Trends, patterns, and networks of illicit wildlife trade in Nepal: A national synthesis

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Abstract
Illicit wildlife trade may have devastating consequences for Nepal’s wildlife populations given its increasing national and global connectivity and proximity with large Indian and Chinese markets. Despite its potential impacts, our understanding about trends, patterns and networks of illicit wildlife trade in Nepal is very limited. Here, we provide a thorough and comprehensive national assessment of such trade in Nepal using 5 years (2011 through 2015) of data on wildlife seizures and arrests (n = 830) collected from 73 districts. Nearly 87% of arrests included seizures, and globally threatened species were confiscated from 56% of total arrests. There were increasing trends of arrest cases over the time period for all species (p = 0.03), leopards (p = 0.02) and red pandas (p = 0.002), and a decreasing trend for rhinoceros (p = 0.04). Seizures of multiple species—especially tigers, leopards, and pangolin—in arrest cases were suggestive of international organized criminal linkages, whereas individual small-scale seizures were likely for local, species-specific markets. The trade networks suggested connections between species core habitats (poaching sites), cities (collection sites), and transit routes between India and China (international markets). Our results show that wildlife trade, except for rhinoceros, is increasing and trade nodes along districts bordering China and India are suggestive of large, international networks.

KEYWORDS
biodiversity conservation, Nepal, threatened species, trade connectivity, trade networks, wildlife trade

1 INTRODUCTION
The use of wildlife—both living and nonliving—by humans has existed for millennia for meat, cosmetic products, cultural/religious ceremonies, medicines and as pets (Baker et al., 2013; Wyler & Sheikh, 2008). The exploitation of animals has expanded at commercial scales, which has caused the decline of many wild populations once considered to be inexhaustible (Baker et al., 2013). The collection of live specimens and body parts, and their transportation and distribution at internal, national and international levels, constitutes wildlife trade (Dongol & Heinen, 2012;...
Van Uhm, 2016). This is now considered to be a major driver of accelerating rates of species decline and extinction (Lenzen et al., 2012; Nijman, 2010; Primack, Paudel, & Bhattacharai, 2013) in addition to habitat loss and fragmentation (Pandit, Sodhi, Koh, Bhaskar, & Brook, 2007) and environmental pollution (Vörösmarty et al., 2010). Wildlife trade is also now believed to be the third largest type of illegal trade globally, after drug and arms trafficking (Barber-Meyer, 2010). Southeast and South Asia are both major hubs of global illegal wildlife trade (Nijman, 2010), with China being the major consumer (Heinen, Shukurov, & Sadykova, 2001). Nepal is no exception as it serves as both a source and a transit country for the trafficking of wild animal and plant specimens and parts (Burgess, Stoner, & Foley, 2014; Shrestha-Acharya & Heinen, 2009; Stoner & Pervushina, 2013; Yi-Ming, Zenxiang, Xinhai, Sung, & Niemelä, 2000).

Nepal harbors a great diversity of flora and fauna, and supports a disproportionately high diversity of globally threatened fauna in comparison to its land area (Paudel & Heinen, 2015b). Many studies suggest that wildlife hunting in Nepal has been common for subsistence consumption and trade for long periods of time (Bhattarai, Wright, & Khatiwada, 2016; Heinen, 1995; Heinen, Yonzon, & Leisure, 1995; Paudel, 2012). The country has made great strides in protecting biodiversity over the past half-century (Heinen, Baral, Paudel, & Sah, 2019) in that nearly 23% of its land area has been set aside as protected areas and associated buffer zones (Paudel, 2013; Paudel & Heinen, 2015a) and the country has recently documented increasing population trends of many critically endangered megafaunal species including tiger, rhino, elephant, and wild buffalo (Heinen & Paudel, 2015; Subedi et al., 2013; Wikramanayake et al., 2011). Reports suggest that poaching of the greater one-horned rhinoceros Rhinoceros unicornis has been reduced drastically and eliminated completely for six 365 day periods since 2011 (Acharya, Thapa, Kuwar, Thapaliya, & Paudel, 2020).

