Characterising the extent of illegal online trade in wildlife using novel approaches

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ABSTRACT

The illegal, international trade in wildlife poses serious and pressing threats at a number of levels. Traded species are increasingly threatened with extinction and these harms extend to compromised biodiversity and ecosystem instability. Associated threats include biosecurity issues such as disease introduction (including zoonoses) and the ingress of alien species.

There is acute awareness of both the critical need for enhanced understanding of the extent and nature of the illegal wildlife trade and how challenging it is to achieve this. The online trading environment presents a particular case where challenges are amplified since it is growing rapidly, diverse and complex to monitor and regulate. Mirroring patterns in conventional trade, the online environment is increasingly being used as a means to conduct legal and illegal wildlife trade. Its attractiveness for illegal trade is illustrated by recent experience where, in response to ivory trade bans, trade shifted from physical trading outlets to online media.

The research focus of this thesis is to contribute towards addressing a key area of unmet need that underpins counter-illegal wildlife trade measures. Specifically, bridging an informational "gap" which the United Nations General Assembly (UNGA) has acknowledged under UN Resolution A/71/L.88 "Tackling Illicit Wildlife Trafficking" (2017). Under UN A/71/L.88 the UNGA has tasked the United Nations Office on Drugs and Crime (UNODC) with collecting information on patterns and flows of illicit wildlife trafficking as a support to addressing the trade. The UNODC describes bridging the informational gap as essential to successful counter illegal wildlife trade measures. I translate this imperative to the fast-growing online environment for illegal wildlife trade where the lack of information is a compelling unmet need.

I apply two approaches to researching illegal online wildlife trade and the behaviours associated with it. These are: a) "Measurement" (modelling) of online trade postings by application of two different mark recapture (MRC) models to downloaded encounter history data for the online ivory trade (Chapters 3 and 4) and b) "Asking" people who may be involved with illegal (online) wildlife trade to share this information through an online survey incorporating sensitive question models (Chapter 5).

In my initial MRC study I build on prior research into online trade in CITES-listed species to evaluate population parameters associated with (illegal) online trade in elephant ivory within the UK. Online media operate "24/7" and, currently, no suitable technology exists to monitor and interrogate this trade continuously. MRC offers a resource-efficient means to monitor trade since it can be applied to estimate trading population parameters based on incomplete observation. I assess study outcomes to identify population parameter inferences and potential actions to address trade based on these. I indicate opportunities for MRC application to enhance understanding of the illegal, online trade in ivory and, potentially, other wildlife trade commodities.

I then explore application of the complex, multi-parameter multi-state open robust design (MSORD) model to time-separated sets of encounter histories of online "ivory" trade items (UK trade). My intent is to examine the suitability of MSORD for modelling data from snap-shot online wildlife trade monitoring studies to derive maximum information and resource benefit from them. In this way, to build knowledge and understanding of the illegal online trade in ivory (and potentially other wildlife trade commodities).

I shift focus to engage with people more directly to understand their involvement in illegal wildlife trade, preferred transaction routes i.e. face to face or online, and how this balance may be changing. I apply sensitive question models (including a novel model) and direct questioning to investigate potentially sensitive purchasing behaviours in a reptile keeper community, principally UK-based. I discuss study outcomes in terms of comparative model performance and consider significant results in the context of the reptile trade. Aspects particular to sensitive question model application are discussed and suggestions for future research made, informed by learnings from this study.

Considered as a whole, the outcomes from this thesis have potential for application to increase knowledge and understanding of the illegal online trade in wildlife and contribute towards bridging the informational gap described. The MRC approaches applied may offer resource-sparing means to monitor online trade and better understand trading population parameters. This enhanced understanding could provide a basis for informed policy development and coordinated interventions ranging from educational, to law enforcement. Behavioural elements of trading populations (such as participation in illegal wildlife trade, sensitivities to it and preferred routes for purchasing items) may be further explored using sensitive question models.

This research indicates that illegal, online wildlife trade is ongoing in the (mainly) UK trading populations I have assessed, despite initiatives and enforcement actions designed to address it. This leads me to consider the effectiveness of such initiatives, and factors that may influence this. I suggest that ensuring clear understanding of the extent and nature of trade being conducted, including the behaviours that underpin it, is essential to designing suitable interventions with an increased likelihood of success.

I recommend further, coordinated research as indicated in this thesis as part of a wider initiative to deepen understanding of illegal (online) wildlife trade as a support to effective counter-measures and biodiversity conservation.

