

Live wild bird exports from West Africa: insights into recent trade from monitoring social media

Running Title: Monitoring West-African bird trade on social media

Alisa J. Davies^{a,b,*}, Ana Nuno^{a,c}, Amy Hinsley^{d,e} & Rowan O. Martin^{f,g}

^a Centre for Ecology and Conservation, College of Life and Environmental Sciences, University of Exeter
Cornwall Campus, Penryn, Cornwall, TR10 9EZ, UK

^b World Parrot Trust, Hayle, Cornwall, TR27 4HY, UK

^c Interdisciplinary Centre of Social Sciences (CICS.NOVA), School of Social Sciences and Humanities (NOVA
FCSH), NOVA University Lisbon, Avenida de Berna, 26-C, 1069-061 Lisboa, Portugal

^d Wildlife Conservation Research Unit (WildCRU), Department of Zoology, University of Oxford, Oxford, OX1
3SZ, UK

^e Oxford Martin Program on Wildlife Trade, Oxford Martin School, University of Oxford, Oxford OX1 3BD, UK

^f Africa Conservation Programme, World Parrot Trust, Hayle, Cornwall, TR27 4HY, UK

^g DST-NRF Centre of Excellence at the FitzPatrick Institute of African Ornithology, Department of Biological
Sciences, University of Cape Town, Cape Town, 7700, South Africa

* Corresponding author (adavies@parrots.org).

Word count: 6726

Keywords: Caged-bird trade; Disease risks; Online trade; Pet trade; Wildlife trade

Acknowledgements

A special thanks to Nik Borrow and Benedictus Freeman for their support and assistance with bird
identification.

Financial Support

This work was supported by the University of Exeter, World Parrot Trust and the European Union's Horizon
2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement
SocioEcoFrontiers (A.N., grant No. 843865).

Conflicts of Interest: The authors declare none

SUMMARY

The expansion of wildlife trade on social media presents many challenges but also opportunities to gain insights into areas of trade where there is little recent data. West Africa has historically been a major source of wild birds in international trade but in 2007, the requirement for CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Parties to monitor a host of West-African species ended and there is little data regarding current trade. To address this gap, we surveyed trade-related posts created by known traders from 2016 to 2020 on a popular social-media platform to identify species composition, trade routes and potential conservation and biosecurity risks. We identified 427 social-media posts featuring a broad taxonomic diversity of birds, including 83 species from 26 avian families, including nine CITES-listed species, four listed in IUCN threatened categories and 19 associated with alien introductions linked to bird trade. Disease risks were identified, with multiple species housed together in densely-stocked facilities and nine species recorded as posing a disease potential risk. Using novel analyses of post-engagement, we observed social-media posts facilitating connections with users across the globe. Trade-related engagement was particularly directed from countries in the Middle East and South Asia; notably India which has strong domestic restrictions on the importation of wild birds. Further research is needed to monitor the impact of trade from this region, as data regarding the population status and volume of trade in many observed species is largely absent.

INTRODUCTION

The international wildlife trade is a multi-billion-dollar industry, with the live pet trade representing a major component (Bush *et al.* 2014). While the pet trade offers economic opportunities (Robinson *et al.* 2018), it also poses risks, depleting wild populations (Tingley *et al.* 2017), introducing invasive species (Reino *et al.* 2017) and endangering animal welfare (Baker *et al.* 2013). Furthermore, the COVID-19 pandemic grimly demonstrates the dangers posed by zoonotic disease transmission (Swift *et al.* 2007, Oxford Martin Programme 2020).

The pet trade is expected to grow with rising affluence (Challender *et al.* 2015) and media representation of exotic species (Nekaris *et al.* 2013), bringing additional challenges. One of these is the expansion of wildlife products onto ecommerce and social-media platforms (Sajeva *et al.* 2013; Lavorgna 2014). Limited enforcement on mainstream websites means that trade has largely not yet shifted to anonymous networks (the ‘dark web’) (Roberts and Hernandez-Castro 2017). Therefore, the internet provides a unique opportunity to gain insights into legal and illegal wildlife trade (Vaglica *et al.* 2017). In particular, social media can facilitate a broad range of functions and can provide both public and private spaces and communication channels (Lavorgna 2014).

Recent studies of trade on social media have investigated a broad range of taxa, including mammals (Siriwat & Nijman 2018), parrots (Martin *et al.* 2018) and orchids (Hinsley *et al.* 2016). Although social-media posts rarely show transactions (Xu *et al.* 2020), they can provide information on species composition, welfare and hygiene standards, and trade routes. While some studies have aimed to quantify trade by identifying unique advertisements (e.g., Morgan and Chng 2018), there has been little consideration of the heterogeneity of ways that traders advertise and promote species, such as posts without sale-related text (Xu *et al.* 2020) or posts featuring shipments (Martin *et al.* 2018). Furthermore, the content and patterns of post-engagement, particularly in comments, can provide opportunities to understand the ways in which social media facilitates trade (Morgan and Chng 2018) and to explore trade networks but have to date received little attention.

In this study, we sought to use social-media activity to explore the current trade in West African birds. This region is of particular interest because prior to the EU ban on imports of wild-caught birds in 2005, Senegal, Mali and Guinea were major exporters of live birds, responsible for 70% of exports in birds listed in the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) (Reino *et al.* 2017). However, 116 species that accounted for the majority of trade from these countries were removed from CITES Appendix III in 2007 (CITES 2007), meaning that CITES Parties were no longer required to report on trade in

these species. Since this time there has been little monitoring of trade in birds from the region and little is known about the current species composition, scale or direction of trade. Existing published data is outdated (e.g., Ruelle and Bruggers, 1983; Clemmons 2003) and there is little monitoring of non-CITES-listed species, including frequently-traded songbirds (Passeriformes) (FAO 2011; CITES 2019). At the 18th CITES Conference of Parties, calls were made for more data on trade in songbirds, with trade in Africa highlighted as the least well understood on a continental scale (CITES 2019). The region also contains several regularly-traded bird species of conservation concern, particularly grey and Timneh parrots (*Psittacus erithacus* and *Psittacus timneh*), both of which are listed as Endangered on the IUCN Red List (IUCN 2020) as a result of overexploitation for the international pet trade (Birdlife 2020). With the decline in demand for birds in Europe, and the Middle East and Asia playing a larger role in driving demand for exotic pets (Bush *et al.* 2014), research is needed to identify the risks to biodiversity and humans posed by new trade patterns.

Aiming to gain an insight into the composition, direction and implications of trade from the region, we analysed social-media posts featuring West African birds from previously known bird traders over a four-year period to gain insights into patterns of trade. We further analysed information on trade routes extracted from post images and text, and investigated spatial patterns of post-engagement in order to understand the role of social media in facilitating connections with buyers around the world.