Despite these commendable achievements, much illegal wildlife trade remains and is likely increasing given the increases in global trade in recent decades (Burgess et al., 2014; Dongol & Heinen, 2012; Stoner & Pervushina, 2013). Studies have shown that wildlife trade depends on easily accessible markets with affluent customers in sink locations, and inadequate livelihood alternatives and poor enforcement mechanisms in source locations (Baker et al., 2013; Baral & Heinen, 2005; Brashares, Golden, Weinbaum, Barrett, & Okello, 2011; Lee et al., 2005; Lindsey et al., 2013). Nepal is a least developed country surrounded by the global second (China) and seventh (India) largest economies. These drivers are relevant here, likely contributing—at varying scales—to the growth of international illicit wildlife trade in Nepal and throughout Asia (Elliott & Schaedla, 2016). In Nepal, the National Parks and Wildlife Conservation Act 1973 (NPWCA 1977), hitherto the main legal mechanism for wildlife conservation, provides protection for 26 species of mammals, nine species of birds and three species of reptiles throughout the country. Wildlife hunting and trade without permission are criminal activities and subject to strict penalties under the law (Heinen & Chapagain, 2002).

Wildlife trade analyses exists at international (Hansen, Li, Joly, Mekar, & Brownstein, 2012; Karesh, Cook, Bennett, & Newcomb, 2005; Patel et al., 2015; Rosen & Smith, 2010) and regional levels (Lin, 2005; Nijman, 2010), including China with bordering and other nearby Asian countries (Yi-Ming et al., 2000; Zhang, Hua, & Sun, 2008). Many of these studies report trade of some species native to Nepal such as tigers, rhinoceroses, leopards, and pangolins. However, knowledge about national illicit trade status of these species, widely reported in global and regional studies, is lacking. Understanding the temporal and spatial trends and patterns, trade networks and the species involved is highly useful to inform policy makers and law enforcement officials about how Nepal is connected with global and regional illicit wildlife trade, and to affect change via targeting law enforcement efforts (Heinen & Chapagain, 2002). Here we analyze nation-wide wildlife arrest and seizure data from 2011 through 2015 focusing on: (a) which groups (i.e., taxa, CITES listed species, threatened species, native/exotic species) are traded most often in Nepal, (b) how wildlife trade has changed over time, and (c) whether there are any species-specific trade networks in Nepal in term of arrest dates and locations for six target species (e.g., tiger, leopard, rhinoceros, red panda, pangolin, and elephant).

2 | METHODS

2.1 | Data

Nepal is a land-locked country bordered by China to north and India to the west, east, and south. Its border with India is porous and citizen of both countries do not need visas to cross. China is relatively inaccessible by road, but trade with China has existed for centuries along the “silk routes” (Panigrahi, 2016). We collected wildlife seizure records for the five-year period from January 1, 2011 to December 31, 2015 by reviewing national wildlife arrest and seizure records throughout Nepal (26°22′–30°27′N, 80°4′–88°12′E), and surveying news outlets. Nepal is a federal republic consisting of 7 provinces, 77 districts, and 753 municipalities (see Supporting
Information: Appendix SI, Figure S1). Districts are subdivisions where (generally) well-equipped administrative units (e.g., agricultural offices, forest offices, etc.) are located, and with adequate data documentation mechanisms in place. There were 75 districts and each has one District Forest Office (DFO) (now Divisional Forest Office), under the Department of Forests (now Department of Forest and Soil Conservation (DoFSC)), that oversees forests and wildlife within its jurisdiction. Additionally, there are 20 protected areas (12 national parks, 1 hunting reserve, 1 wildlife reserve, and 6 conservation areas; Paudel & Heinen, 2015b; Supporting Information: Appendix SI, Figure S1) managed by the Department of National Parks and Wildlife Conservation (DNPWC), a sister agency of the DoFSC.

We collected wildlife seizure and arrest records from 73 DFOs and 20 Protected Area Offices (PAOs) offices through the Ministry of Forest and Environment. Both government agencies have power of court pursuant in respect to summoning the concerned persons and their witness, examining evidence, prescribing dates for appearance and documents to be prepared for the purpose of making decisions on any matter related to wildlife poaching and trade. If the incident occurs inside protected areas and/or their buffer zones, formal procedures are conducted through the respective PAO. Buffer zones are designated areas surrounding protected areas that may include forests, human settlements, and agriculture lands (Heinen et al., 2019). For all other incidents (outside of PAs), DFOs are responsible for carrying out legal actions. First, we contacted all DFOs and PAOs and requested them to fill out a predefined questionnaire based on official archives related to wildlife trade prosecution cases. In cases where there was any doubt, staff in the respective DFOs and PAOs were contacted and consulted directly.

