Table 2, Figure 6).

4 | DISCUSSION

Our analysis of 20 years of LEMIS turtle export data revealed dynamic and shifting patterns of international

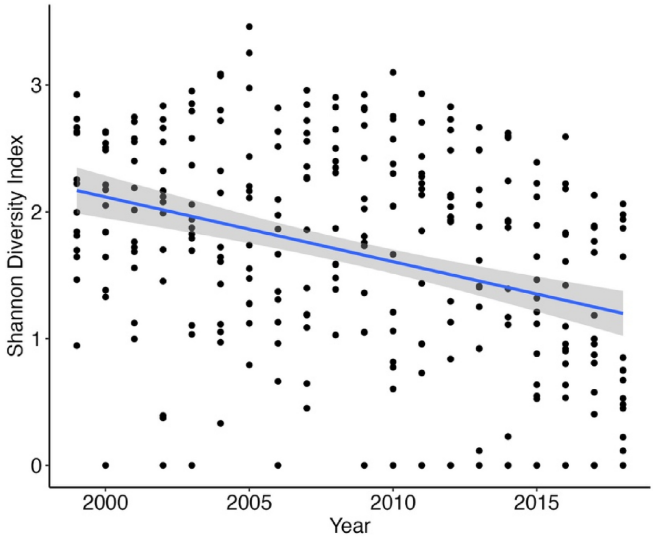


FIGURE 4 Shannon Diversity Index of the exporting port-importing country pairs for each genus each year (black dots) with trendline (blue) and standard error (gray).

turtle trade and mixed responses to CITES listings. Exports of some genera listed under both Appendix II and III slowed after listing (*Clemmys*, *Graptemys*, and *Macrochelys* spp.), but listing did not slow trade for two of the Appendix II species. Indeed, contrary to our expectations, average export volumes for only two genera were lower in the years after listing (*Graptemys* and *Clemmys* spp.), and for three genera the trade continued on an upward trajectory or increased in overall volume indicating little or counterintuitive effects of listing. The spatial diversity of trade declined following CITES listings, where fewer exporting ports and importing countries were involved in US turtle trade. However, this was also true for all US species over the 20 years. Although the long-term effects of regulations remain to be seen for several taxa, our analyses are useful for teasing out trends that would have otherwise been missed (Wauchope et al., 2021), and exploring the effects of CITES on a per-taxa basis further enables a comparison of production systems and demand shifts in species exports that continued to increase versus those that notably plummeted. Below, we examine these patterns in more detail and consider other drivers at play.

Our findings only partially corroborate other studies that have documented declines in trade of species after being listed under CITES (Foster et al., 2022; Kuo & Vincent, 2018;Lam et al., 2016; Shepherd et al., 2020) and reveal nuances worth exploring further. Declines in turtle trade may be a direct result of the CITES listing and permitting process which aims to prevent overexploitation, but it could also be due to the indirect effects of time lags and increased costs of permits, lower demand for listed species, and/or shifts into illegal trade that all vary depending on the species (Lam et al., 2016; Shepherd et al., 2020). Species are listed under Appendix II of CITES when "trade must be controlled in order to avoid utilization incompatible with their survival" (CITES, 2023), and species tend to be listed when trade has notably increased or there is reason to believe it will in the near future. Thus, it makes sense that trade would slow down following the implementation of a CITES II listing. For example, shortly after the trade in box turtles (*Terrapene* spp.) surged in the 90s and they were subsequently listed under Appendix II, exports essentially ceased (Reed & Gibbons, 2003). One interviewee describing this process said there was not any evidence that the trade in box turtles was sustainable, so FWS would not be issuing any permits for exports for a while. It is likely that *Clemmys* exports decreased, at least in part, as a direct result of CITES implementation. However, *Malaclemys* and *Emydoidea* exports remained high and were more erratic after listing in 2013, and we did not detect significant changes in trends (Table 2, Figure 5). However, CITES listings may not have immediately measurable and/or direct effects on trade volumes. Rather, it provides additional oversight of the trade, and changes to supply chains may be more gradual and indirect—if they occur at all.

Declines in trade may also be due to more logistical factors. In many countries, including the US, Non-Detriment Findings (NDFs) for exports of Appendix II species are initially made on a case-by-case basis (except for certain species which have annual findings). This can be a time-consuming process, and agencies often lack sufficient funding and resources to efficiently deal with permit applications. We heard from interviewees that initial applications of newly listed species can take months to review and that there is a backlog of applications. This may serve as a deterrent to middlemen who rely on moving animals quickly, or smaller businesses and hobbyists that may avoid the extra costs and hassle, resulting in a drop in exports. The larger, established farms and breeding operations may be better equipped to handle the added cost and delays, and Annual Master Permits for consistent producers likely also facilitates continued trade (AFWA, 2020).

Both *Graptemys* and *Macrochelys* exports dropped immediately following listing under Appendix III in 2006 (Table 2), and although exports of *Chelydra* and *Apalone* turtles had already started to decline, their export volumes took an additional dip after they were listed in 2016 as well (Figure 2), perhaps indicating an initial backlog following implementation. Paper trails are more likely to exist for species that were more heavily regulated within the US prior to CITES listings, such as *Macrochelys*

TABLE 2 Before-after model coefficient estimates with 95% confidence intervals for models measuring change in export volume and Shannon Diversity Index (H).