METHODS

Background and ethics

We gathered posts from an international social-media platform that was selected for its popularity and range of functions. Following on from similar studies (Hinsley *et al.* 2016; Martin *et al.* 2018), the platform will not be explicitly named. Information was only gathered if we could reasonably assume that it was intentionally made public. Traders made posts to solicit trade and the only personal information that was analysed was location information stated clearly on the page. Identifying information was removed from the database following analysis and no de-anonymising information has been published. Finally, there was no communication with users. The study was approved by the University of Exeter's ethics committee (eCORN002679 v3.4) and followed ethical guidance from the British Psychological Society (2017) and Kosinski *et al.* (2015).

Study approach and sampling strategy

Our study approach had two key research objectives and incorporated three main analytical streams: species analysis; Cargo Tracking Code analysis; and content analysis of post and comment text, which fed into both objectives (Fig.1).

Insert Figure 1

Following a pilot study (see Supplementary Materials 1), we identified nine pages known a-priori to be involved in commercial trade of birds from West Africa states (Guinea, Senegal and Mali), based on intelligence from the World Parrot Trust, that had at least one post advertising trade or had comments asking about trade since June 2017. These pages were identified as ‘seed-pages’ and posts created and shared by them were named ‘S-posts’. We then gathered data on pages that were associated with S-posts by commenting, sharing, being tagged in a comment or having a post shared to their page, referred to as ‘A-pages’. In order to capture comment engagement, we also recorded any S-posts that had been shared by A-pages, which we labelled ‘A-posts’.

Data collection

We gathered data between April-June 2020, where we surveyed all relevant posts from a four-year period between 1 June 2016 and 1 June 2020. We accounted for the heterogeneity in ways traders might use posts by recording any post featuring or related to trade in West African birds including updates to profile and cover pictures, shared posts, live videos and posts featuring generic photos copied from other sources. We recorded posts shared from before the sampling period but not the original posts. Duplicate posts were recorded in order to capture comment engagement. However, to avoid duplication in species identification, all posts containing the same combination of media files (e.g., three photos containing species x and y) were identified using the same post identification code (PIC). PICs were then used as the sample unit for species identification rather than posts (further details on data collection are provided in Supplementary Materials 1).

We extracted photos, videos, post text and comments from all relevant posts and examined them to derive our key variables (Table 2). We collected comment text using an online comment-exporting service (<https://exportcomments.com/>). Where necessary, we translated non-English text using Google translate (<https://translate.google.com/>). To give an indication of private engagement, we recorded and compared the total and publicly-visible number of comments and number of times the post had been shared. All seed-pages and A-pages were given a unique random ID code and any stated location information recorded.

Species analysis

Species identification was conducted in consultation with two experts in West African birds following a percentage agreement test (see Supplementary Materials 1). Where possible, the species, genus and family of visible birds was recorded. If it was not possible to identify species or genus with reasonable certainty, only the family was recorded. The number of birds for each species in each post was estimated using categories 1-10, 11-100 and 100+ (Martin *et al.* 2018); image quality and movement in and out of shot prohibited greater precision. This does not represent the true volume, as posts were often not independent because they showed the same images or facilities. To check if images were copied, we checked all photos using Google's reverse-image search function. If the image existed on another site unrelated to the trader, we did not estimate quantity for the species and classified it as 'copied'. We counted the number of PICs that featured an enclosure with more than one species in it and estimated the number of visible co-present species. To estimate the study's adequacy in identifying the species that traders were offering, we calculated a species accumulation curve and an extrapolated species richness estimate (Colwell *et al.* 2012) using the 'vegan' package (v2.5-6, Oksanen *et al.* 2019) with R version 4.0.2 (R Core Team 2020) (see Supplementary Materials 1).

To explore the potential conservation and disease implications of trade in these species, we cross-referenced our list of species with those recorded in relevant databases. The global conservation status of each species was determined using the IUCN Red List of Threatened Species (IUCN 2020). Potential invasion risks were assessed using the Global Invasive Species Database (GISD 2020a), which includes species that threaten native biodiversity, and the Global Avian Invasions Atlas (GAVIA), which is a comprehensive database of historical and contemporary alien introductions and populations (Dyer *et al.* 2017). We assessed health risks using data from the World Organisation for Animal Health (OIE) World Animal Health Information System (WAHIS)-Wild interface 2008-2017, as collated by Emre Can, D'Cruze and Macdonald (2019). This database gathers incidence reports from OIE member countries regarding 54 diseases in wild animals thought to pose a potential disease risk to humans and other animals.

Trade mapping

We identified trade routes from posts featuring transport carriers and that stated a shipment's destination. Where possible, Cargo Tracking Codes visible in imagery were used to identify the date, route and airline of shipments using a tracking database (<https://www.track-trace.com/aircargo>).

We determined the location of users primarily using the country named in the page description or stated as the location of birth and/or residence (Di Minin *et al.* 2015). When the location of residence and birth differed, the location of residence was recorded because it was more recent. For seed-pages, this was cross-referenced using information from posts and comments, which led to the location being corrected for one seed-page.

Content analysis

We used content analysis to identify posts and comments where an interest in selling or buying birds was explicit. All text was independently read and categorised by two researchers (A.D. and A.N.) and any disagreements were discussed and resolved. Post text agreement was 97.5% and comment text agreement was 96.5%. Post text explicitly offered trade if it stated that the reader could have the bird; referred to animals being for sale, in stock or available; or referenced a price. Text referencing shipments, shops or businesses without meeting these criteria were not counted.

Comments made by seed-pages on their own posts were excluded from analysis, as were comments only containing images. A comment enquiring about trade either expressed that the individual wanted an animal; asked about price or the possibility of exporting to a country; or requested further contact with the trader. Comments only asking for the trader's location or about other shipments without meeting other criteria were not counted. The location of all A-pages and those A-pages that made trade enquiries were mapped using the rworldmap version 1.3-6 (South 2011) to investigate spatial patterns of engagement.

Descriptive summaries were produced and due to high skewness, numerical data was summarised with the median and interquartile range. Species frequency was summarised as the number and percentage of PICs in which a species appeared.

RESULTS

We identified a total of 427 relevant post, with 221 unique post identification codes (PICs), that related to the West African bird trade, of which 341 (79.9%) were posts by trading pages (S-posts), and 86 (20.1%) were

shared by other users (A-posts). There was an average of one entry per PIC (1–2, range = 1–23) and an average of 34 posts per seed-page (14.5–59, range = 2–99). Post entries were present in 44 of the 48 months of the sampling period, with an average of five S-posts per month (3–10, range = 1–46). We identified 574 A-pages, 63 of which shared A-posts. Location could be determined for 378 A-pages (65.9%). A total of 1563 comments by 515 pages were collected from 182 posts. A third of shares of S-posts (37.6%, n = 97) and a small proportion of comments (7%, n = 118) were not publicly visible so could not be recorded.

