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Mobile decision-tree tool technology as a means to detect wildlife crimes and build enforcement networks

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ABSTRACT

Accurate field identification of illegally traded wildlife and wildlife products is critically important in the detection and suppression of wildlife crimes. Yet many law enforcement officers and concerned citizens lack access to resources for identifying species and products; this is particularly true for those with no formal expertise in biology, zoology or wildlife training. Emerging digital technologies such as mobile applications may provide important easy-to-use decision-tree style tools for in situ identification. With local government and civil society partners, we are piloting such tools in China and Vietnam to identify whole animals and ivory products; and in the United States developing tools that will be used at U.S. military bases in Afghanistan to identify species from wildlife products. We are coordinating these efforts to minimize redundancy and overhead; we benefit from shared backend support for a photo database and species ID keys that can be translated easily to ensure enough flexibility for targeting needs of the specific country and audience. Planned inclusion of 'ask the expert' and geolocation functions will increase accuracy in identification and aid monitoring and research of supply chains. For these emerging technologies to be successful, deployment must be accompanied with on-the-ground trainings to recruit and retain enforcement personnel. The establishment of a supporting network of experts and a user community will be critical for long-term implementation and evaluation of success. Preliminary response from users of a pilot app in China demonstrates high potential for employing these technologies as routine tools to help fight wildlife crimes.

1. Introduction

The illegal trade of animals and products made from parts of animals is a major global threat to wildlife. In the last 25 years, populations of many iconic species such as elephant, rhinoceros, tiger, and saiga antelope have decreased dramatically or become locally extinct, and much of this decline is due to illegal hunting for coveted products such as ivory, medicines, and clothing (Emslie et al., 2013; Li et al., 2007; Maisels et al., 2013; Milner-Gulland et al., 2001; Walston et al., 2010). Weak enforcement systems have enabled wildlife to be poached and traded to markets where sales of wildlife and products made from wildlife parts fuel illegal business (Bennett, 2011). Responsibility for enforcement is spread across individuals along supply chains, from rangers to transportation and border guards. Lack of awareness and interest in wildlife conservation are one of the major obstacles, along with lack of training and technical resources, for combating these crimes (Bennett, 2011; Kaaria and Muchiri, 2011). Law enforcement authorities stationed at borders, including customs, immigration, police, military, agricultural and transportation personnel (The World Bank, 2013) are at the front line of the wildlife crime trade-chain battlefield in ensuring illicitly traded products are not crossing borders or being offered for sale in local markets. The rapidly increasing international trade and flow of travelers has put considerable pressure on border authorities, who must screen a broad range of goods and decide whether or not to release a shipment in a matter of minutes or even seconds (Gerson et al., 2008). Building capacity of enforcement personnel can increase the quality of market

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surveillance for illegally traded wildlife. However, the ability for these law enforcement entities to impact illegal wildlife trade requires having access to easy-to-use tools and resources to aid in the identification of traded wildlife and products.

Knowledge, motivation, and technical resources specific to wildlife are three main factors that can improve the impact of law enforcement agencies on illegal wildlife trade (Bennett, 2011; Gerson et al., 2008; Kaaria and Muchiri, 2011). Ideally, customs agents would have extensive training as well as easy access to the latest forensic techniques and laboratories to facilitate identification of wildlife to the species level (Bell, 2011; Rosen and Smith, 2010). In reality, training is limited; and, while promising, forensic science must occur in properly equipped laboratories (Anderson, 2013), far away from the front lines of trade activity. In the past, organizations have experimented with wild species identification prototypes mimicking field guides (Tallant et al., 2010). This approach revealed significant practical limitations as it required some previous knowledge of wildlife to ultimately be successful in identifying to a species level. Capitalizing on this experience, the "decision-tree style" may be a more viable approach to allow successful operation by officers with relatively little training to make quick and reliable identification of potential crimes in the field (Rosen and Smith, 2010).