Nepal police take actions in coordination with DFOs. At the central level, the Central Bureau of Investigation (CIB) has a wildlife crime control unit that investigates and prosecutes crimes related to the killing and trade of endangered wildlife and their body parts through its regional and district units. We also obtained data directly from the CIB, much of which was useful for corroborating data found elsewhere (above and below).

We also systematically searched news articles related to wildlife trade in the three leading daily national newspapers: Kantipur Daily, Nagarik News, and Gorkhapatra. The first two are private whereas the third is a government publication. These newspapers are among the top three in terms of readership, circulation, number of reporters across the country, and topical coverage (Sharecast Initiative Nepal, 2019). Since newspapers offer regular reporting of social and environmental issues (Schmidt, Ivanova, & Schäfer, 2013), we hoped to maximize coverage of wildlife trade issues that might have not been documented in government records. We first scanned each newspaper published from January 1, 2010 to December 31, 2015 and searched for any news items about wildlife trade and/or poaching. As wildlife trade is secretive, we are aware of many possible gaps in these data. We attempted to address them by cross-checking and updating data from the CBI and formal proceedings by the DFO, DNPWC offices, and newspaper reports. Using multiple sources of data may lead to false positives, so we checked multiple entries by location, date and quantity of seizure, to reduce this possibility. We thus believe that our data provide the best representative sample of wildlife trade currently available in Nepal, and that our methods are both exhaustive and robust given the clandestine nature of the topic.

### 2.2 Data analysis

Our data included arrest cases, which covered both seizures of wildlife body parts—which mostly involved arrests of people in possession of contraband—and arrests of people in connection with wildlife trade. We separated data by seizure and arrest only, and by wildlife species, taxonomic group (mammals, birds, reptiles, Actinopterygii, other fish, and unidentified), origin (non-native, native, and unknown), IUCN’s threatened species status (critically endangered, endangered, and vulnerable), CITES Appendix status (Appendices I, II, II, including not listed and unidentified), arrest/seizure location (by district) and quantity of each seizure. We found that wildlife seizure data were not consistently quantified. Wildlife skins and bones, for example, were reported in total number, volume and/or weight in different cases. Such problems posed difficulties in data aggregation and subsequent analyses, so we carried out analyses separately for seizure and arrest cases. We used linear regression to assess annual trends of seizures and arrests-only during the five-year period. We sorted wildlife species separately in an increasing order in terms of the number of body parts and weight in seizure cases. We then assigned the position of respective wildlife species as a trade score, for which we also calculated the overall trade score for each species by combining the two separate scores. While this method is rather crude, it was the most effective available given that various offices recorded confiscated items differently.

Illegal wildlife trade includes a coordinated network of several tiers of operatives ranging from poachers to collectors, distributors and consumers (Heinen & Chapagain, 2002). We considered that illicit trade events of any single target species (elephant, rhinoceros, leopard, tiger, red
panda, and pangolin) in the same time (year) were connected and constitute a network. This assumption emanates from Crime Pattern Theory (CPT), which posits that any crime is not a random event, but occurs in a systematic fashion tied to the geospatial movement of offenders (Brantingham & Brantingham, 2008). CPT has been used previously in conservation research (Kurland, Pires, & Marteache, 2018). Criminal acts occur in areas where the offenders find low risk zones for capture that they learn from clues and past experiences. We therefore examined activity patterns of offenders in a subset of time (year) to discern potential trade networks.