Species analysis

We identified birds in 199 PICs (90%), whereas in other PICs birds were either not visible, a whole photo album was shared or there was no media. In 45 PICs (20.4%), at least one identification was not made at species level. Shipments appeared in 50 PICs (64 S-posts) and birds were explicitly advertised in 74 S-posts (21.7%).

We recorded 721 identifications, with an average of one identification per PIC (1–4, range = 1–25). This included 26 families, 51 genera and 83 species (Supplementary Information 2). Species could not be determined with certainty for 69 identifications, most frequently in the families Estrildidae (n=28), Viduidae (n=21) and Sturnidae (n=9). Therefore, several finch, starling and whydah species may have been present but could not accurately be identified. A species accumulation curve, with a predicted total species richness of 95.4 ± 7.6 (Fig.2), suggested that the study effort was sufficient to capture around 87% of the species presented by the traders in this study.

Insert Figure 2.

Parrots were frequently represented, and accounted for the two most common species, namely rose-ringed parakeets (*Psittacula krameri*) (26.2%, n=58) and Senegal parrots (*Poicephalus senegalus*) (18.6%, n=41). Furthermore, Psittacidae (n=68) and Psittaculidae (n=61) were the most common families. The Estrildidae family was also well represented (26.2%, n=58), with yellow-fronted canaries (*Crithagra mozambica*) being the third most common species (17.2%, n=38).

Four species are listed as threatened on the IUCN Red List and 22 are considered to be in decline (IUCN, 2020), while nine species were listed on the CITES appendices (Table 2). Three species listed on CITES Appendix I, namely grey parrots, Timneh parrots and black-crowned cranes (*Balearica pavonina*), were shown and advertised by traders. Excluding posts created before their listing date (02/01/17), grey parrots were featured in

eight S-posts (seven PICs), with seven S-posts explicitly offering trade, while Timneh parrots were featured in six S-posts (four PICs), with two featuring shipments and four containing trade-related text. Black-crowned cranes appeared in one post after their listing date (26/11/19), although this did not advertise trade.

Insert Table 2

Two species were not previously listed by the IUCN as being used for ‘pet/display animals’ under ‘Use and Trade’ (IUCN 2016). These two species were the Adamawa turtle dove (*Streptopelia hypopyrrha*), observed in nine S-posts (nine PICs, all 1-10 individuals) by a single trader; and the four-banded sandgrouse (*Pterocles quadricinctus*), observed in six S-posts (three PICs, all between 11-100 individuals) by three seed-pages.

Of the observed species, 42 had at least one alien population or introduction recorded in the GAVIA database and in 17 species, at least one instance was attributed to the caged-bird trade. Three species, the rock dove (*Columba livia*), common waxbill (*Estrilda astrild*) and ring-necked parakeet, were also listed in the GISD.

The OIE WAHIS-Wild database recorded disease incidents in nine observed species (Appendix S1). Posts showed enclosures that were frequently stocked to high densities and contained multiple species, with 61 PICs featuring at least two co-housed species and some enclosures containing at least eight species (equivalent conditions shown in Supplementary Information 3)

Trade route mapping

Seven S-posts from two seed-pages, both based in Mali, stated the destinations for shipments that occurred within the sampling period. Five Cargo Tracking Codes (CTCs) corresponding to verified shipments were extracted from four S-posts by three seed-pages, four exporting from Bamako, Mali via Ethiopia Airlines and one exporting from Diass, Senegal via Turkish Airlines (Fig. 3). Four shipments occurred within two months of their respective social-media posts but in one case, the post was made over a year after the shipment occurred. In one post, CTCs revealed that post text data was inaccurate, naming only one destination when the CTCs indicated two shipments. The in-text data from this post was discounted.

Insert Figure 3.

We excluded 507 comments for being made by the trader on their own post and 131 for not containing text content, leaving 925 comments for analysis. Trade enquiries occurred in 185 comments by 130 A-pages, of which location could be identified for 93 (Fig. 4).

Insert Figure 4.

DISCUSSION

Live birds have been trapped and exported from West Africa for decades but recent information on this trade is lacking. Our study revealed how social media is being used to promote trade and describes substantial international trade in a remarkable diversity of Afrotropical bird species. This trade has potential implications for conservation, animal welfare and biosecurity, with several species considered threatened and identified as vectors of infectious diseases. Employing a novel approach to analysing post-engagement yielded insights into how social media facilitates trade connections around the world, and identified possible hotspots for trade, particularly in the Middle East and southern Asia.

The prediction of total species richness derived from the species accumulation curve suggests that our study captured a large proportion of the species promoted within our sample of traders. As we do not have a means to estimate the proportion of traders from the region represented by our sample, making inferences to the general population based on our sample must be done with caution. Nevertheless, the majority of species observed have been recorded previously in exports from the region including in trade reported to CITES (www.trade.cites.org: UNEP WCMC, Cambridge UK) and other country-specific reports - e.g., Senegal (Ruelle and Bruggers 1983). This suggests that the trade observed in this study is broadly a continuation of practices that have taken place for at least several decades. We also identified species that have not been previously recognised as being traded for pet and exhibition purposes on the IUCN Red List, demonstrating how this approach can provide new insights into the scope of bird-trade in the region.

Implications for conservation

While most of the species that were observed are currently categorised by the IUCN as ‘Least concern’, little is known of the status of many wild bird populations in West Africa or the impact of trade (Dendi *et al.* 2017). Several species, particularly songbirds such as the yellow-fronted canary, have been exported in very large

quantities in the past and although we were unable to accurately quantify the volume of current trade, it was evident that large numbers continue to be captured.

Songbirds captured from the wild often have high levels of mortality in the first few days (Alves *et al.* 2012; Shepherd *et al.* 2004), therefore the birds seen in trade likely under-represents the true volume of birds captured. The potential threat posed to African songbirds by the live-bird trade is demonstrated by the population collapse of European goldfinches (*Carduelis carduelis*) in western North Africa, where populations have declined by nearly 57% in the last 26 years (Khelifa *et al.* 2017). Concerningly, the practice of capturing goldfinches using mist nets may also be impacting palearctic migrants, many of which are in decline (Khelifa *et al.* 2017). In our study, we observed European turtle doves (*Streptopelia turtur*), a migratory species that has decline by 98% in the UK since the 1970s (Burns *et al.* 2020). While it is not possible to know if these European turtle doves were specifically targeted for trade, capture on overwintering grounds represents another threat to this imperilled species.