			App. II (2013)			App. III (2006)	
		Coefficient	***Clemmys* Coef. Est. (95% CI)**	***Emydoidea* Coef. Est. (95% CI)**	***Malaclemys* Coef. Est. (95% CI)**	***Graptemys* Coef. Est. (95% CI)**	***Macrochelys* Coef. Est. (95% CI)**
Export volume (log scale)	Equation (1)	β_1 : Avg. change	**−1.27 (−1.82, −0.72)**	0.53 (−0.47, 1.52)	**0.95 (0.28, 1.62)**	**−0.63 (−0.96, −0.31)**	**0.23 (0.09, 0.38)**
	Equation (2)	β_2 : Immediate change	**−1.55 (−1.63, −1.46)**	−0.30 (−2.07, 1.47)	−0.14 (−1.05, 0.76)	**−0.46 (−0.80, −0.13)**	**−0.24 (−0.43, −0.06)**
		β_3 : Change in trend	**−0.34 (−0.37, −0.31)**	−0.03 (−0.51, 0.44)	−0.17 (−0.41, 0.07)	**−0.19 (−0.26, −0.12)**	**−0.08 (−0.12, −0.04)**
	Equation (3) (null)	β_5 : Trend over time	−0.02 (−0.07, 0.04)	0.07 (−0.00, 0.15)*	**0.12 (0.09, 0.17)***	**−0.07 (−0.09, −0.05)**	**0.02 (0.01, 0.04)**
Shannon (H) (Linear)	Equation (1)	β_1 : Avg. change	**−1.20 (−1.73, −0.67)**	**−1.22 (−1.82, −0.61)**	**−1.49 (−1.83, −1.15)**	**−0.84 (−1.09, −0.58)**	−0.19 (−0.46, 0.08)
	Equation (2)	β_2 : Immediate change	**−1.29 (−2.33, −0.25)**	-	**−1.86 (−2.44, −1.27)**	**−1.06 (−1.40, −0.75)**	0.46 (−0.07, 0.98)
		β_3 : Change in trend	−0.17 (−0.46, 0.11)	-	−0.09 (−0.25, 0.06)	**−0.19 (−0.26, −0.13)**	0.09 (−0.02, 0.20)
	Equation (3) (null)	β_5 : Trend over time	**−0.06 (−0.11, −0.00)**	**−0.08 (−0.13, −0.02)**	**−0.07 (−0.13, −0.02)**	-	**−0.03 (−0.05, −0.00)**

Note: Export volumes were modeled with a negative binomial distribution and log-link function; coefficient estimates are given in the log scale. Spatial complexity models used the Shannon Diversity Index as a response variable and were modeled with linear regression. Estimates in bold indicate statistical significance (95% confidence intervals that do not overlap zero). Asterisks for Equation (3) coefficients denotes a lower AIC score than that of Equation (2), indicating a better fit without the BA term. Estimates are not included ("-") Shannon Index models where residuals were non-normal (Shapiro–Wilk $p < .05$).

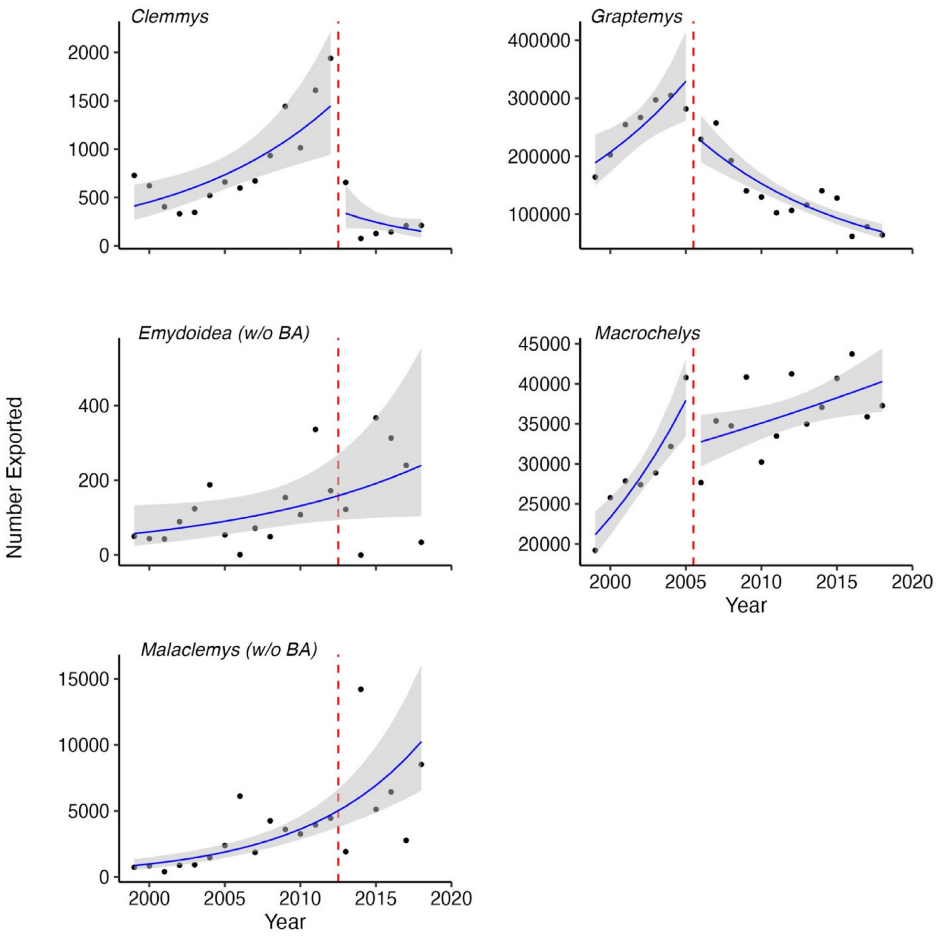


FIGURE 5 Negative binomial regressions (blue trendlines) for models with the lowest AIC score (Equation (2) with the Before-After term or Equation (3) without the Before-After term ("w/o BA")) for each US-native genus listed under CITES with 95% confidence intervals in gray. Dots mark the number of live individuals exported each year. Red dashed vertical lines mark the year each genus is listed under CITES (left column: 2013, Appendix II; right column: 2006, Appendix III).

turtles, which have a smaller range and more restrictive harvest regulations relative to *Graptemys* turtles and are proposed for listing under the Endangered Species Act. This may partially explain why *Macrochelys* exports did not decrease like *Graptemys* turtle exports did after listing (Figure 5). The data also showed a more obvious shift from multiple ports of export for *Graptemys* turtles to solely being shipped out of New Orleans—likely from established Louisiana farms.