Thus, in our data, we assumed that any arrest case in 2013, both confiscated and arrest only, for tiger, for example, is connected to other tiger arrest cases in the same year. We included both confiscated and arrest-only data to discern a coordinated time-bound network of tiger trade. This, however, does not mean that tiger cases in 2014 are not linked with cases in 2013, since we presented the tiger trade network among districts for the 5-year period. We therefore developed an adjacency matrix by district and year and computed network analyses of the six species of main interest (i.e., tiger, leopard, rhinoceros, red panda, pangolin, and elephant) using the “igraph” package (Csardi & Nepusz, 2006) in R v.3.0.2. Nodes in our analyses represent districts and vertexes are the number of congruent seizure events within the same year. We calculated eigenvector centrality and transitivity of each network using “igraph.” Eigenvector centrality is the measure of centrality in the network, which evaluates both the number of connections of a node and connectedness of its neighbors. Transitivity is the probability that the adjacent edges of a node are connected and are equal to 6 times the number of triangles (a loop of length three) divided by the number of paths of length two (Newman, 2010). We used “igraph” and “circlize” packages (Gu, Gu, Eils, Schlesner, & Brors, 2014) to construct plots of the trade network, where we deleted nodes having node degrees less than median values to improve clarity in the plots.
3.1 | Nature and temporal patterns of wildlife trade

Altogether, 830 wildlife-related arrest cases were reported between January 2011 and December 2015 in Nepal. Most of them were seizures of wildlife (live or death animals, or their body parts; 71% of a single species (87%), but there were reports of as many as five different species in some single arrest cases \((n = 830, \text{min} = 1, \text{max} = 5, \text{mean} = 1, \text{mode} = 1, \text{variance} 0.192)\). The most common species in multiple-seizure arrest cases was common leopard \((n = 9)\), which congruently occurred with tiger \((n = 5)\), pangolin \((n = 4)\), and red panda \((n = 2)\); Figure 2).

Body parts of tigers were confiscated in seven cases, mostly with leopards \((n = 5)\), pangolin \((n = 3)\), and red panda \((n = 2)\). Musk deer and bear were confiscated together in two cases (Figure 1).

Arrests of convicted people included 35 wildlife species described to the species-level and 25 species to the genus level (Figure 2, see Supporting Information, Supporting Information).
Appendix S2 for details). The most reported seizure cases were of common leopard (Panthera pardus; 17%), followed by pangolin (both Manis crassicaudata, M. pentadactyla; 12%), Bengal tiger (Panthera t. tigris; 10%), red panda (Ailurus fulgens; 9%), greater one-horned rhinoceros (Rhinoceros unicornis; 7%), bear (three species occur in Nepal: Ursus arctos, Ursus thibetanus, and Melursus ursinus; 6%) and deer (Muntiacus muntjac, Axis axis, Rusa unicolor, etc.; 6%). Nearly 71% of arrests with confiscation were associated with globally threatened species (endangered 38% and vulnerable 33%) whereas unidentified species accounted for 14%. In terms of the origin of specimens, 97% of arrests with confiscation were associated with native species (i.e., species found in Nepal) although the origin of most traded specimens was unclear. Mammals were the top-most taxonomic group in term of arrest case (81%), followed by birds (7%) and reptiles (3%). Actinopterygii and other fish contributed less than 1% of total arrest cases. CITES Appendix listed species accounted nearly 65% of seizure cases (57%—Appendix I, 4%—II and 1%—III), whereas CITES nonlisted species and unidentified species made up 14 and 21%, respectively.

Our database showed that leopard parts (hides, skulls, tooth, bones) totaling 429 pieces, in additional to 109.75 kg of body-parts, were seized from 32% of the districts in Nepal. Seizures of pangolin included scales (39 kg, 311 pieces) and whole bodies (n = 8) from 18 different districts. Tiger seizures included body parts (585 pieces, 798.93 kg) and whole bodies (n = 2) from 19 districts. Similarly, seizures of bear comprised of gallbladder pieces (n = 44), gallbladder weights (2.6 kg), dried meat pieces (n = 3), and bones (n = 41) from 13 districts. Seizures of musk deer included 10 whole musk-pods, a total of 1.5 kg of dried musk-pods, hides (n = 4), skulls (n = 26), and meat (0.5 kg) from 14 districts. Among species exotic to Nepal, African birds accounted for most (n = 119 specimens), but wool or “shahtoosh” of Tibetan antelope confiscated from Gorkha and Dadhing districts constituted the largest wildlife seizures made in Nepal (1,550 kg) during the study period. Large-scale seizures (>50 kg) in arrest cases included tiger, pangolin and Tibetan antelope. Seizures of red panda included 2 live animals and 81 pieces of skins from 10 districts. Seizure of rhinoceros included mainly horns from 17 districts of Nepal, which were reported both in numbers (31 pieces) and by weight (3.7 kg).