Several species of parrots were among the most frequently observed birds in our study. Parrots are among the most popular birds in trade, with African parrots making up three of the four most traded bird species listed on the CITES appendices between 2010 and 2014 (Martin 2018). Recent field studies have highlighted how populations of African grey and Timneh parrots have undergone rapid population declines in parts of their range due to demand for trade (e.g, Hart *et al.* 2016; Lopes *et al.* 2018), prompting CITES Parties to transfer them to CITES Appendix I in 2017. Concerningly, both species were observed on multiple occasions with some posts of grey parrots featuring over 100 specimens. However, the majority of these occurred before the species was transferred to Appendix I when legal international trade in wild-sourced specimens for commercial purposes ended; 59% of unique posts of Grey and Timneh parrots occurred in the six-month period before the Appendix listing, with the rest occurring throughout the subsequent 3.5 years of the study. Senegal parrots and red-faced lovebirds were also frequently recorded and large volumes of exports have been reported to CITES (Martin 2018). Studies of the status of wild populations of these species are lacking (Martin *et al.* 2014) despite being listed on CITES Appendix II, which necessitates exporting countries to determine that trade is non-detrimental to wild populations.

We also observed several large-bodied species which may be particularly susceptible to over-exploitation due to slow intrinsic rates of population growth (Ripple *et al.* 2017). Among these species were great blue turacos (*Corythaeola cristata*), which have experienced localised declines in West Africa (Annorbah, 2016), and black-

crowned cranes (IUCN Red List *Vulnerable*), which were transferred to CITES Appendix I in 2019 (Kone *et al.* 2007). Raptors were notably absent with only a single crowned eagle (*Stephanoaetus coronatus*) observed in posts.

The potential for wild populations of many of the observed species to sustain current levels of capture is unknown and further investigation is urgently needed, particularly for frequently traded species such as Senegal parrots. Direct field studies may provide valuable insights into the impact of trade and other threats; however, baseline data is frequently lacking and many species have large distributions potentially making it difficult to detect localised impacts. Most trade we observed was overt and legal. Therefore, traders and trappers can be reliable sources of information on the changing status of wild populations (e.g., Hart *et al.* 2016). Information such as price variation, availability and source localities might provide valuable insights into the sustainability of trade.

Implications for the spread of alien species

The global trade in live birds has led to the establishment of numerous naturalised populations outside their native range (Reino *et al.* 2017). These can have significant economic and environmental costs, such as competing with native species (Pimental 2011). Just over half (51%) of the species observed in our study had a record of an alien introduction or population in the GAVIA database, some of which have been extraordinarily successful, and are now globally widespread. Self-sustaining populations of ring-necked parakeets, for instance, have to date been recorded in over 35 countries across Europe, North America, the Middle East and Southern Africa (GISD 2020b). Concerns over the negative impacts of these populations have prompted eradication efforts but these have often proved challenging and there have been calls for greater regulation of international trade to prevent further spread (Shiels and Kalodimos, 2019). Ring-necked parakeets were the species most commonly observed in our study and were often featured in large numbers. Prior to their removal from the CITES appendices in 2007, ring-necked parakeets were among the most frequently reported bird species in trade (Martin 2018) and our data suggests that they continue to be captured and exported in large numbers from West Africa. The scale of this ongoing trade in wild ring-necked parakeets has possibly not been fully appreciated by researchers and decision-makers due to their removal from the CITES Appendices and we strongly encourage greater scrutiny of this trade.

Infectious disease

Birds were frequently seen to be housed in conditions that could promote the development and spread of diseases. Large quantities of birds were observed at high stocking densities with multiple species housed in close proximity within the same room. One of the major recommendations for preventing disease transmission is reducing contact between species (Kareesh *et al.* 2005) and housing species together could also increase the risk of viral recombination (Julian *et al.* 2013). The exportation of birds carrying infectious pathogens risks introducing diseases to importing countries (Swift *et al.* 2007). In 2006, a risk assessment of the health and welfare risks associated with imports of wild birds into the European Union, of which 88% came from the African continent at that time, concluded that the need to continue importation be carefully considered in light of the risks (EFSA 2006). Our study indicates that this threat persists in Asian countries that continue to import wild birds from Africa, as well as to transit countries such as Ethiopia (Siraw *et al.* 2009). Multiple strains of Beak and Feather Disease Virus (BFDV) have been found in wild and captive rose-ringed parakeets in Senegal and the Gambia, as well as in Timneh parrots seized from traders in Senegal (Fogell *et al.* 2018). Prior to their seizure, these parrots were held in a bird exporter's facility in close proximity to a large number of other bird species, suggesting significant potential for disease transfer between species. Spill over of BFDV to wild populations threatens wild populations of endangered parrots (Regnard *et al.* 2014).

Trade routes and engagement

Although we were only able to identify destination countries and trade routes in a limited number of instances, our findings were consistent with previous work that indicates a growing role of the Middle East and Asia in fuelling demand for exotic live animals from Africa (Bush *et al.* 2014). Comments enquiring about trade were concentrated in a few notable hotspots. Countries in southern Asia, particularly India, Pakistan and Bangladesh, represented a large proportion of users making trade-related comments. The extent of trade-related interest suggests that significant demand for African birds may exist in India and highlights the possibility of important and potentially illegal trade routes circumventing restrictions aimed at curbing the spread of Avian Influenza. It is important to note, however, that in most cases it was not possible to verify movements of birds. Furthermore, differences in the number of trade-related comments between countries may be strongly influenced by regional differences in population, internet penetration and preferences for particular social-media platforms.

Patterns of engagement demonstrated the vast potential of social media to enable exporters of wildlife to connect with potential buyers in other countries. People in 56 countries spread across every continent engaged with posts featuring West African birds and many used social media to make initial trade-related enquiries. This lays bare the extraordinary power of social-media platforms to facilitate wildlife trade and raises questions about where responsibility rests for ensuring online trade does not exacerbate the risks the wildlife trade poses to biodiversity, people and the economy. We recommend that our findings be used to guide further research into the role of social media in trade, and the impacts of this trade on wild populations of popular and threatened species.