Decision-trees are a system to provide classification based on inputs and organization of information. They have wide-spread application, from determining water treatments, to diagnosing medical conditions and classifying astronomical images (Murphy, 2001; Murphy and Olson, 1996; Salzberg et al., 1995). Often, decision-trees facilitate analysis by assigning probabilities to supplied data selections, with additional weights to account for potential errors, to calculate the outcome of system manipulations (Murphy, 2001). Decision-trees can also be simple dichotomous or multichotomous keys employed to identify items of the natural world such as flowering plants, minerals, or insects (Carle, 2010; Alan Plante et al., 2003; Watts, 1998). These keys use a process of elimination to narrow the possibilities at each selection and can be effective as a tool to classify or identify based on different factors. This approach could be equally useful for identification of traded wildlife and wildlife products but until now has yet to be tested.

Emerging technologies such as interactive web pages and mobile applications provide an opportunity to make multichotomous keys available to a variety of audiences at a relatively low cost, as use of mobile technologies is booming around the globe (ADMA, 2012; Smith, 2013). For these tools to curb wildlife trade at the scale necessary to prevent decline of wildlife populations, organizations must deploy them in strategic locations and to a network of individuals engaged in using them for specific purposes. The Wildlife Conservation Society (WCS) has been involved in the enforcement of wildlife trade for over a decade supporting networks of trained park rangers and training customs, police and forestry officers in places such as Congo, Thailand, China, Indonesia, Malaysia, and Vietnam (Bennett, 2012; Lee et al., 2005; Roberton, 2013; Walston et al., 2010; WCS, 2013a) and training military police to secure on-base markets (Kretser, 2012; Kretser et al., 2012). These networks represent opportunities to test whether emerging technologies using decision-tree approaches will be a viable method for enforcement. We present three cases from WCS field programs in China, Vietnam, and the United States illustrating how to build a network of users employing decision-tree style tools to improve detection of wildlife crimes.

2. Methods

WCS is developing and pilot-testing decision-tree style technological resources to identify wildlife and products made from wildlife parts to a species level across three diverse contexts and audiences in China, Vietnam, and the United States. All authors on this paper are WCS staff and are intimately involved and leading this development process. To streamline mobile technology production efforts, we are creating a back-end database structure that can be adapted to multiple tools and includes species information as well as photographs. Front-end technology enables each program to be tailored to the specific site context including language, local legal framework, and types of wildlife available in the markets. Information particular to the database comes from existing literature on the species of interest, experts in the field, and inspection of products previously confiscated. Identifying the end-user and the context is important to the development and deployment of these tools.

We report on progress of three programs to improve identification of wildlife crimes. In all cases, we rely on initial impressions of challenges and opportunities based on our experiences developing the technology and participant observation. For China and Vietnam, we examine how frequently the tools are downloaded and user retention (i.e., those individuals who continue to use the technology) over time measured by dividing the active users in the past 3 months by the number of lifetime downloads. For China, we provide limited data from user surveys following trial runs of this technology with customs and forestry police. We trained 93 customs officers from Guangdong and Guangxi provinces and 33 forestry police from Qinghai province ($n = 126$). We also met with individuals from the academic community to provide information and expertise on the user experience." These informal discussions informed the development of a pilot survey. We administered the voluntary survey using convenience sampling of individuals who participated in app training sessions ($n = 74$). The surveys measured users' perceived benefits and usefulness of the mobile app and their opinions about future improvements to the app and the interface. The self-administered survey featured closed-ended questions with some yes/no responses and some 5-point Likert-type scale responses according to the nature and scope of each question. We summarize the app technology employed by WCS to date in a table representing a typology of uses based on location, language, and features. This will enable future comparison among apps.