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To quote a pal who’s a bit of a poet (it’s not me, feeling coy) -

The Warren Dunes, Michigan

Some time,
perhaps
at five thirty
while I stood
the Dunes
moved - they do
that, they move four inches
annually
on average.

And the forests
atop them, rooted
in them,
moved too

AUTHOR'S DECLARATION

All chapters in this thesis were written by Lydia M. Yeo and are presented in the style of manuscripts for publication.

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Medicinal Plant Specialist Group

Logo attribution: IUCN Medicinal Plant Specialist Group: “The Silphion Plant”.

Chapter 1: Introduction

1.1 Wildlife trade - historical perspective

Wildlife trade is a highly diverse and complex area of human activity which may be described as “the sale and exchange by people of wild animal and plant resources” (Broad et al., 2003). It has no universally accepted definition, which adds to current challenges in regulation and monitoring. Under Roman law, wild animals were *res nullius*, i.e. they belonged to no-one so could be freely captured and traded (Benton and Straumann, 2010; Harrop, 2010). It is suggested that this concept gained international acceptance and adoption through the reach of the Roman Empire (Harrop, 2010). The principle of *res nullius* still applies to wild animals in some countries at the present time (Mekouar, 1999; FAO, 2002).

The Ancient Egyptians created one of the first bans on international trade in wild animals, banning the trade in wild cats ca.1700 BC (Faure and Kitchener, 2009). This trade, active since Neolithic times, features in a paleogenetic study of archaeological cat remains that found anthropogenic dispersal of *Felis silvestris lybica* occurred along trading routes, and formed part of the domestication process of the modern domestic cat (*F. catus*) (Ottoni et al., 2017). This presents another perspective on trade and its potential impacts upon species (whether or not “threatened” (IUCN, 2012)); anthropogenic “adaptive radiation” with selective breeding has influenced a species’ development with wider biodiversity impacts as part of this process.

In an example of over-exploitation linked to legitimate trade, the medicinal “Silphion” plant (no taxonomic name; synonyms include “silphium”) became extinct ca. 2000 years ago, as recorded by Pliny the Elder (23-79 AD). This was attributed to unsustainable harvesting to supply trade (Leaman, 2001; Parejko, 2003; IUCN, 2007; Keller, 2014). Until its extinction, Silphion (i.e. its derivatives) had been a principal trading commodity of Cyrenaica (State of Libya) for over 200 years (Leaman, 2001; Kiehn, 2006). It is interesting to note that the Medicinal Plant Specialist Group of the International Union for the Conservation of Nature has adopted an image of the Silphion plant, taken from the only surviving image of the

plant on ancient coinage, as their logo (see: https://www.iucn.org/ssc-groups/plants-fungi/medicinal-plant-specialist-group/mpsg-logo).

1.2 Legal and Illegal Wildlife trade

A diverse range of taxa continue to be traded, both legally and illegally. International, legal trade in over 35000 endangered species is managed under the Convention on International Trade in Endangered Species of Wild Fauna (CITES). Wildlife trade is of significant interest to conservationists and importance to wider society since, whether legal or illegal, it has the potential to affect species, habitats, biodiversity, ecosystems and human populations. Broadly, human interest may be pro- or anti- trade depending on an individuals' perspective, their relationship with wildlife trade and whether they have a vested interest in it. Interest may stem from polarised origins such as "biophilia" (Wilson, 1984) or consumer demand (TRAFFIC, 2016).

Wildlife trade operates at a number of geographical levels, from local, to intra- and international. It may be conducted legitimately (Broad et al., 2003) or illicitly (Alacs and Georges, 2008; Broad et al., 2003). Traded items include live specimens of plants and animals and numerous products derived from them, such as pelts, taxidermy specimens, ivory, timber, bark and fish-products. Commodities including medicinal plants, essential oils, industrial plants oils and waxes are highly significant products of international trade. Diverse commercial enterprises deal in wildlife or wildlife products as commodities, including the pharmaceutical, food, clothing and construction industries, the pet (companion animal) trade and zoological parks (Broad et al., 2003; Reeve, 2002).

Legitimate trade is estimated to contribute hundreds of billions of dollars to the global economy and to affect many millions of individual plants and animals each year (Broad et al., 2006; Sutherland, 2009; South and Wyatt, 2011). Its exact scale is acknowledged to be difficult to quantify with any accuracy, and this challenge is amplified for illegal wildlife trade.