In some cases, CITES listings may shift trade of a species to countries outside of its native range altogether. The collection and breeding of turtles and other herpetofauna have grown as a hobby worldwide, creating sizeable stocks of nonnative animals in trade (Auliya, 2003; Bush et al., 2014; Collis & Fenili, 2011; Robinson et al., 2015). European countries, for example, are among the top destinations for live reptile trade (Auliya et al., 2016; also see Figure S2), and CITES trade data show that while exports of *Graptemys* turtles from the US to Europe have declined, exports of these turtles from East Asia to Europe increased from 2007 to 2019 (Figure S3). Although we do not know what export volumes from East Asia were prior to listing, several interviewees noted that it had become cheaper for European and other countries to import US turtles from China than from the US, perhaps due to additional permitting requirements for species exported from their native ranges. Other popular pet species, especially *Terrapene* turtles, are exported in higher volumes from Europe than from the US (Figure S3).

It is unclear, however, the extent to which illegal trade contributes to the supply of US turtles and relates to CITES listings. Quantifying this clandestine activity is inherently challenging, and records of seized turtles in the LEMIS data alone were not enough to correlate to CITES listings or discern trends (Figure S4), though several recent cases of illegal turtle trade in the US show how smuggling and laundering circumvent the CITES permitting process (Easter et al., 2023; Sevin et al., 2022). In interviews and workshops, we also learned that CITES export permits have become a commodity in and of themselves among illegal traders. Indeed, combinations of continued demand, scarcity-driven price increases, a lack of enforcement capacity or will, or difficulty of obtaining permits for legal trade likely means that some amount of illegal trade is to be expected with stringent trade regulations (Challender, Sas-Rolfes, et al., 2019; Cooney et al., 2021). Shifts into or the continuation of

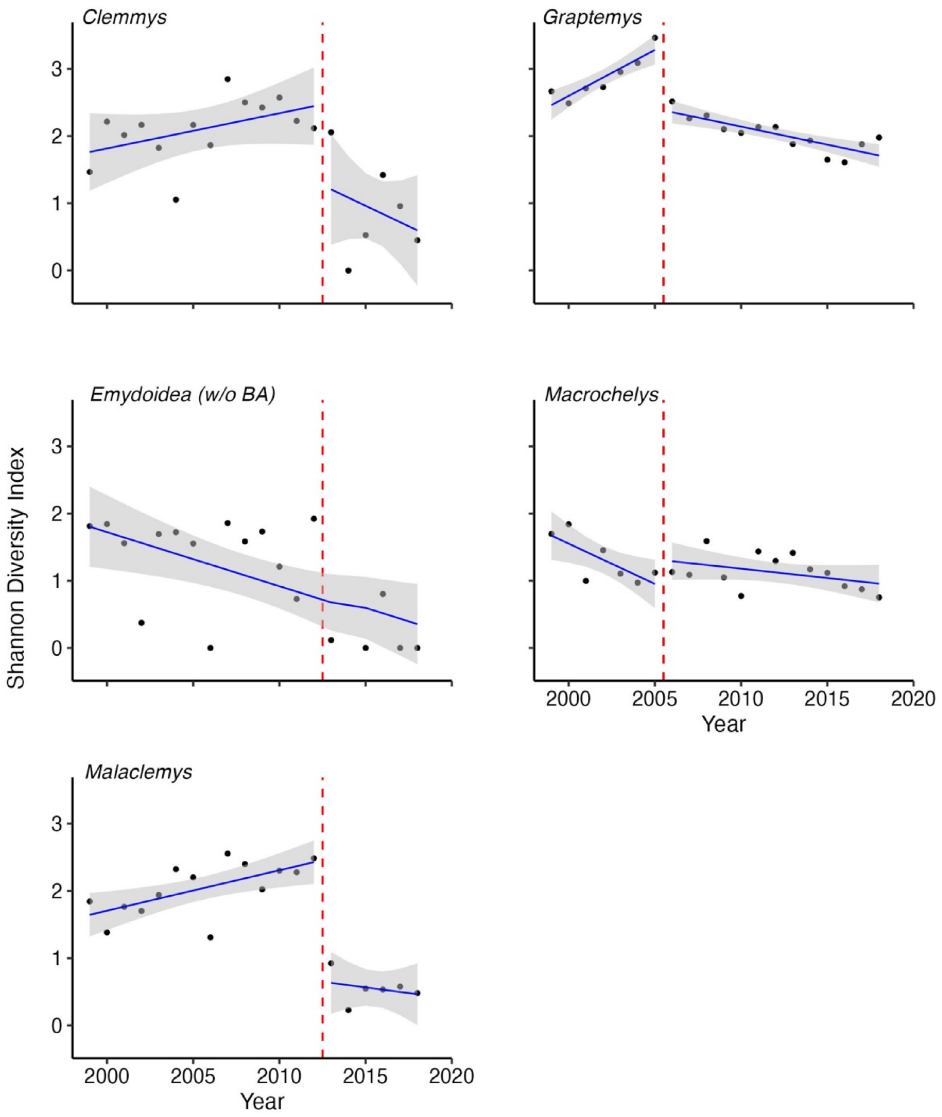


FIGURE 6 Linear regressions (blue trendlines) for models with the lowest AIC score (Equation (2) with the Before-After term or Equation (3) without the Before-After term, "w/o BA") for each US-native genus listed under CITES with 95% confidence intervals in gray. Dots mark the Shannon Diversity Index (H) of exporting port-importing country pairs for each year. Red dashed vertical lines mark the year each genus is listed under CITES (left column: 2013, Appendix II; right column: 2006, Appendix III).

illegal trade of CITES-listed species, especially of species with complex legal supply chains, have been demonstrated in several contexts (e.g., Auliya et al., 2016; Hinsley et al., 2017; Lyons & Natusch, 2011; Shepherd et al., 2020; Wyatt, 2009), including turtles (CITES, 2016; Nijman & Shepherd, 2007). Despite the challenges of effectively controlling illegal trade of CITES-listed species, one positive outcome of listings is that in cases where there has been little domestic oversight on trade, CITES listings and implementation stimulate greater attention to the issue by managers and law enforcement (Friedman et al., 2018; Heinrich, Shepherd, & Sy, 2022), as has been the case for turtles in the US. It is therefore also important to consider any growing trends in illegal trade within the context of increased law enforcement attention and effort.