3. Results and discussion

3.1. China

With a population of over 1.3 billion, China is potentially the largest demand market for several species of wildlife globally due to the traditional use of wildlife for medicine, food, and trophies and the increase of that use due to rapid economic development. In recent years, Chinese authorities have progressively acknowledged the impact illegal wildlife trade has on global biodiversity as well as the country's international reputation (Hu Jintao, 2012). The destruction of 6.15 tons of ivory artifacts and tusks in January 2014 by crushing marked China's commitment to take a resolute stance against illegal wildlife trafficking. Since 2009, WCS has supported capacity building efforts, including species identification training of Chinese law enforcement agencies on wildlife conservation and innovative investigation techniques. Written assessments carried out immediately after training programs found a twofold increase in species identification skills of law enforcement officers compared to the pre-training baseline where about 33% of participants demonstrated species identification skills (Wong, pers comm.). After six months, only 41% of participants retained knowledge gained from the workshops (Wong, pers comm.). We needed a tool to improve knowledge retention

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and be a resource for law enforcement post-trainings. We developed "Wildlife Guardian", a mobile application to aid animal and product identification in China. The platform allows users to identify canids, felids, ungulates, birds, turtles and tortoises by selecting the correct match of up to five body parts or features. Customs agents, forestry police, and interested citizens who volunteer to patrol local markets can use the app to directly share intelligence on their findings.

In March 2013 we launched the first free version of the Wildlife Guardian app in China (http://goo/gl/GhULy), with the ability to identify over 300 species (Table 1). To date, more than 1173 users have installed the software on iOS systems (currently around 30% of market share in China, (Statcounter, 2014). A new version with a redesigned interface for improved usability and support for the Android platform is currently pending approval on Google Play store.

Our survey demonstrated overall positive feedback on initial testing of the mobile app (Fig. 1). Users welcomed the app concept and implementation with 60% considering Wildlife Guardian 'very valuable' and 25% 'valuable' for wildlife conservation. In particular, 70% of the police officers declared the app as 'very useful' for supporting their specific work or activities and the remaining 30% considered it 'useful.' Survey results also provided useful information to further improve the software and adequately respond to the needs and concerns of the Chinese law enforcement officers, the primary target users. This information, along with feedback from planned focus groups testing, will guide the development of Wildlife Guardian to ensure this app meets conservation and law enforcement needs in the region.

3.2. Vietnam

Wildlife trafficking in Vietnam is driving species to extinction across Southeast Asia and has been fueled by a growing demand from urban wealth centers and for export, mainly to China. Wildlife crime law enforcement is considered weak and Vietnamese law enforcement officers suffer from low education and training levels (Brook et al., 2014; Nguyen et al., 2007; Nowell, 2012; TRAFFIC, 2008; WCS, 2012, 2013b). WCS has worked to address wildlife trade in Vietnam for nearly a decade by developing relationships with law enforcement agencies and training over 800 law enforcement officers in wildlife crime investigation and enforcement techniques. Although training programs provide a forum for building interest and inter-agency cooperation, similar to the experience in China, the trainings have limited success in knowledge retention after six months.

In 2012, in collaboration with the Centre for Natural Resource and Environmental Studies (CRES), one of the National CITES Scientific Authorities, and with official endorsement from the Vietnam Forest Administration and General Department of Customs, we launched Vietnam's first online wildlife identification tool, www.giamdinhloai.vn, to provide species and legal knowledge to enforcement officers to support detection and prosecution of wildlife crimes (Table 1). When the project was first conceived in 2010, Vietnam had low smartphone usage country wide, particularly in frontline enforcement officers, thus a website was a more accessible tool from work stations and checkpoints. The web interface contains species identification tools; law documents and species resources (e.g., images, video clips, reports, and research papers); and online tools to request instant support (e.g., Skype, emails). The website has password-protected sections for sensitive information. Our program collaborates with enforcement agencies to check user information and registration before activating each account. The website includes step-by-step, visually-aided guidelines to help users identify 152 protected species listed in Vietnam as well as look-alikes and a number of other highly endangered but commonly traded species and products including rhino horns, elephant ivory, and tiger products.

The first year of operation of the online Vietnamese ID tool enabled improvements to the interface design and allowed building the support network required to provide identifications. Although we have not administered a structured evaluation, the launch has had promising early results. For example, 17 of Vietnam's leading wildlife conservationists and scientists support the website by providing information, photos and free wildlife identification to the user community. Furthermore, over 300 users from Customs (representing all Customs offices in the country), Forest Protection Department, and the Environmental Police registered on the site. During the first year of operation, the site had 3487 page views, with a 30% increase in page views in the second half of the year. As of August 2014 the site has over 8599 views. To maximize use of the website and provide credibility required for law enforcement users, we secured the collaboration and endorsement of eight key agencies in government that promote the website to provincial sub-departments, provide content to the site (e.g., laws, images, and other relevant documents); and give technical expertise and support as identification experts.