REFERENCES

- Alves, R.R.N., Lima, J.R.D.F. and Araujo, H.F.P. (2012) The live bird trade in Brazil and its conservation implications: an overview. *Bird Conserv Int* 23: 53-65.
- Annorbah, N.D. (2016). Assessing distribution, abundance and impacts of trade and habitat change in western populations of African Grey Parrot (*Psittacus erithacus*). PhD Thesis. Manchester Metropolitan University,
- Baker, S.E., Cain, R., van Kesteren, F., Zommers, Z.A., D'Cruze, N. and MacDonald, D.W. (2013). Rough trade: Animal welfare in the global wildlife trade. *Bioscience* 63: 923-938.
- BirdLife International (2020). IUCN Red List for birds. Available at: <http://www.birdlife.org>.
- British Psychological Society (2017). *Ethics Guidelines for Internet-mediated Research*. INF206/04.2017. Leicester. Available at: www.bps.org.uk/publications/policy-and-guidelines/research-guidelines-policy-documents/researchguidelines-poli.
- Burns, F., Eaton, M.A., Balmer, D.E., Cladow, R., Donelan, J.L., Douse, A., Duigan, C., Foster, S., Frost, T., Grice, P.V., Hall, C., Hanmer, H.J., Harris, S.J., Johnstone, I., Lindley, P., McCulloch, N., Noble, D.G., Risely, K., Robinson, R.A. and Wotton, S. (2020). *The state of the UK's birds 2020*. The RSPB, BTO, WWT, DAERA, JNCC, NatureScot, NE and NRW, Sandy, Bedfordshire.
- Bush, E.R., Baker, S.E. and Macdonald, D.W. (2014) Global trade in exotic pets 2006-2012. *Conserv. Biol.* 28:663–676.

- 364 Emre Can, O.E., D’Cruze, N. and Macdonald, D.W. (2019). Dealing in deadly pathogens: Taking stock of the
365 legal trade in live wildlife and potential risks to human health. *Glob. Ecol. Conserv.* 17:e00515.
- 366 CITES (2007). *Notification to the Parties No. 2007/007*. Geneva, Switzerland.
- 367 CITES (2019). *Songbird trade and conservation management (Passeriformes)* [CoP18 Doc. 79] Colombo, Sri
368 Lanka
- 369 Challenger, D., Harrop, S. and MacMillan, D. (2015) Towards informed and multi-faceted wildlife trade
370 interventions. *Glob. Ecol. Conserv.* 3:129-148.
- 371 Clarke, T.A., Reuter, K.E., LaFleur, M. and Schaefer, M.S. (2019). A viral video and pet lemurs on Twitter.
372 *PLoS One* 14: e0208577.
- 373 Clemmons, J.R. (2003). *Status survey of the African Grey Parrot (Psittacus erithacus) and development of a*
374 *management program in Guinea and Guinea-Bissau*. CITES, Geneva, Switzerland.
- 375 Colwell, R.K., Chao, A., Gotelli, N.J., Lin, S.Y., Mao, C.X., Chazdon, R.L. and Longino, J.T. (2012). Models
376 and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of
377 assemblages. *J. Plant. Ecol.* 5:3-21.
- 378 Cooney, R. and Jepson, P. (2006). The international wild bird trade: What’s wrong with blanket bans? *Oryx*,
379 40:18–23.
- 380 Dendi, D., Luiselli, L., Fakae, B.B. and Eniang, E.A. (2018) Past trends, current research and future perspectives
381 of West African ornithology. *Vie et Milieu* 68:3-18.
- 382 Dyer, E.E., Redding, D.W. and Blackburn, T.M. (2017). The global avian invasions atlas, a database of alien
383 bird distributions worldwide. *Sci. Data* 4:170041.
- 384 The EFSA Journal (2006) Scientific Opinion on “Animal health and welfare risks associated with the import of
385 wild birds other than poultry into the European Union”. 410:1-55,
- 386 FAO (2011). *International trade in wild birds, and related bird movements, in Latin America and the*
387 *Caribbean*. Animal Production and Health Paper No. 166. Rome.

- 388 Fogell, D.J., Martin, R.O., Bunbury, N., Lawson, B., Sells, J., McKeand, A.M., Tatayah, V., Trung, C.T. and
 389 Groombridge, J.J. (2018) Trade and conservation implications of new beak and feather disease virus detection in
 390 native and introduced parrots. *Conserv. Biol.* 32:1325–1335.
- 391 Global Invasive Species Database (2020a) Available at: <http://www.iucngisd.org/gisd/>
- 392 Global Invasive Species Database (2020b) Species profile: *Psittacula krameri*. Available at:
 393 <http://www.iucngisd.org/gisd/speciesname/Psittacula+krameri>.
- 394 Hart, J., Hart, T., Salumu, L., Bernard, A., Abani, R. and Martin, R. (2016) Increasing exploitation of grey
 395 parrots in eastern DRC drives population declines. *Oryx* 50:16.
- 396 Hinsley, A., Lee, T.E., Harrison, J.R. and Roberts, D.L. (2016) Estimating the extent and structure of trade in
 397 horticultural orchids via social media. *Conserv. Biol.* 30:1038–1047.
- 398 IUCN (2020) The IUCN Red List of Threatened Species. Available at: <https://www.iucnredlist.org>.
- 399 Julian, L., Piasecki, T., Chrzastek, K., Walters, M., Muhire, B., Harkins, G.W., Martin, D.P. and Varsani, A.
 400 (2013) Extensive recombination detected among beak and feather disease virus isolates from breeding facilities
 401 in Poland. *J Gen Virol* 94:1086–1095.
- 402 Karesh, W.B., Cook, R.A., Bennett, E.L. and Newcomb, J. (2005). Wildlife trade and global disease emergence.
 403 *Emerg. Infect. Dis.* 11:1000–1002.
- 404 Khelifa, R., Zebba, R., Amari, H., Mellal, M.K., Bensouilah, S., Laouar, A. and Mahdjoub, H. (2017)
 405 Unravelling the drastic range retraction of an emblematic songbird of North Africa: potential threats to Afro-
 406 Palearctic migratory birds. *Sci. Rep.* 7:1092.
- 407 Kone, B., Fofana, B., Beilfuss, R. and Dodman, T. (2007) The impact of capture, domestication and trade on
 408 Black Crowned Cranes in the Inner Niger Delta, Mali. *Ostrich* 78:195–203.
- 409 Kosinski, M., Matz, S.C., Gosling, S.D., Popov, V. and Stillwell, D. (2015). Facebook as a research tool for the
 410 social sciences: Opportunities, challenges, ethical considerations, and practical guidelines. *Am. Psychol.* 7:543-
 411 556.
- 412 Lavorgna, A. (2014). Wildlife trafficking in the Internet age. *Crime Sci.* 3:1–12.