There was a significantly increasing trend of arrest cases for all species (F = 16.15, R² = 0.83, p = 0.03) during five-year period, and for confiscated cases involving
leopard ($F = 13.79$, $R^2 = 0.82$, $p = 0.034$). However, a significantly decreasing trend of confiscated cases was observed for rhinoceros ($F = 13.66$, $R^2 = 0.82$, $p = 0.034$) between 2011 and 2015 (Figure 3). Over the course of the study period, seizure amounts did not increase significantly when data were analyzed separately based on numbers and weights for tigers, pangolins, elephants, musk deer, red pandas, and all species combined.

Seizure databases included a variety of wildlife parts such as tusk, hair and bones of elephant, hides of leopards, musk-pods of musk deer, horns of rhinoceros and scales of pangolin. A total of 2,088 kg of body parts, in addition to 1,721 pieces not reported by weight, were recovered from seizure cases. Bengal tiger ranked highest in terms of number of seizures of body parts (33%), followed by leopard (24%), pangolin (18%), bear (8%), rhinoceros (4%), red panda (5%), and musk deer (2%). When ranked by total weight, tiger constituted more than half of all seized wildlife (57%), followed by pangolin (35%), leopard (35%), and elephant (1%). Overall, tiger was the most traded species, followed by pangolin and common leopard, bear, elephant, and musk deer (Figure 4).

### 3.2  Illicit trade networks

The database showed that arrests with confiscation were made from 60 districts in Nepal (range 1–190, mean $= 14.91$, $SD = 25.85$), where Kathmandu district accounted for more than 20% of all seizures, followed by Chitwan (5.5%) and Sindhupalchok (4.7%). Illicit trade of tiger parts showed a highly connected network (transitivity $= 0.75$) and suggested two clusters: (a) Kathmandu and peripheral districts and (b) Kanchanpur and peripheral districts (Figure 5).

Kanchanpur had the highest node connection, mainly with Bardia, Darchula, and Surkhet districts. Kathmandu showed connectivity with Makawanpur, Bara and Parsa districts. Eigenvector centrality was highest for Kathmandu (1), Bardia (0.93), and Kailali (0.87; Figure 5).

The illicit trade network for common leopard showed connectivity (transitivity $= 0.71$) with 22 districts. Kathmandu had the highest node value followed by Kavrepalanchok and Lalitpur. Eigenvector centrality was highest for Kathmandu (1), Kavrepalanchok (0.95), Lalitpur (0.91), Kailali (0.85), and Dang (0.85; Supporting Information, Appendix S1, Figure S2). Kathmandu and Chitwan were the major hubs for the illicit rhinoceros trade network with several districts as connecting points (transitivity 0.80). Eigenvector centrality was highest for Chitwan (1), followed by Kathmandu (0.96), Kailali (0.93), Lalitpur (0.87), Nawalparasi (0.87), Bardia (0.87), Makawanpur (0.87), and Morang (0.87; Supporting Information, Appendix S1, Figure S3). The illicit network for red panda was centered in Kathmandu, with a strong network with its peripheral districts (except for Jhapa; transitivity $= 0.75$). The eigenvector centrality was high in Kathmandu (1), Nuwakot (0.97), Bhaktapur (0.82), Rasuwa (0.82), and Sindhupalwhok (0.82; Supporting Information, Appendix S1, Figure S4). The network of illicit pangolin trade suggested its hub is in central and eastern Nepal (transitivity $= 0.77$; Supporting Information, Appendix S1, Figure S5). Eigenvector centrality showed that Sindhupalchok (1), Bhaktapur (1), and Darchula (1) were major trade hubs, followed by Kathmandu (0.91) and Jhapa (0.91), Sankhuwasabha (0.84), and Kavrepalanchok (0.78). Three districts of southern Nepal (Bardia, Kailali and Jhapa) constituted an elephant trade network (Supporting Information, Appendix S1, Figure S6).