3.3. United States

In war zones, foreign aid workers and military can elevate demand for products made from local wildlife (Mishra and Fitzherbert, 2004). The United States Department of Defense (DoD) stations military police at U.S. bases overseas to provide customs clearance and to also patrol weekly or monthly bazaars where local vendors are invited to sell products on-base to U.S. citizens (Kretser et al., 2012). On-base market sweeps uncovered hundreds of products made from rare and endangered wildlife, and research from one U.S. military base indicated that over 40% of military returning from overseas service had either purchased

Table 1
Typology of elements contained in existing WCS mobile technologies for identification of traded wildlife species.

	Whole animal	Animal parts	# of species	Focal countries	Target users	Decision tree	Geolocation[a]	Ask an expert[b]	Social media component	Languages	Device
Wildlife Guardian	Yes	Yes[c]	475	China, Hong Kong	Chinese law enforcement agencies and citizens	Yes	Yes[d]	Yes	Yes[e]	Mandarin, English	Mobile phone
Giamdinhloai	Yes	Yes[c]	152	Vietnam	Vietnamese law enforcement agencies	Yes	No	Yes	No	Vietnamese	Website
Wildlife Alert	No	Yes	75	Afghanistan	U.S. military	Yes	No[e]	No[e]	No	English	Mobile phone

[a] Ability to automatically include geographic coordinates to user-submitted reports.
[b] Ability to seek advice from experts in species identification from within the app.
[c] Only some species have parts identified.
[d] Under development in forthcoming release.
[e] Planned but funding not secure.

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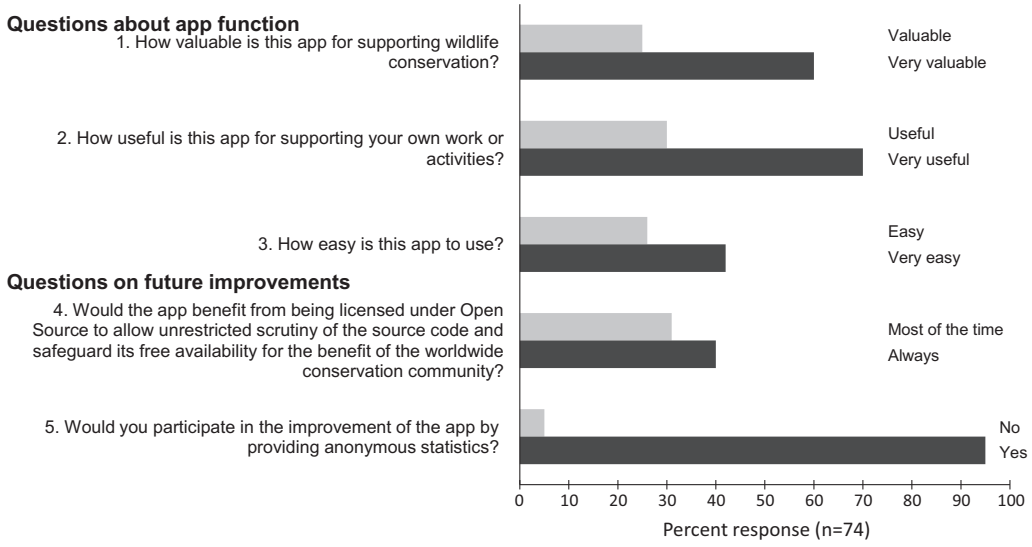

Fig. 1. Survey responses from China forestry police and customs agents during a pilot trial of Wildlife Guardian.

or seen other military personnel purchase wildlife products (Kretser et al., 2012). While WCS has provided training to military police to look for products made from threatened and endangered wildlife, frequent turnover in military personnel every 6–9 months coupled with security concerns limiting access to bases reduces the feasibility of in-person trainings. Additionally, limited resources are available for actual species identification. Typically, the products available on military bases are fabricated from wildlife parts rather than the whole animal. For this context, we are developing a mobile app that aims to identify species from the parts used to make a product. Users select fur, antlers, bones and ivory, shells, or feathers and then progress through a series of multichotomous questions about the colors and characteristics of the wildlife part. The app generates a potential list of matching species for final user confirmation.