Other factors outside of CITES are likely contributing to fluctuations in turtle trade. For example, a combination of domestic regulations, market saturation, and a decline in demand have influenced the overall boom and bust trade pattern of US turtles (Figure 1), which is driven by the more voluminously exported genera (e.g., *Trachemys*, *Pseudemys*, *Chelydra*, *Apalone*; van Dijk et al., 2000; CITES, 2011; Mali et al., 2014). Large-scale commercial harvesting of wild turtles was banned or restricted in several states in the US during this study's time period which likely reduced exports and trade route variability (Figure 4), especially of the more abundant and widespread species (Bennett & Loda, 2020; Colteaux & Johnson, 2017; Mali et al., 2014). Many countries have also banned the import of red-eared sliders (*T. scripta elegans*) due to their invasion potential (van Dijk et al., 2000). These turtles made up the majority of exports which were destined for East Asia up until the late 2000s when there was a decline in exports and switch to Central America (Figures 1 and 2, Reed & Gibbons, 2003; AFWA, 2020). Trends in turtle production and harvest in two of the least restrictive states in the

US—Louisiana and Arkansas (Bennett & Loda, 2020)—mirror overall declines. Louisiana turtle farms produced over 85 million turtle hatchlings from 2004 to 2019, but yearly production declined from 13 million in 2004 to 1.2 million in 2019. The number of producers also declined from a peak of 86 in 2008 to 14 in 2019 (LSU AgCenter, 2019). In Arkansas, 53 licensed trappers reported harvest of over 150,000 turtles in 2007, but by 2017, only 6 licensed trappers reported harvest of fewer than 25,000 turtles. The number of purchased commercial turtle harvest permits also declined from 146 in 2007 to 35 in 2017 (Irwin, 2018). Interviewees pointed to a drop in prices and lack of demand for the more common species that are typically harvested and farmed on large commercial scales as the main driver of these declines. Demand for common snapping turtles (*Chelydra serpentina*), for instance, peaked around 2013, and farms overseas are now reportedly producing enough on their own to no longer need to import them at the same scales from the US.

These trends, however, obscure finer scale shifts in supply and demand of species more typically destined for pet and hobbyist trades. While export volumes of *Graptemys* and *Clemmys* turtles fell, *Kinosternon* and *Sternotherus* exports rose significantly, leading to their own CITES listing in 2022 (Figure 2; CITES, 2022a, 2022b). Following the boom-and-bust logic of other turtle species (CITES, 2011), the increased difficulty of obtaining some species following CITES listings (due to price increases or decline in exports now requiring permits) may have influenced the rise of others. Indeed, *Graptemys*, *Clemmys*, and *Terrapene* turtles have long been attractive pet species, but interviewees suggested that *Kinosternon* and *Sternotherus* just recently gained popularity in the pet trade. The demand for different species could be driven by myriad factors outside of or indirectly related to CITES listings, as well. Declining wild populations may affect market availability. *Clemmys* turtles, for example, are considered endangered by the IUCN and are declining even where they are protected (Howell et al., 2019). Exploitation for the pet trade, along with habitat loss and other factors, is considered a driver of their declines (van Dijk, 2011), whereas *Kinosternon* and *Sternotherus* turtles are relatively abundant. Popular media may also influence the demand for featured species (Nekaris et al., 2013; Nijman & Nekaris, 2017; Veríssimo et al., 2019). Anecdotally, *Emydoidea* turtles were featured in Reptile Magazine in 2012 as one of the most "engaging and interesting" turtles to keep (CITES, 2013), and exports of them remained relatively high even after CITES listing in 2013 in comparison to years before listing. Specialist collectors may also be more interested in species due to their perceived or actual rarity (Courchamp et al., 2006; Purcell et al., 2014) or consistently high-value species with colorful markings and patterns (e.g., *Terrapene* and *Malaclemys* spp.), regardless of price or CITES listing. Some interviewees even reported rumors of cartels using turtles as investment opportunities and stockpiling certain species to control the market. Several other exogenous factors could be driving trade patterns as well such as hurricanes impacting farm stocks or global economic downturns.

Whatever the drivers of trade patterns are, it is difficult to know the extent to which CITES implementation prevents overexploitation without reliable data on the supply side of traded wildlife. Source codes in both LEMIS and CITES data are meant to show the origins of the species—if they were captive bred, farmed, ranched, or sourced from the wild (Table S1)—and several studies have based their analyses on this information (e.g., Harfoot et al., 2018; Mali et al., 2014; Robinson et al., 2015). However, as mentioned earlier, many have warned that the source codes in trade data are flawed (AFWA, 2020; Hinsley & Roberts, 2018; Mali et al., 2014; Schlaepfer et al., 2005), and we purposefully did not include any analyses that use source codes because our interviews with wildlife agency managers, turtle farmers, and review of correspondence between FWS and state agencies made it especially clear that these data, at least for turtles, are unreliable. For example, *Graptemys* and *Macrochelys* turtle exports switched almost entirely to source code "W" *after* they were listed under Appendix III in 2006 (Figure S5) when most of these turtles are likely hatchlings from turtle farms. This allowed trade of Appendix III turtles while not explicitly labeling them as captive-born or captive-bred due to unclear origins of the turtles, including if founder stock were legally acquired (CITES, 2022c; USFWS, 2021). Turtle farms often do not meet the strict requirements of CITES to be considered captive breeding facilities (AFWA, 2020), nor do they always have the paperwork to prove legal origins of their breeding stock. Indeed, in some states, turtle aquaculture facilities are not required to track or report the turtles they acquire for their breeding stock, wild-caught or otherwise. Appendix III listings are meant to monitor trade and could be a valuable tool in wildlife trade management and enforcement (Heinrich & Gomez, 2021; Heinrich, Shepherd, & Sy, 2022; Heinrich, Toomes, et al., 2022), but not knowing the source of traded wildlife defeats its purpose and may create a veneer of legality (Blundell & Rodan, 2003).