### 4  DISCUSSION

Our study provides the first detailed national assessment of illicit wildlife trade in Nepal. Our analysis suggests that wildlife trade of protected species is widespread (67% districts of Nepal) and increasing (all species, red panda, and leopard). We also documented seizures of multiple species in single arrest cases, mostly of tigers and leopards, pangolins and leopards, and bear and musk deer. The seizures were reported more often in (a) Kathmandu, (b) species home range districts, and (c) areas bordering India and China. This suggests that well-organized illicit wildlife trade syndicates still occur in Nepal, and that Nepal acts as both a source and a transit country. It is unknown, however, whether all seized wildlife parts originated from Nepal although 97% of reported species are native to the country. Future research could focus in this direction.

Illegal wildlife trade was largely uncontrolled in Nepal until the 1990s. The capital of Nepal, Kathmandu, had many open shops selling wildlife parts, mainly fur products marketed to tourists made of wild cats and other mammalian carnivores, during the 1980s (Barnes, 1989). Heinen et al. (1995) documented more than six dozen such shops in operation in 1990/1991 that had several hundred fur coats in total, made from more than 20 protected species. Such open merchandizing came to an end in large part and/or went mostly underground because of strict enforcement of legislation. Various legislation and regulations in Nepal (e.g., National Parks and Wildlife Conservation Act 1973, Forest Act 1993, etc.) impose a complete ban on wildlife hunting and trade, and suspected persons are liable to criminal prosecution based on the species in question. Small-scale local market
seizures of barking deer, bharal, blue bull, fish, goral, monkey, frogs, parrots, peafowl, songbirds, turtles, pigeons, porcupines, rabbits, jungle fowl, sambar deer, spotted deer, Himalayan tahr, and wild boar are suggestive of local-level hunting for subsistence consumption and/or religious/cultural proposes (Bhattarai et al., 2016; Fortier, 2009; Jackson, 1979; Paudel, 2012; Sharma et al., 2018). We also recorded seizures of common species along with globally threatened species of main interest here (tigers, leopards, one-horned rhinoceros, pangolins, elephants, and red pandas), suggesting possible nodes of hunters or collectors feeding multiple species-specific trade networks. It is possible that these were originally local-levels hunters who later become involved in international trade due to new opportunities that improved household income.

Although illicit tiger trade did not increase significantly in terms of the number of cases or seizure quantities, tiger remained the most traded species during our study period, suggesting that tigers are still being poached and demand persists (Stoner & Pervushina, 2013). Our results showed two clear clusters of the tiger trade network corresponding to tiger strongholds in Nepal. Bardia and the adjacent Banke National Parks and Sukhaphanta National Park in western Nepal constitute the second largest tiger population in the country, and both are contiguous with tiger-bearing protected areas of India: Dudwa National Park and Katerniahat Wildlife Reserve (Wikramanayake et al., 2011). Several other India tiger reserves (e.g., Corbett and Rajaji National Parks) are located close but nonadjacent to the western border of Nepal. This cluster includes areas of western and northwestern Nepal boarding both India and China that offer the shortest routes between those two countries, given that the direct borders between India and China across large stretches of the Himalayas are under dispute and are largely closed.

We thus highly suspect that a coordinated international illicit tiger trade syndicate operates there and likely involves poaching of animals from both India and Nepal to supply the Chinese market for tiger bone and other parts. The second cluster includes Kathmandu and its peripheral districts. Interestingly, we did not find Chitwan district as a major node of illicit tiger trade although it supports Nepal’s largest tiger population (DNPCWC/MoFSC/GoN, 2007). Here, a small node exists connecting Kathmandu with areas along the Nepal–China highway. Karmacharya et al. (2018) determined that Nepal is also a source country for illicit tiger trade by examining DNA microsatellite loci of confiscated body parts (Karmacharya et al., 2018). Stoner and Pervushina (2013) reported illicit tiger trade hotspots along the India–Nepal border. Our results reinforce these findings and suggest that poached tiger parts likely all end up in China. Although China imposed a trade ban on the importation of tigers and rhinoceros and their parts, many experts call for much stronger actions to reduce demand in that country (Ellis, 2005; Nowell, 2010).