Illegal wildlife trade is often classified as an environmental crime and, worldwide, this form of crime is estimated to be worth $91-258 billion p.a. (UNEP, 2016). As such environmental crime is the fourth most lucrative class of crime after drugs, counterfeiting and human trafficking. Its value is increasing rapidly, and is estimated to have increased by 26% between 2014 and 2016 (UNEP, 2016). As a specific category of environmental crime, the illegal wildlife trade is estimated to be worth $7-23 billion per annum (UNEP, 2016). As a typically cryptic activity, illegal trade poses detection challenges so that clear understanding of demographic parameters of trading populations, including extent, is difficult to attain. The broad range in estimated value ascribed to the trade points towards this uncertainty. However, a growing body of research is helping to elucidate key facets of the trade, especially which goods are being traded, and in what volumes (Blundell and Mascia, 2005; Blundell and Mascia, 2006; Wilson-Wilde, 2010a; Wilson-Wilde, 2010b; Wyatt, 2011, Pires and Moreto, 2016).

1.3 The online environment - an expansion opportunity for illegal wildlife trade

The increasing availability of the online environment over the past ca. 30 years has presented an opportunity for wildlife trade expansion. Mirroring trends in wider retail, online media are increasingly being used as a means to conduct wildlife trade, both legal and illegal (IFAW, 2005; Beardsley, 2007; Wu, 2007; IFAW, 2008; Izzo, 2010; Shirey and Lamberti, 2011; Lavorgna 2014, 2015; IFAW 2018). There is evidence that, where bans are imposed upon wildlife trade, proponents adapt by shifting trade towards online media (see later discussion).

The illegal online trade in wildlife is of significant conservation concern. Principal reasons include challenges in detection and quantitation and the rate at which it is expanding and becoming established (IFAW, 2005, 2008, 2018; Wu 2007; Sajeva et al., 2013). Associated harms to individuals, communities and economies proximate to (but not as perpetrators) the source or trade route for illegal wildlife trade commodities represent an additional, important adverse impact (Wyatt, 2013). Broadly, illegal wildlife trade constitutes a form of wildlife crime with a wide array of potential “victims” encompassing

people, the state, non-human animals, plants and environments (Wyatt, 2013; Brashares et al., 2014; Van Uhm, 2014, 2016).

1.4 Regulatory framework for international wildlife trade

The main regulatory instruments under which international wildlife trade is managed are two incidentally related biodiversity Conventions, i.e. the Convention on Biological Diversity (CBD), which entered into force on 29th December, 1993 (see: https://www.cbd.int/convention/text/) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (see: https://www.cites.org/eng/disc/text.php) which entered into force on 1st July, 1975.

The CITES, which pre-dates the CBD by nearly 2 decades, is an international trade agreement between governments to which "States and regional economic integration organisations" may sign up. CITES does not take the place of national laws, but provides a framework within which Parties must adopt domestic legislation to implement CITES nationally (CITES 2018 see: https://www.cites.org/eng/disc/what.php).

The CBD was developed under the United Nations Environment Programme (UNEP) and its objectives and scope are stated as: "The conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from commercial and other utilization of genetic resources. The agreement covers all ecosystems, species, and genetic resources" (see: https://www.cbd.int/history/ accessed September 2018). The CBD therefore references wildlife trade indirectly, through the "sustainable use" and "commercial" elements of its objectives.

The lack of explicit alignment between the CBD and CITES, from inception, and adverse impacts to effectiveness has been highlighted by Cooney (2001). Under UNEP's biodiversity liaison group efforts are ongoing to improve alignment and enhance synergies between and the CITES and other biodiversity-related Conventions. The CITES Strategic Vison 2008 - 2020, updated in 2016, references this need through goals to consolidate the Convention's strengths and further improve the relationship with "relevant multilateral

environmental agreements and related conventions, agreements and associations" (see: CITES Strategic Vision 2008-2020 accessed September 2018)

Lavorgna et al. (2018) comment on the loopholes created for criminal exploitation by the lack of harmonisation under CITES. In addition, its "unintended consequences" described as potentially criminogenic including views that CITES legitimises trade in endangered flora and fauna (citing Sollund, 2011). Lack of monitoring and enforcement of online trade is identified as a specific criminogenic opportunity. However, a systematic assessment of CITES and its implementation, applying criminological and conservation science principles, is supportive of the Convention as "the most powerful international convention on biodiversity conservation" (Lavorgna et al., 2018). As part of this assessment, a number of observations relevant to this thesis were made regarding the online trade in wildlife, i.e. opportunities to direct resources towards monitoring online wildlife trade markets were identified; the fact that "traditional law enforcement does not translate well into cyberspace (Wall, 2007)" was highlighted and the potential for situational crime prevention techniques to be applied to counter "the maze of online trade" suggested.