The mobile app, Wildlife Alert, targeting U.S. military police is presently under construction (Table 1). This pilot app will be used by U.S. military police working in Afghanistan where the problem of military personnel purchasing wildlife products persists (Kretser et al., 2012). Given the complicated decision-tree involved in determining species level identification from parts of an animal, the pilot app contains only 75 species, with a focus on felids, canids, and some ungulates that are either protected in Afghanistan or commonly traded and thus potentially confused with other species. The back-end database requires designing a new structure to identify species from animal parts and little work has been done in this area previously. Presently efforts are focused on database design and building a network of potential users through existing training programs in place between WCS and the Department of Defense. Smartphones are being used increasingly within the U.S. military for special operations (Rock, 2014 and Srivastava, 2014), and thus represent a feasible conservation application. Given the availability of wildlife products to military personnel in other countries (Kulish, 2013), we will seek funding to expand the geography of this app to serve African countries where U.S. military presence is increasing.

3.4. Building networks

Success largely depends on facilitating and maintaining an active network of users. Organizations must work with local government agencies to provide training and outreach (both offline and online) to spread awareness about the availability of these tools, solicit feedback, and make modifications to better meet users' needs. Social networks linked to the apps may provide a forum for users to post and discuss questions pertaining to the technology and identification in the field. This feature will be available in the forthcoming version of Wildlife Guardian.

Due to the automated nature of these technologies, some ambiguity may remain once a user has worked through the decision-tree framework. In the recent survey among law enforcement officers in China, while 67% preferred a completely automated species/products identification function, one third of the respondents deemed the availability of experts for consultations as "very useful". For this reason, an 'ask the expert' module for sending questions and photographs to a panel of experts for advice and confirmation is available in China and underway for Vietnam. We plan to extend this feature to the US-based software in future versions. We are also assembling a network of local and international experts who can provide around-the-clock advice to law enforcement operations, which often happen outside regular office working hours. Ideally this function will be executed such that external experts could be remunerated for their time and contributions to the effort.

3.5. Geolocation

Geolocation is another powerful tool that may be included as an element of these computerized identification tools. Geolocation is the ability to collect data at a specific location and have that data uploaded to a remote database as a spatially referenced point (Kuntsche and Labhart, 2013; Vivoni and Camilli, 2003). Variations on geolocation have been used in conservation applications where data is collected on mobile devices (e.g., global positioning systems) and then manually downloaded (e.g., Liebenberg et al., 1999; stokes 2010). Technological advances allow data to be collected on individual cells and automatically synched with a remote database (Kuntsche and Labhart, 2013). Geolocation on points of sale or interception of wildlife products and species, including photographs, would have utility for the broader law enforcement community as data collected via websites or mobile applications could sync with larger Wildlife Enforcement Monitoring Systems (WEMS) (Chandan et al., 2011) and meet some of the need for research on and monitoring of supply chains of transnational

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crimes related to wildlife (Warchol, 2004). Geolocation is not live in any of the technologies described herein, although it is planned to be incorporated into future versions of the software at each site. This technology is already operational in Wildlife Witness (Taronga, 2014), a mobile app for documenting suspicious wildlife trade activity; however it is not coupled with an identification system. Implementation of geolocation should consider techniques to minimize battery use, particularly in rural or remote areas where recharging facilities are limited. Using GPS only for submission, network based locations, or reusing cached locations may be viable alternatives depending on the setting.

4. Conclusions

Decision-tree style resources for field identification of species in potential wildlife crimes are promising as an emerging enforcement tool. The tools in either app or web-based format can be adapted to particular contexts and are expandable, easy to use, and helpful for individuals with little to no training in wildlife as is the case with many enforcement individuals (Bennett, 2011; Rosen and Smith, 2010). Mobile app technology also has an additional benefit in that a user does not require internet connection to use the app. Many border areas or protected parks have limited network service; thus this feature will be critical for facilitating use by law enforcement personnel stationed in remote areas. Preliminary feedback suggests that users find the tools easy to use and likely to be a valuable resource.