For species not listed under CITES, LEMIS source codes may be misleading in other ways that complicate listing decisions. For example, *Sternotherus* turtles were listed under Appendix II in 2023. In the listing proposal, researchers speculated that due to their low clutch sizes and thus low viability for large-scale commercial

breeding, most of the 597,823 reportedly captive-bred *Sternotherus* turtles exported from 2013 to 2019 were more likely wild-caught (CITES, 2022a). It is also possible those exports came from ranching operations with a mix of wild-caught and captive-born animals that label their exports as captive-bred without the oversight of CITES permitting. How facilities are defined as farms, ranches, or open or closed systems needs to be clarified and used consistently, as each has different implications for the level of offtake from the wild, but these terms are used in different ways (CEC, 2019). For example, how long and under what conditions should a wild-caught turtle be raised in a controlled environment before it or its hatchlings can be considered ranched or farmed (Colteaux & Johnson, 2017; Mali et al., 2014)? Using consistent terms and reporting for CITES and non-CITES listed taxa that cover the range in which species are harvested and raised is essential for monitoring trade.

State harvest reports, where available, are also difficult to use to corroborate these data as they rely on consistent and accurate reporting of trappers and collectors. To refer to an earlier example, Arkansas harvesters estimated that only 50% of total harvest is reported. Further, information on the number of turtle farms and captive breeders that exist (or have existed over time), or the species or number that are produced or taken from the wild in different states are severely lacking. Some states track this at a broad level through their permitting systems; others split tracking between the state wildlife agency and state agricultural agency, creating further confusion. One state agency referred us to the US Department of Agriculture's 2012 and 2018 censuses when we requested yearly data, but participation in this census is voluntary, clearly underestimates farm numbers, and lacks species-level information. Consistent reporting requirements at the species level from harvester to farmer to exporter, including where wild turtles were harvested and between state agencies would greatly assist managers in tracking shifts in the supply chain (Sigouin et al., 2017), especially in cases where the port of export (e.g., Los Angeles) is likely a long way from the original source. Such reporting could also aid in listing decisions and streamlining the permitting process when species are listed or uplisted.

These trade data issues are not new or unique to the US, and for many species of freshwater turtles and other herpetofauna, a lack of basic biological and demographic monitoring of wild populations creates additional challenges for sustainable and adaptive management (Phelps et al., 2010; Smith et al., 2011). In the absence of these data, estimates of sustainability can come from long-term trends of body sizes, life history traits, and offtake rates (Brown et al., 2012; Natusch et al., 2019). For turtles, including the size or age class of traded animals would help to evaluate sustainability, as it is more likely that hatchlings originated from captive breeding or ranching operations, and adults are the most vulnerable age class to take from the wild (CEC, 2019; Foster & Vincent, 2005; Sigouin et al., 2017). Unfortunately, for long-lived and slow-reproducing species such as turtles, by the time overexploitation of a population is confirmed, they could already be in a downward trajectory that is difficult to reverse. That is why it is critical to understand the efficacy of regulatory tools already in place and utilize existing, albeit flawed, datasets and triangulation to discern trends.

5 | CONCLUSION

Our analysis of LEMIS data, triangulated with mixed qualitative data, showed mixed effects of CITES Appendix II and III listings on turtle exports from the US from 1999 to 2018. We explained how several direct and indirect factors related to CITES permitting, turtle production systems, markets for different species, domestic regulations, and shifting demands influence the dynamic and fluctuating patterns of turtle trade. This study is limited by several factors that are often inherent in wildlife trade data, including the lack of shipments labeled to the species level, unknown sources of turtles, and a limited time frame of exports post-CITES listings. However, our in-depth look at individual genera and the before-and-after changes in the average, immediate, and trend of export volumes and spatial patterns elucidated dynamics that would have been otherwise missed. These details are crucial for management decisions, especially since CITES is designed to consider trade at both the individual species level and at broader taxonomic levels. Nevertheless, we echo the calls of many to improve monitoring systems to better determine trade sustainability, including consistently used and defined source codes, reporting requirements throughout the supply chain, and age-class monitoring of traded animals.

ACKNOWLEDGMENTS

We would like to thank the National Science Foundation's Graduate Research Fellowship Program, the School for Environment and Sustainability and Rackham Graduate School at the University of Michigan, and the Society for Conservation Biology for funding and supporting this work. We are also grateful to all our research participants for sharing their time and expertise, without which this work would not have been possible.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

LEMIS data are available online at fws.gov/library. Data and code used for this analysis are available on Data Dryad: https://doi.org/10.5061/dryad.t1g1jwt91.

ORCID

Tara Easter https://orcid.org/0000-0002-4694-9700
Neil Carter https://orcid.org/0000-0002-4399-6384

REFERENCES

AFWA. 2020. Case study: U.S. freshwater turtles and tortoises of wild fauna and flora.

Allaire, J. J., Gandrud, C., Russell, K., & Yetman, C. (2017). networkD3: D3 JavaScript Network Graphs from R.

Anderson, S. C., Flemming, J. M., Watson, R., & Lotze, H. K. (2011). Serial exploitation of global sea cucumber fisheries. *Fish and Fisheries*, *12*, 317–339.

Auliya, M. (2003). Hot trade in cool creatures: a review of the live reptile trade in the European Union in the 1990s with a focus on Germany.

Auliya, M., Altherr, S., Ariano-Sanchez, D., Baard, E. H., Brown, C., Brown, R. M., Cantu, J. C., Gentile, G., Gildenhuys, P., Henningheim, E., Hintzmann, J., Kanari, K., Krvavac, M., Lettink, M., Lippert, J., Luiselli, L., Nilson, G., Nguyen, T. Q., Nijman, V., … Ziegler, T. (2016). Trade in live reptiles, its impact on wild populations, and the role of the European market. *Biological Conservation*, *204*, 103–119.

Bennett, E., & Loda, J. (2020). Robbing the Wild: How 10 states' refusal to ban trapping is hurting America's wild turtles. Available from: https://www.biologicaldiversity.org/species/reptiles/pdfs/4_Robbing_the_Wild.pdf

Bennett, E. L., Underwood, F. M., & Milner-Gulland, E. J. (2021). To trade or not to trade? Using Bayesian belief networks to assess how to manage commercial wildlife trade in a complex world. *Frontiers in Ecology and Evolution*, *9*, 1–16.

Blundell, A. G., & Rodan, B. D. (2003). Mahogany and CITES: Moving beyond the veneer of legality. *Oryx*, *37*, 85–90.

Booth, H., Pooley, S., Clements, T., Iqbal, M., Putra, H., Lestari, W. P., Lewis, S., Warwick, L., & Milner-gulland, E. J. (2020). Assessing the impact of regulations on the use and trade of wildlife: An operational framework, with a case study on manta rays. *Global Ecology and Conservation*, *22*, e00953.