- 413 Lopes, D., Martin, R., Henriques, M., Monteiro, H., Cardoso, P., Tchantchalam, Q., Pires, A.J., Regalla, A. and
 414 Catry, P. (2019). Combining local knowledge and field surveys to determine status and threats to Timneh
 415 Parrots *Psittacus timneh* in Guinea-Bissau. *Bird Conserv. Int.*, 29:400-412.
- 416 Martin, R.O., Perrin, M.R., Boyes, R.S., Abebe, Y.D., Annorbah, N.N.D., Asamoah, A., Bizimana, D., Bobo,
 417 K.S., Bunbury, N., Brouwer, J., Diop, M.S., Ewnetu, M., Fotso, R., Garteh, J., Hall, P., Holbech, L.H.,
 418 Madindou, I.R., Maisels, F., Mokoko, J., Mulwa, R., Reuleaux, A., Symes, C., Tamungang, S.A., Taylor, S.,
 419 Valle, S., Waltert, M., and Wondafrasah, M. (2014) Research and conservation of the larger parrots of Africa
 420 and Madagascar: a review of knowledge gaps and opportunities, *Ostrich*, 85:205-233.
- 421 Martin, R.O. (2018) The wild bird trade and African parrots: past, present and future challenges. *Ostrich*
 422 89:139-143.
- 423 Martin, R.O., Senni, C. and D’Cruze, N.C. (2018). Trade in wild-sourced African grey parrots: Insights via
 424 social media. *Glob. Ecol. Conserv.* 15:e00429.
- 425 Di Minin, E., Tenkanen, H. and Toivonen, T. (2015). Prospects and challenges for social media data in
 426 conservation science. *Front. Environ. Sci.* 3:63.
- 427 Morgan, J. and Chng, S. (2018). Rising internet-based trade in the Critically Endangered ploughshare tortoise
 428 *Astrochelys yniphora* in Indonesia highlights need for improved enforcement of CITES. *Oryx* 52:744–750.
- 429 Nekaris, B.K.A.I., Campbell, N., Coggins, T.G., Rode, E.J. and Nijman, V. (2013). Tickled to Death: Analysing
 430 Public Perceptions of “Cute” Videos of Threatened Species (Slow Lorises - *Nycticebus* spp.) on Web 2.0 Sites.
 431 *PLoS One* 8:e69215.
- 432 Pimentel, D. (2011) *Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and*
 433 *Microbe Species* (2nd ed.) CRC Press, Boca Raton
- 434 Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O’Hara, R.B.,
 435 Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E. and Wagner, H. (2019) *vegan: Community Ecology*
 436 *Package*. R package version 2.5-6. Available at: <https://CRAN.R-project.org/package=vegan>.
- 437 R Core Team (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical
 438 Computing, Vienna.

- 439 Regnard, G.L., Boyes, R.S., Martin, R.O., Hitzereth II and Rybicki, E.P. (2015) Beak and feather disease
440 viruses circulating in Cape parrots (*Poicephalus robustus*) in South Africa. *Arch Virol* 160:47–54.
- 441 Reino, L., Figueira, R., Beja, P., Araújo, M.B., Capinha, C. and Strubbe, D. (2017). Networks of global bird
442 invasion altered by regional trade ban. *Sci. Adv.* 3:e1700783.
- 443 Ripple, W.J., Wolf, C., Newsome, T.M., Hoffmann, M., Wirsing, A.J. and McCauley, D.J. (2017) Extinction
444 risk is most acute for the world’s largest and smallest vertebrates. *PNAS* 114:10678-10683.
- 445 Robinson, J.E., Griffiths, R.A., Fraser I.M., Raharimalala, J., Roberts, D.L. and St John F.A.V. (2018)
446 Supplying the wildlife trade as a livelihood strategy in a biodiversity hotspot. *Ecology and Society* 23:13
- 447 Roberts, D.L. and Hernandez-Castro, J. (2017) Bycatch and illegal wildlife trade on the dark web. *Oryx* 51:393–
448 394.
- 449 Ruelle, P. and Bruggers, R.L. (1983) *Senegal’s trade in cage birds*. Washington, D.C.
- 450 Sajeve, M., Augugliaro, C., Smith, M.J. and Oddo, E. (2013). Regulating Internet Trade in CITES Species.
451 *Conserv. Biol.* 27:429–430.
- 452 Shepherd, C.R., Sukumaran, J. and Wich, S.A. (2004). *Open Season: An analysis of the pet trade in Medan,*
453 *Sumatra 1997-2001*. TRAFFIC Southeast Asia, Petaling Jaya, Selangor, Malaysia
- 454 Shiels, A.B. and Kalodimos, N.P. (2019) Biology and Impacts of Pacific Island Invasive Species. 15. *Psittacula*
455 *krameri*, the Rose-Ringed Parakeet (Psittaciformes: Psittacidae). *Pac. Sci.*, 73:421-449.
- 456 Siraw, B. and Chaka, H. (2009). *Qualitative Risk Assessments (Release and Exposure Assessments) for the Risk*
457 *of introduction of Highly Pathogenic Avian Influenza (H5N1) Virus into Ethiopia Via Wild Birds Trade*
458 *Transiting in the Country and for the Risk of Transmission of Highly Pathogenic Avian Influenza (H5N1) Virus*
459 *between Large Scale Commercial and Small Scale Commercial Poultry Farms in Ethiopia*. Africa/Indonesia
460 Team Working Paper No.21.
- 461 Siriwat, P. and Nijman, V. (2018). Illegal pet trade on social media as an emerging impediment to the
462 conservation of Asian otters species. *J. Asia-Pacific Biodivers.* 11:469–475.
- 463 South, A. (2011) rworldmap: A New R package for Mapping Global Data. *The R Journal* 3:35-43.

- 464 Swift, L., Hunter, P.R., Lees, A.C. and Bell, D.J. (2007). Wildlife trade and the emergence of infectious
465 diseases. *Ecohealth*, 4:1.
- 466 Tingley, M.W., Harris, J.B.C., Hua, F., Wilcove, D.S. and Yong, D.L. (2017). The pet trade's role in
467 defaunation. *Science* 356:916.
- 468 Oxford Martin Programme on the Illegal Wildlife Trade (2020). Position statement: Managing Wildlife Trade in
469 the Context of Covid-19 and Future Zoonotic Pandemics. Oxford. Available at:
470 [https://www.oxfordmartin.ox.ac.uk/publications/position-statement-managing-wildlife-trade-in-the-context-of-](https://www.oxfordmartin.ox.ac.uk/publications/position-statement-managing-wildlife-trade-in-the-context-of-covid-19-and-future-zoonotic-pandemics/)
471 [covid-19-and-future-zoonotic-pandemics/](https://www.oxfordmartin.ox.ac.uk/publications/position-statement-managing-wildlife-trade-in-the-context-of-covid-19-and-future-zoonotic-pandemics/).
- 472 UNEP-WCMC (2020) The Checklist of CITES Species Website. CITES Secr. Geneva, Switzerland. Available
473 at: <http://checklist.cites.org/>.
- 474 Vaglica, V., Sajeve, M., McGough, H.N., Hutchison, D., Russo, C., Gordon, A.D., Ramarosandratana, A.V.,
475 Stuppy, W. and Smith, M.J. (2017). Monitoring internet trade to inform species conservation actions. *Endanger.*
476 *Species Res.* 32:223–235.
- 477 Xu, Q., Cai, M. and Mackey, T. (2020). The illegal wildlife digital market: an analysis of Chinese wildlife
478 marketing and sale on Facebook. *Environ. Conserv.* 47:206-21.