Some challenges still remain with equipment ownership, misidentifications as the databases are developing, and larger coordination across multiple tools as these novel approaches become more prolific and integrated into daily work of individuals working in enforcement. Issues may arise as organizations juggle whether to invest in dedicated phones for enforcement personnel to use only while working or have employees use personal devices. The former represents a significant investment, the latter an assumption that individuals have compatible phones and possess some media literacy. Caution should also be used with these new technologies as false negatives and false positives may be prevalent as the databases are developing. False negatives, or allowing items through when confiscation should happen, could be detrimental to wildlife; while false positives, or confiscating when a product meets country regulations, could negatively impact individuals or local economies (Bowen-Jones et al., 2003. Future work may need to involve better coordination across all groups working with these mobile identification keys to share resources to ensure decision trees operate correctly and improve the interfaces to minimize the potential for user error. Additionally, as is common in true decision-tree algorithms, there are likely opportunities to explore the possibility of assigning weights to each diagnostic question depending on how critical a question is to the identification of an actual species as well as the severity of the false negative that could occur (e.g., a false negative that could allow a rhino horn or ivory through a checkpoint would be weighted more heavily to avoid this situation).

Lasting success for these technologies hinges on global support for these initiatives and continued outreach and investment in on-the-ground training of law enforcement networks. Social media and access to experts via interfaces available on apps and websites may be possible engagement tools that could spur continued use of these technologies after the initial release, provided experts can be compensated for their contributions to the network. Future research will require in-depth evaluations of these technologies to assess the potential long-term impact on illegal trade. While recognizing that many factors impact a species' population, ultimately success of these tools should be measured by increasing abundance of frequently traded species in native habitats. Short of that, confiscations of wildlife and wildlife products will likely increase initially and then decline as those responsible recognize the improved capabilities of law enforcement officials. Such indices need to be monitored if the conservation community is to know how training resources such as mobile technologies can aid in the fight against wildlife crimes.

References

Alan Plante, A., Peck, D., Von Bargen, D., 2003. Mineral identification Key II. A collector's corner. Accessed June 9, 2014. <http://www.minsocam.org/msa/collectors_corner/id/mineral_id_keyi1.htm>.

Anderson, L.G., 2013. Life and science are wild in forensic park. DEPAUW Magazine, Winter. pp. 10–19.

Asia Digital Marketing Association, 2012. Asia-Pacific Digital Marketing Yearbook. Accessed on January 25, 2014. <www.asiadigitalmarketingyearbook.com>.

Bell, L., 2011. Forensic science in support of wildlife conservation efforts – morphological and chemical approaches (global trends). Forensic Sci. Rev. 23 (1), 29–35.

Bennett, E.L., 2011. Another inconvenient truth: the failure of enforcement systems to save charismatic species. Oryx 45 (4), 476–479.

Bennett, E.L., 2012. How to stop wildlife poachers. New York Times, The Opinion Pages. May 24.

Bowen-Jones, E., Brown, D., Robinson, E.J.Z., 2003. Economic commodity or environmental crisis? An interdisciplinary approach to analysing the bushmeat trade in central and west Africa. Area 35 (4), 390–402.

Brook, S.M., Dudley, N., Mahood, S.P., Polet, G., Williams, A.C., et al., 2014. Lessons learned from the loss of a flagship: the extinction of the Javan rhinoceros Rhinoceros sondaicus annamiticus from Vietnam. Biol. Conservation 174, 21–29.

Carle, D.M. 2010. Identification keys to the larvae and pupae of New Jersey black flies (Diptera: Simuliidae. Entomol News, 121, 2, 139–158, BioOne doi: http://dx.doi.org/10.3157/021.121.0205.

Chandan, R., Krishnan, P., Nguyen, K., 2011. Wildlife enforcement monitoring system (WEMS): a solution to support compliance to multilateral environmental agreements. Gov. Inform. Q. 28, 231–238.