Although seizures of body parts of common leopards were reported from 22 districts, our results showed illicit leopard trade hubs in central and western Nepal. Common leopards are distributed throughout Nepal (Jnawali et al., 2011) and are the most problematic wildlife species in terms of human and livestock fatalities and injuries (Acharya, Paudel, Neupane, & Köhl, 2016). We suspect that leopards killed in retaliatory actions enter into the illicit wildlife trade, and that poachers may benefit from increasing public resentment. We suspect that leopard trade might be of significantly larger scales than reported in our data, which is similar to the findings of Mondol et al. (2015), who recorded widespread leopard poaching throughout India, with central India as a poaching hotspot.

Network analysis for rhinoceros showed that Kathmandu and Chitwan were closely connected and each had a cluster of districts. This suggests that Chitwan National Park, which harbors the largest rhinoceros population in Nepal (Jnawali et al., 2011; Subedi et al., 2013), and Kathmandu, the capital of Nepal, were rhinoceros trade hotspots. Our results suggest that there is a rapidly decreasing trend of arrest cases related to rhinoceros, which supports government reports of zero poaching of rhinoceros for several years since 2011 (Acharya et al., 2016). Our network pattern may have corresponded with arrest cases of poachers reported by law enforcement agencies, and seizure cases may be either from previously killed rhinoceros and/or during trafficking from India to China through Nepal. We suspect that some of these seizures may be fake horns, which enter the market at various points by smugglers to get high prices.

Kathmandu was the major trade hub for red panda with adjoining districts (e.g., Nuwakot, Bhaktapur, Rasuwa, and Sindupalchok). These districts form a large portion of the Nepal-China corridor, and cover parts of prime red panda habitat in Nepal (e.g., Langtang National Park in Rasuwa District, directly north of Kathmandu). One record was reported from Jajarkot (far-western Nepal), and there are now growing reports of red panda trade from that area (Damber Bista, Red Panda Network, personal communication). Although there were very few seizures of red pandas along an international supply chain after being listed by CITES (Glatston, 2010), they were traded for sport and skins locally in India (Mishra, Madhusudan, & Datta, 2006), China (Wei & Zhang, 2011), and Myanmar (Min, 2012). In China, pelts and tails have been traded at high prices for cultural
purposes (Wei & Zhang, 2011), but Xu and Guan (2018) reported an end to red panda trade in China after enforcement of national laws. Much more research is warranted on market linkages for red panda from Nepal.

The illicit pangolin trade network suggested central and eastern Nepal as major trade hotspots. In eastern Nepal, seizures were reported from the lowland region boarding India, the mid-hills and high mountains adjacent to China. We suspect pangolin seizures were from local populations, as they are easy to catch and transport because of their small-body size and wide distribution throughout forests, including human-modified landscapes (e.g., human settlements and agricultural lands) (SMCRF & PHG, 2016). Jhapa and Sankhuwasabha Districts (including Ilam) are likely major transit points of pangolin to India and China. The same is true in Central Nepal where Kathmandu, Sindulpalchowk, Rasuwa, Bhaktapur, Lalitpur, and Makawanpur Districts may serve as trade routes from Nepal to China.

In conclusion, we confirm that illicit international wildlife trade networks for a number of rare species (e.g., tiger, leopard, pangolin, and pangolin) exist in Nepal, suggesting an urgent need to focus on local and national circumstances that drive trade (Oldfield, 2003). We suggest that improving law enforcement is critically important but, alone, does not reduce illicit trade. There is also need of increased community awareness and participation in conservation, capacity strengthening of conservation organizations and reductions in rural poverty that, together could be effective over the long-run. However, greater vigilance in trade and business routes (e.g., highways and airports) connecting Nepal’s business centers and Nepal’s neighbors, is of urgent priority.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS
Prakash K. Paudel and Krishna Prasad Acharya conceived the ideas and collected data. Prakash Kumar Paudel developed methodology, conducted the analysis and wrote the first draft of the manuscript. Krishna Prasad Acharya, Shant Raj Jnawali, Hem Sagar Baral, Joel T. Heinen edited, reviewed and revised subsequent drafts.

DATA AVAILABILITY STATEMENT
All data are included in the manuscript and appendix.

ETHICS STATEMENT
No ethics approval was required for this research.

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**SUPPORTING INFORMATION**

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

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