Table 1. Description of key variables derived from post media, text and comments, organised by research objective.

Variable ^a	Description
Species analysis	
Taxon (I, T)	Family, genus and species
Quantity (I)	Estimate of quantity, categorised as 1-10, 11-100, 100+ or copied.
Cohabitation (I)	Number of PICs featuring more than one species in the same enclosure and estimate of number of cohabiting species.
Trade-related post text (T)	Number of posts explicitly advertising sale as a result of content analysis.
Trade Mapping	
Destination in post text (T)	Text referencing the destination of a shipment
Cargo Tracking Codes (I)	Shipment date, airline, origin and destination.
Page Location (P)	Country or territory of origin or current residence.
Users making trade-related comments (C)	Number of users enquiring about trade in comments as a result of content analysis.

^a Variables are labelled to indicate their source: I = post imagery, T = post text, P = page information, C = comments

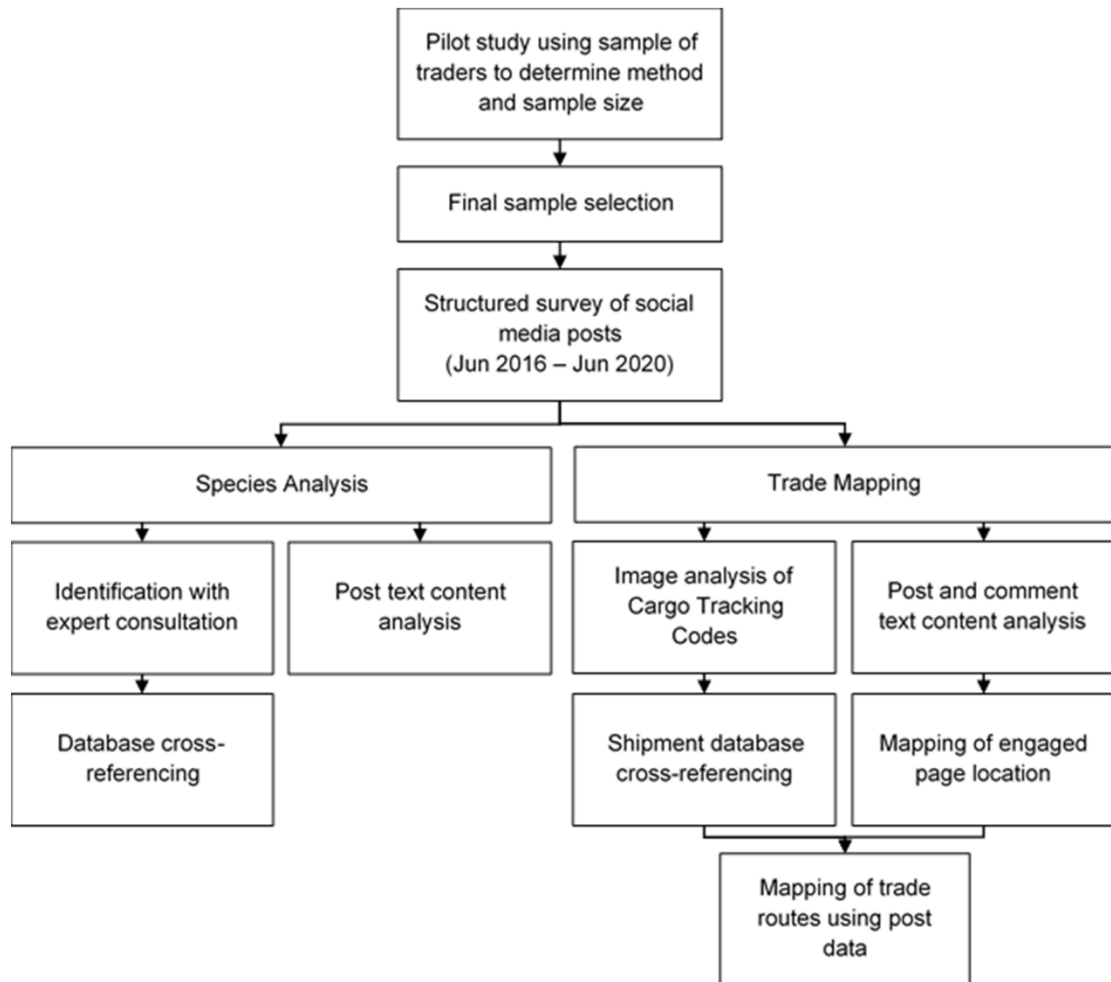
1 **Table 2.** The frequency, estimated quantity, IUCN Red List status and CITES appendix listing for all observed threatened or CITES-listed species.

Species	Frequency in PICs, By estimated volume					IUCN Red List Status ^b	CITES Appendix Listing
	1-10	11-100	100+	Copied ^a	Total		
Senegal parrot (<i>Poicephalus senegalus</i>)	5	29	2	5	41	LC	II
Green turaco (<i>Tauraco persa</i>)	7	12	0	3	22	LC	II
Grey parrot (<i>Psittacus erithacus</i>)	5	7	5	4	21	EN	I
Red-headed lovebird (<i>Agapornis pullarius</i>)	3	10	0	2	15	LC	II
Timneh parrot (<i>Psittacus timneh</i>)	1	5	0	0	6	EN	I
Red-fronted parrot (<i>Poicephalus gulielmi</i>)	1	2	0	0	3	LC	II
Northern white-faced owl (<i>Ptilopsis leucotis</i>)	0	0	0	2	2	LC	II
Black-crowned crane (<i>Balearica pavonina</i>)	2	0	0	0	2	VU	I
Black-necked parrot (<i>Poicephalus fuscicollis</i>)	1	0	0	0	1	LC	II
Crowned Eagle (<i>Stephanoaetus coronatus</i>)	1	0	0	0	1	NT	II
European turtle dove (<i>Streptopelia turtur</i>)	0	1	0	0	1	VU	-

2 ^{a.} In estimated volume, copied indicates that the bird was represented in an image copied from another website.

3 ^{b.} LC = Least concern, NT = Near threatened, VU = Vulnerable, EN = Endangered.