Emslie, R.H., Milliken T., Talukdar B., 2013. African and Asian rhinoceroses – status, conservation and trade report to the 16th meeting of the CITES conference of the parties, CoP16 Doc. 54.2 (Rev. 1) Annex 2. Accessed January 27, 2014. <www.cites.org/eng/cop/16/doc/E-CoP16-54-02.pdf>.

Gerson, H., Cudmore, B., Mandrak, N.E., Coote, L.D., Farr, K., Baillargeon, G., 2008. Monitoring international wildlife trade with coded species data. Conserv. Biol. 22 (1), 4–7.

Hu Jintao, C.H., Making great efforts to promote ecological progress. Report to 18th Party Congress, November, 2012, chapter VIII. Accessed on January 26, 2014. <http://news.xinhuanet.com/english/special/18cpcnc/2012-11/17/c_131981259_9.htm>.

Kaaria, B.I., Muchiri, N.L., 2011. Enforcement challenges across borders: detecting and prosecuting illegal wildlife trafficking. Ninth Int. Conf. Environ. Compliance Enforcement, 204–208.

Kretser, H.E. An unconventional battle on U.S. bases: training the military to curb wildlife trafficking. Wildlife Prof, Summer 2012. pp. 52–54.

Kretser, H.E., Johnson, M.F., Hickey, L.M., Zahler, P., Bennett, E.L., 2012. Demand for wildlife trade products available to U.S. military personnel serving abroad. Biodivers. Conserv. 21 (4), 967–980, doi: http://dx.doi.org/10.1007/s10531-012-0232-3.

Kulish, N. Ivory culprit in kenya: Ex-official from U.S. New York Times, July 24, 2013. Accessed on January 27, 2014. <http://www.nytimes.com/2013/07/25/world/africa/surprising-culprit-in-ivory-smuggling-ex-us-official.html?_r=0>.

Kuntsche, E., Labhart, F., 2013. Using personal cell phones for ecological momentary assessments: an overview of current development. Eur. Psychologist 18 (1), 3–11.

Lee, R.J., Gorog, A.J., Dwiyahreni, A., Siwu, S., Riley, J., et al., 2005. Wildlife trade and implications for law enforcement in Indonesia case study from North Sulawesi. Biol. Conserv. 123, 477–488.

Li, L., Zhou, Y., Bennett, E.L., 2007, Report of a survey on saiga horn in markets in China. Report to the 14th meeting of the CITES conference of the parties, COP14 Inf14. <http://www.cites.org/common/cop/14/inf/E14i-14.pdf>.

Liebenberg, L., Steventon, L., Benadie, K., Minye, J., 1999. Rhino tracking with the CyberTracker field computer. Pachyderm 27, 59–61.

Maisels, F., Strindberg, S., Blake, S., Wittemyer, G., Hart, J., et al., 2013. Devastating decline of forest elephants in central Africa. PLoS ONE 8 (3), e59469. http://dx.doi.org/10.1371/journal.pone.0059469.

Milner-Gulland, E.J., Kholodova, M.V., Bekenov, A., Bukreeva, O.M., Grachev, A., Amaglan, A., 2001. Dramatic declines in saiga antelope populations. Oryx 35, 340–345.

Mishra, C., Fitzherbert, A., 2004. War and wildlife: a post conflict assessment of Afghanistan's Wakhan corridor. Oryx 38 (1), 102–105.

Murphy, C., 2001. Identifying diagnostic errors with induced decision trees. Med. Decis. Making 21, 368–373.

Murphy, P., Olson, B.H., 1996. Decision-tree construction and analysis. Am. Water Work Assoc. 88 (2), 59–67.

Please cite this article in press as: Kretser, H.E., et al. Mobile decision-tree tool technology as a means to detect wildlife crimes and build enforcement networks. Biol. Conserv. (2014), http://dx.doi.org/10.1016/j.biocon.2014.08.018

Nguyen, M.H., Vu, V.D., Nguyen, V.S., Hoang, V.T., Nguyen, H.D., et al., 2007. Report on the review of Vietnam's wildlife trade policy. CRES/FPD/UNEP/CITES/IUED, Hanoi, Vietnam.