Bowman, M. (2013). A tale of two CITES: Divergent perspectives upon the effectiveness of the wildlife trade convention. *Review of European, Comparative & International Environmental law*, *22*, 228–238.

Brown, D. J., Schultz, A. D., Dixon, J. R., Dickerson, B. E., & Forstner, M. R. J. (2012). Decline of red-eared sliders (Trachemys scripta elegans) and Texas spiny softshells (Apalone spinifera emoryi) in the lower Rio Grande valley of Texas. *Chelonian Conservation and Biology*, *11*, 138–143.

Buhlmann, K. A., Akre, T. S. B., Iverson, J. B., Karapatakis, D., Mittermeier, R. A., Georges, A., Rhodin, A. G. J., van Dijk, P. P., & Gibbons, J. W. (2009). A global analysis of tortoise and freshwater turtle distributions with identification of priority conservation areas. *Chelonian Conservation and Biology*, *8*, 116–149.

Bush, E. R., Baker, S. E., & Macdonald, D. W. (2014). Global trade in exotic pets 2006–2012. *Conservation Biology*, *28*, 663–676.

Cardeñosa, D., Fields, A. T., Babcock, E. A., Zhang, H., Feldheim, K., Shea, S. K. H., Fischer, G. A., & Chapman, D. D. (2018). CITES-listed sharks remain among the top species in the contemporary fin trade. *Conservation Letters*, *11*, e12457.

CEC. (2019). *Trinational trade and enforcement training workshop to support the legal and sustainable trade in turtles and tortoises*. Montreal.

Challender, D. W., Hinsley, A., Veríssimo, D., & Milner-Gulland, E. (2019). Illegal wildlife trade: Scale, processes, and governance. *Annual Review of Environment and Resources*, *44*, 201–228.

Challender, D. W. S., Brockington, D., Hinsley, A., Hoffmann, M., Kolby, J. E., Massé, F., Natusch, D. J. D., Oldfield, T. E. E., Outhwaite, W., 't Sas-Rolfes, M., & Milner-Gulland, E. J. (2022). Mischaracterizing wildlife trade and its impacts may mislead policy processes. *Conservation Letters*, *15*, e12832.

Challender, D. W. S., Harrop, S. R., & Macmillan, D. C. (2015). Understanding markets to conserve trade-threatened species in CITES. *Biological Conservation*, *187*, 249–259.

Challender, D. W. S., Sas-Rolfes, M', Ades, G. W. J., Chin, J. S. C., Ching-Min Sun, N., Chong, J., Connelly, E., Hywood, L., Luz, S., Mohapatra, R. K., de Ornellas, P., Parker, K., Pietersen, D. W., Roberton, S. I., Semiadi, G., Shaw, D., Shepherd, C. R., Thomson, P., Wang, Y., … Nash, H. C. (2019). Evaluating the feasibility of pangolin farming and its potential conservation impact. *Global Ecology and Conservation*, *20*, e00714.

Chen, F. (2016). Poachers and snobs: Demand for rarity and the effects of antipoaching policies. *Conservation Letters*, *9*, 65–69.

CITES. (2011). Tortoises and freshwater turtles (decision 15.79, agenda item 19): AC25 WG7 Doc. 1. Available from: https://cites.org/eng/com/ac/25/wg/index.php

CITES. (2013). Consideration of Proposals for Amendment of Appendices I and II: CoP16 Prop. 30. Available from: https://cites.org/eng/cop/16/prop/index.php

CITES. (2016). Tortoises and freshwater turtles (Testudines spp.): CoP17 Doc. 73. Available from: https://cites.org/eng/cop/17/doc/index.php

CITES. (2022a). Consideration of Proposals for Amendment of Appendices I and II: CoP19 Prop. 31. Available from: https://cites.org/eng/cop/19/amendment-proposals

CITES. (2022b). Consideration of Proposals for Amendment of Appendices I and II: CoP19 Prop. 29. Available from: https://cites.org/eng/cop/19/amendment-proposals

CITES. (2022c). Consideration of Proposals for Amendment of Appendices I and II: CoP19 Prop. 23. Available from: https://cites.org/eng/cop/19/amendment-proposals

CITES. (2023). How CITES works. Available from: https://cites.org/eng/disc/how.php Accessed February 9, 2023.

Collis, A. H., & Fenili, R. N. (2011). The modern U.S. Reptile history. Available from: https://usark.org/wp-content/uploads/2013/02/The_Modern_US_Reptile_Industry_05_12_2011Final.pdf

Colteaux, B. C., & Johnson, D. M. (2017). Commercial harvest and export of snapping turtles (Chelydra serpentina) in the United States: Trends and the efficacy of size limits at reducing harvest. *Journal for Nature Conservation*, *35*, 13–19.

Cooney, R., Challender, D. W. S., Broad, S., Roe, D., & Natusch, D. J. D. (2021). Think before you act: Improving the

conservation outcomes of CITES listing decisions. *Frontiers in Ecology and Evolution*, *9*, 1–6.

Courchamp, F., Angulo, E., Rivalan, P., Hall, R. J., Signoret, L., Bull, L., & Meinard, Y. (2006). Rarity value and species extinction: The anthropogenic allee effect. *PLoS Biology*, *4*, 2405–2410.

Davies, A., Hinsley, A., Nuno, A., & Martin, R. O. (2022). Identifying opportunities for expert-mediated triangulation in monitoring wildlife trade on social media. *Conservation Biology*, *36*, 1–7.

Easter, T., Trautmann, J., Gore, M., & Carter, N. (2023). Media portrayal of the illegal trade in wildlife: The case of turtles in the US and implications for conservation. *People and Nature*, *00*, 1–16.

Foster, S. J., Justason, T., Magera, A. M., & Vincent, A. C. J. (2022). CITES makes a measurable difference to the trade in live marine fishes: The pioneering case of seahorses. *Biological Conservation*, *272*, 109653.

Foster, S. J., & Vincent, A. C. J. (2005). Enhancing sustainability of the international trade in seahorses with a single minimum size limit. *Conservation Biology*, *19*, 1044–1050.