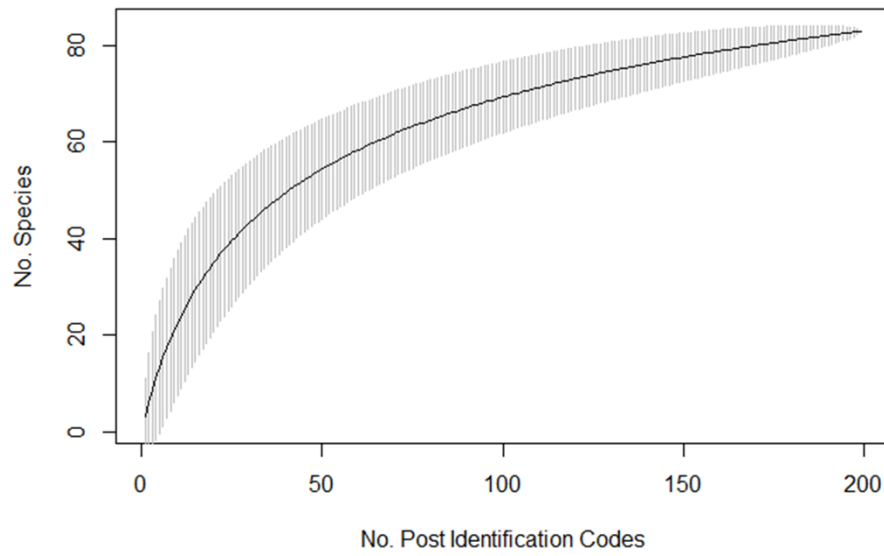
1 **Figure 1** Diagram of study approach steps and analysis workstreams



2

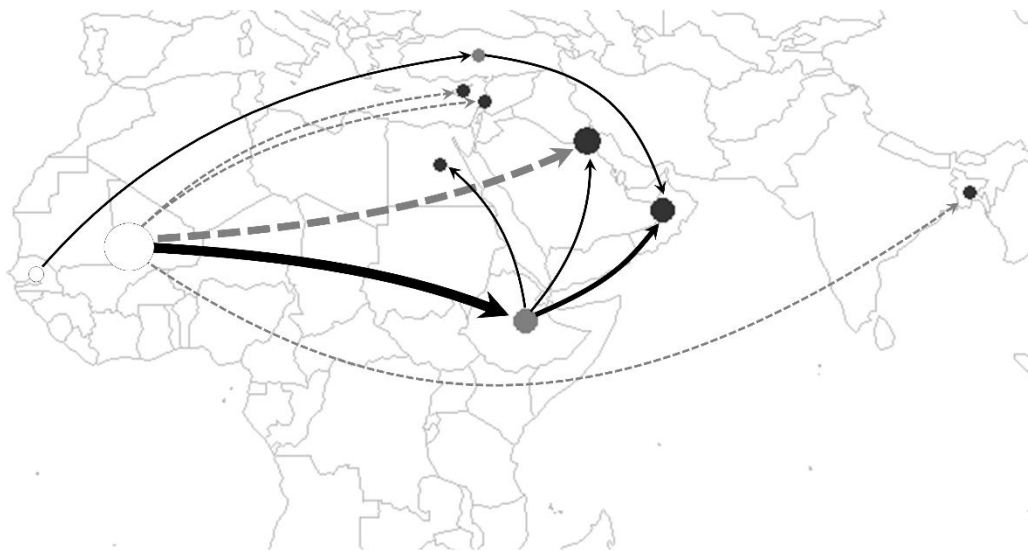
3

- 1 **Figure 2** Species accumulation curve with 95% confidence intervals, showing cumulative number of species
- 2 identified by post identification code (N = 199)

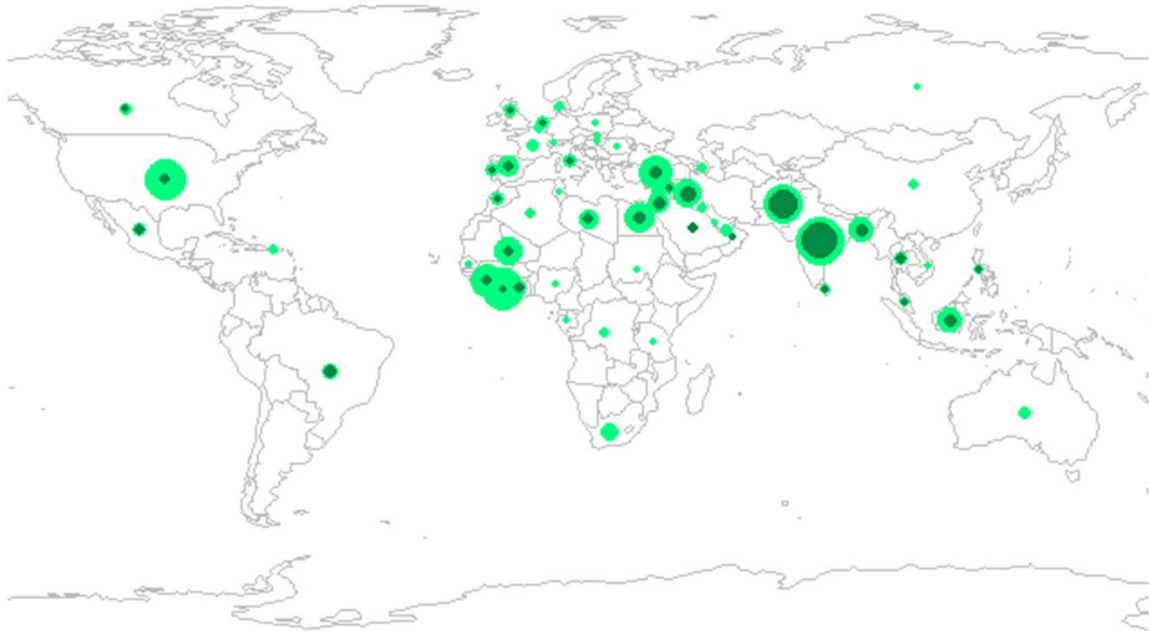


3

- 1 **Figure 3** International trade routes based on information from social-media posts (n=10). Black solid lines
- 2 indicate routes validated by Cargo Tracking Codes in post images (n=5). Grey dashed lines indicate routes
- 3 described in post text (n=6), and as such may not include transit countries. Line width is proportional to number
- 4 of shipments (range 1-4). White circles indicate exporting countries, grey circles indicate transit countries and
- 5 black circles indicate importing countries. Circle size is proportional to the number of routes including the
- 6 country (range 1-11)



- 1 **Figure 4** The global location of users engaged with posts. Circles are proportional to the number of pages (range
2 1 - 43). Light circles represent all associated pages (n=378). Dark circles represent pages that made trade-related
3 comments (n=93)



4