Nowell, K., 2012. Wildlife crime scorecard: assessing compliance with and enforcement of CITES commitments for tigers, rhinos and elephants. WWF Global Wildlife Trade Campaign, Switzerland.

Roberton, S. Corruption along the Vietnam-China border permits massive smuggling of endangered Animals. August 7, 2013, Policy Innovations. Accessed January 26, 2014. <http://www.policyinnovations.org/ideas/briefings/data/000260>.

Rock, M. U.S. Military focuses on apps for war. Apps & Games. Accessed online January 22, 2014. <http://www.mobiledia.com/news/87649.html>.

Rosen, G.E., Smith, K.F., 2010. Summarizing the evidence on the international trade in illegal wildlife. Ecohealth 7, 24–32.

Salzberg, S., Chandar, R., Ford, H., Murthy, S.K., White, R., 1995. Decision trees for automated identification of cosmic-ray hits in Hubble Space Telescope images. Public. Astron. Soc. Pac. 107 (709), 279–288.

Smith, A. 2013, Smartphone ownership update. Pew Research Center. Accessed online January 22, 204. <http://pewinternet.org/Reports/2013/Smartphone-Ownership-2013.aspx>.

Srivastava, K. This one thing is our military's new secret weapon. And you have it, too. Mobile, Strategies & Solutions. Accessed January 22, 2014. <http://www.mobiledia.com/news/155775.html>.

Statcounter, 2014. Top mobile and tablet operating systems in China. Accessed July 30, 2014. <http://gs.statcounter.com>.

Stokes, E.J., 2010. Improving effectiveness of protection efforts in tiger source sites: developing a framework for law enforcement monitoring using MIST. Integrative Zool. 5, 363–377.

Tallant, J., Brook, S., Roberton, S., Tran, T.X. (Eds.), 2010. An Identification Guide to Commonly Traded Wildlife Products in Southeast Asia, second ed. Wildlife Conservation Society, Hanoi, Vietnam.

Taronga Conservation Society Australia, 2014. Wildlife Witness accessed June 5, 2014. <http://taronga.org.au/trade>.

The World Bank. The role of customs. Trade logistics and facilitation. Accessed on November 7, 2013. <http://go.worldbank.org/7A8JFTUTN0>.

TRAFFIC, 2008. "What's driving the wildlife trade? A review of expert opinion on economic and social drivers of the wildlife trade and trade control efforts in Cambodia, Indonesia, Lao PDR and Vietnam". East Asia and Pacific Region Sustainable Development Discussion Papers. East Asia and Pacific Region Sustainable Development Department, World Bank, Washington, DC.

Vivoni, E.R., Camilli, R., 2003. Real-time streaming of environmental field data. Comput. Geosci. 29, 457–468.

Walston, J., Robinson, J.G., Bennett, E.L., Breitenmoser, U., da Fonseca, G.A.B., et al., 2010. Bringing the tiger from the brink—the six percent solution. PLoS Biol. 8 (9), e1000485. http://dx.doi.org/10.1371/journal.pbio.1000485.

Warchol, G.L., 2004. The transnational illegal wildlife trade. Criminal Justice Stud. 17 (1), 57–73.

Watts, M.T., 1998. Tree Finder: A Manual for the Identification of Trees by their Leaves, third ed. Nature Study Guild, New York, USA.

Wildlife Conservation Society, 2012. In plain sight: An analysis of transnational wildlife crimes in Quang Ninh Province, Viet Nam. Wildlife Conservation Society – Viet Nam Program, Hanoi, Vietnam.

Wildlife Conservation Society, 2013a. Smart patrol for smart protection of Thailand's World Heritage Site in western forest complex. Executive Report Summary. Accessed on January 26, 2014. <http://www.wcsthailand.org/english/>.

Wildlife Conservation Society, 2013b. Forest law enforcement and wildlife management status survey in Phong Nha-Ke Bang region and Quang Binh province. Wildlife Conservation Society – Viet Nam Program, Hanoi, Vietnam.

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