Friedman, K., Gabriel, S., Abe, O., Adnan Nuruddin, A., Ali, A., Bidin Raja Hassan, R., Cadrin, S. X., Cornish, A., de Meulenaer, T., Dharmadi, Fahmi, Huu Tuan Anh, L., Kachelriess, D., Kissol, L., Jr., Krajangdara, T., Rahman Wahab, A., Tanoue, W., Tharith, C., Torres, F., Jr., … Ye, Y. (2018). Examining the impact of CITES listing of sharks and rays in southeast Asian fisheries. *Fish and Fisheries*, *19*, 662–676.

Fukushima, C. S., Mammola, S., & Cardoso, P. (2020). Global wildlife trade permeates the tree of life. *Biological Conservation*, *247*, 108503.

Harfoot, M., Glaser, S. A. M., Tittensor, D. P., Britten, G. L., McLardy, C., Malsch, K., & Burgess, N. D. (2018). Unveiling the patterns and trends in 40 years of global trade in CITES-listed wildlife. *Biological Conservation*, *223*, 47–57.

Heinrich, S., & Gomez, L. (2021). India's use of CITES appendix III. *Nature Conservation*, *44*, 163–176.

Heinrich, S., Shepherd, C. R., & Sy, E. Y. (2022). Using CITES appendix III to protect native species found in international trade: The case of the Philippines. *Philippine Journal of Science*, *151*, 127–137.

Heinrich, S., Toomes, A., Shepherd, C. R., Stringham, O. C., Swan, M., & Cassey, P. (2022). Strengthening protection of endemic wildlife threatened by the international pet trade: The case of the Australian shingleback lizard. *Animal Conservation*, *25*, 91–100.

Hinsley, A., Nuno, A., Ridout, M., John, F. A. V. S., & Roberts, D. L. (2017). Estimating the extent of CITES noncompliance among traders and end-consumers; lessons from the global orchid trade. *Conservation Letters*, *10*, 602–609.

Hinsley, A., & Roberts, D. L. (2018). The wild origin dilemma. *Biological Conservation*, *217*, 203–206.

Howell, H. J., Legere, R. H., Jr., Holland, D. S., & Seigel, R. A. (2019). Long-term turtle declines: Protected is a verb, not an outcome. *Copeia*, *107*, 493–501.

Hughes, D. W. (1999). The contribution of the pet turtle industry to the Louisiana economy. *Aquaculture Economics and Management*, *3*, 205–214.

Irwin, K. (2018). *Commercial aquatic turtle harvest 2004–2017*. Little Rock.

Janssen, J., & Krishnasamy, K. (2018). Left hung out to dry: How inadequate international protection can fuel trade in endemic species—The case of the earless monitor. *Global Ecology and Conservation*, *16*, e00464.

Janssen, J., & Shepherd, C. R. (2018). Challenges in documenting trade in non-CITES listed species: A case study on crocodile skinks (Tribolonotus spp.). *Journal of Asia-Pacific Biodiversity*, *11*, 476–481.

Klemens, M. W. (Ed.). (2000). *Turtle conservation*. Smithsonian Institution Press.

Kuo, T. C., & Vincent, A. (2018). Assessing the changes in international trade of marine fishes under CITES regulations—A case study of seahorses. *Marine Policy*, *88*, 48–57.

Lam, J. T. L., Koldewey, H. J., Yasué, M., & Vincent, A. C. J. (2016). Comparing interview and trade data in assessing changes in the seahorse Hippocampus spp. trade following CITES listing. *Oryx*, *50*, 36–46.

Lavorgna, A. (2014). Wildlife trafficking in the internet age. *Crime Science*, *3*, 1–12.

Lovich, J. E., Ennen, J. R., Agha, M., & Gibbons, J. W. (2018). Where have all the turtles gone, and why does it matter? *Bioscience*, *68*, 771–781.

LSU AgCenter. (2019). Louisiana Summary: Agriculture and Natural Resources. Available from https://www.lsuagcenter.com/portals/communications/publications/publications_catalog/money and business/louisiana_summary_agriculture_and_natural_resources Accessed December 19, 2022.

Luiselli, L., Starita, A., Carpaneto, G. M., Segniagbeto, G. H., & Amori, G. (2016). A short review of the international trade of wild tortoises and freshwater turtles across the world and throughout two decades. *Chelonian Conservation and Biology*, *15*, 167–172.

Lyons, J. A., & Natusch, D. J. D. (2011). Wildlife laundering through breeding farms: Illegal harvest, population declines and a means of regulating the trade of green pythons (Morelia viridis) from Indonesia. *Biological Conservation*, *144*, 3073–3081.

Mali, I., Vandewege, M. W., Davis, S. K., & Forstner, M. R. J. (2014). Magnitude of the freshwater turtle exports from the US: Long term trends and early effects of newly implemented harvest management regimes. *PLoS One*, *9*, e86478.

Miller, E. A., McClenachan, L., Uni, Y., Phocas, G., Hagemann, M. E., & Van Houtan, K. S. (2019). The historical development of complex global trafficking networks for marine wildlife. *Science Advances*, *5*, eaav5948.

Mittermeier, R. A., van Dijk, P. P., Rhodin, A. G. J., & Nash, S. D. (2015). Turtle hotspots: An analysis of the occurrence of tortoises and freshwater turtles in biodiversity hotspots, high-biodiversity wilderness areas, and turtle priority areas. *Chelonian Conservation and Biology*, *14*, 2–10.

Moll, D., & Moll, E. O. (2004). *The ecology*. Oxford University Press on Demand.

Morton, O., Scheffers, B. R., Haugaasen, T., & Edwards, D. P. (2021). Impacts of wildlife trade on terrestrial biodiversity. *Nature Ecology & Evolution*, *5*, 540–548.

Natusch, D. J. D., Lyons, J. A., Riyanto, A., Mumpuni, K. S., & Shine, R. (2019). Detailed biological data are informative, but

robust trends are needed for informing sustainability of wildlife harvesting: A case study of reptile offtake in Southeast Asia. *Biological Conservation*, *233*, 83–92.

Nekaris, B. K. A.-I., Campbell, N., Coggins, T. G., Rode, E. J., & Nijman, V. (2013). Tickled to death: Analysing public perceptions of 'cute' videos of threatened species (Slow Lorises – Nycticebus spp.) on web 2.0 sites. *PLoS One*, *8*, e69215.

Nijman, V., & Nekaris, K. A. I. (2017). The Harry potter effect: The rise in trade of owls as pets in Java and Bali, Indonesia. *Global Ecology and Conservation*, *11*, 84–94.

Nijman, V., & Shepherd, C. R. (2007). Trade in non-native, CITES-listed, wildlife in Asia, as exemplified by the trade in freshwater turtles and tortoises (Chelonidae) in Thailand. *Contributions to Zoology*, *76*, 207–211.

Phelps, J., Webb, E. L., Bickford, D., Nijman, V., & Sodhi, N. S. (2010). Boosting CITES. *Science*, *330*, 1752–1753.

Purcell, S. W., Polidoro, B. A., Hamel, J. F., Gamboa, R. U., & Mercier, A. (2014). The cost of being valuable: Predictors of extinction risk in marine invertebrates exploited as luxury seafood. *Proceedings of the Royal Society B: Biological Sciences*, *281*, 1–9.

QSR International Pty Ltd. (2020). NVivo. Available from https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Reed, R. N., & Gibbons, J. W. (2003). Conservation status of live U.S. nonmarine turtles in domestic and international trade. Aiken, SC.

Robinson, J. E., Griffiths, R. A., St John, F. A., & Roberts, D. L. (2015). Dynamics of the global trade in live reptiles: Shifting trends in production and consequences for sustainability. *Biological Conservation*, *184*, 42–50.

Robinson, J. E., & Sinovas, P. (2018). Challenges of analyzing the global trade in CITES-listed wildlife. *Conservation Biology*, *32*, 1203–1206.

Scheffers, B. R., Oliveira, B. F., Lamb, I., & Edwards, D. P. (2019). Global wildlife trade across the tree of life. *Science*, *366*, 71–76.

Schlaepfer, M. A., Hoover, C., & Dodd, C. K., Jr. (2005). Challenges in evaluating the impact of the trade in amphibians and reptiles on wild populations. *Bioscience*, *55*, 256–264.

Sevin, J., Wixted, K., Kisonak, L., MacDonald, B., Thompson-Slacum, J., Buchanan, S., & Karraker, N. (2022). Turtles in trouble. *The Wildlife Professional*, *16*, 26–31.

Shepherd, C. R., Leupen, B. T. C., Siriwat, P., & Nijman, V. (2020). International wildlife trade, avian influenza, organised crime and the effectiveness of CITES: The Chinese hwamei as a case study. *Global Ecology and Conservation*, *23*, e01185.

Sigouin, A., Pinedo-Vasquez, M., Nasi, R., Poole, C., Horne, B., & Lee, T. M. (2017). Priorities for the trade of less charismatic freshwater turtle and tortoise species. *Journal of Applied Ecology*, *54*, 345–350.

Smith, M. J., Williams, R. J., & Purves, D. W. (2011). Boosting CITES through research. *Science*, *331*, 857.

Stanford, C. B., Iverson, J. B., Rhodin, A. G. J., Paul van Dijk, P., Mittermeier, R. A., Kuchling, G., Berry, K. H., Bertolero, A., Bjorndal, K. A., Blanck, T. E. G., Buhlmann, K. A., Burke, R. L., Congdon, J. D., Diagne, T., Edwards, T., Eisemberg, C. C., Ennen, J. R., Forero-Medina, G., Frankel, M., ... Walde, A. D. (2020). Turtles and tortoises are in trouble. *Current Biology*, *30*, R721–R735.

Stringham, O. C., García-Díaz, P., Toomes, A., Mitchell, L., Ross, J. V., & Cassey, P. (2021). Live reptile smuggling is predicted by trends in the legal exotic pet trade. *Conservation Letters*, *14*, e12833.

Thomas-Walters, L., Hinsley, A., Bergin, D., Burgess, G., Doughty, H., Eppel, S., MacFarlane, D., Meijer, W., Lee, T. M., Phelps, J., Smith, R. J., Wan, A. K. Y., & Veríssimo, D. (2021). Motivations for the use and consumption of wildlife products. *Conservation Biology*, *35*(2), 483–491.

UN. (2023). UNSD — Methodology. Available from https://unstats.un.org/unsd/methodology/m49/. Accessed February 26, 2023

USFWS (U.S. Fish and Wildlife Service). (2021). Species status assessment report for the alligator snapping turtle (*Macrochelys temminckii*), Version 1.2. March 2021. Atlanta, GA.

van Dijk, P. P. (2011). *Clemmys guttata*. The IUCN Red List of Threatened Species 2011: e.T4968A97411228. https://doi.org/10.2305/IUCN.UK.2011-1.RLTS.T4968A11103766.en

van Dijk, P. P., Stuart, B. L., & Rhodin, A. G. J. (Eds.) (2000). Asian turtle trade: Proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. *Chelonian Research Monographs*, *2*, 1–164. https://doi.org/10.1046/j.1365-3008.2001.0193b.x

Veríssimo, D., Anderson, S., & Tlusty, M. (2019). Did the movie finding dory increase demand for blue tang fish? *Ambio*, *49*, 903–911. https://doi.org/10.1007/s13280-019-01233-7

Watters, F., Stringham, O., Shepherd, C. R., & Cassey, P. (2022). The U.S. market for imported wildlife not listed in the CITES multilateral treaty. *Conservation Biology*, *36*, e13978.

Wauchope, H. S., Amano, T., Geldmann, J., Johnston, A., Simmons, B. I., Sutherland, W. J., & Jones, J. P. G. (2021). Evaluating impact using time-series data. *Trends in Ecology & Evolution*, *36*, 196–205.

Wyatt, T. (2009). Exploring the organization of Russia Far East's illegal wildlife trade: Two case studies of the illegal fur and illegal falcon trades. *Global Crime*, *10*, 144–154.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Easter, T., & Carter, N. (2024). Analysis of 20 years of turtle exports from the US reveals mixed effects of CITES and a need for better monitoring. *Conservation Science and Practice*, *6*(4), e13092. https://doi.org/10.1111/csp2.13092