Legitimate trade conducted under CITES is considered to be relatively visible due to the licencing, certification and data logging mechanisms employed. However, there is debate over how reliable these data are (Blundell and Mascia, 2005 and 2006). In addition, much wildlife trade falls outside the remit of CITES so is less available for scrutiny. Records of wildlife trade may be inadequate if kept incidentally and as a secondary focus of customs data (Blundell and Mascia, 2005; South and Wyatt, 2011).

In 2016, CITES initiated the regular collection of data on illegal trade by its Parties (CITES, 2016). The first reports, covering data from 2016, were due to be submitted to CITES by October 31st, 2017. Unlike data on legal trade, this illegal trade data will not be directly available in the public domain. Instead, it will be evaluated by the International Consortium on Combatting Wildlife Crime (ICCWC) and published as future updates to the United Nations Office on Drugs and Crime (UNODC) World Wildlife Crime Report: Trafficking in Protected Species (2016). The ICCWC is a collaboration between CITES,

INTERPOL, UNODC, the World Bank and the World Customs Organization. Its purpose is to support to wildlife law enforcement agencies and networks at national, regional and global levels. The ICCWC Strategic Mission 2014-2016 and Strategic Programme 2016-2020 reference the need for information to support enhanced understanding of wildlife crime, which includes illegal wildlife trade, under -

"Focus Area 5: Improving use of knowledge and innovation to inform contemporary approaches to wildlife and forest crime: Current responses to wildlife crime are undermined by a lack of knowledge and gaps in our understanding of the scale and dynamics of crime, its drivers and emerging trends. Targeted research is required to help improve understanding of the scale and value of wildlife crime, and to identify, test and develop new and innovative approaches that may prove useful in the fight against wildlife crime." (ICCWC 2014, 2016).

Under UNEP, the CBD recently published an initiative to catalyse activities to better meet the urgent challenges of biodiversity loss (CBD, 2018). As the post-2020 global biodiversity framework this initiative aims to enhance efforts to meet biodiversity loss challenges by implementing "transformational change". Prerequisites include changes in behaviour by producers and consumers, governments and businesses; a deeper understanding, based on scientific evidence, of the factors, motivations and levers that can facilitate such transformational change; and innovation in the means of implementation. To achieve this, interdisciplinary approaches are indicated as well as systems-thinking with systems transition to enhance CBD implementation (see The Deming System of Profound Knowledge® (SoPK) (Accessed September 2018) for a general overview and Black and Cosey (2014) for a conservation effectiveness perspective).

1.5 Illegal wildlife trade: a crime of global concern

Since 2012 there has been a growing recognition of wildlife crime, including illegal wildlife trade, as a serious crime demanding a robust response. Examples of harms inflicted by illegal (online and non-online) trade include compromised biodiversity (Flores-Palacios and Valencia-Dıaz, 2007; Loucks et al., 2007; Barry, 2011; Wyatt, 2011; Young et al., 2016); population and species extinctions (Ceballos et al., 2017); the introduction of alien species (Derraik and Phillips, 2010; Johnson, 2010) and the introduction of exotic diseases, including zoonoses (Pavlin et al., 2009). Wider ecosystem imbalance (Myers et al., 2007) may also result.

A series of events at national, regional and global levels have advanced the aim of recognition of wildlife crime as a serious crime. These include the UK Conference on Illegal Wildlife Trade in 2014 and subsequent conference in Botswana (Kasane) in 2015. Both events produced statements of intent consolidating next steps for aligned, anti-illegal wildlife trade activities, i.e., the London Declaration, 2014 (UK Government 2014) and the Kasane Statement (UK Government 2015). At the United Nations Congress on Crime Prevention and Criminal Justice in Doha, Qatar in 2015 a landmark development was achieved in the first tabling of wildlife crime as a Congress agenda item and its inclusion within the Doha Declaration adopted at that Congress (UNODC, 2015a). Shortly afterwards, the first United Nations Resolution to recognise the illegal wildlife trade as one of the largest transnational criminal activities, comparable to trafficking in drugs, arms and people, was adopted by the United Nations General Assembly (UNGA, 2015). This signalled heightened political concern over the adverse impacts of poaching and the illegal wildlife trade upon species, ecosystems and local communities as well as the need to counteract these (UNODC, 2015b). Momentum continues to grow and, in 2017, the 193 Member States of the United Nations adopted a comprehensive Resolution on tackling illicit wildlife trafficking (UNGA, 2017); see Resolution on tackling illicit wildlife trafficking). The growth in online trade and cybercrime relating to wildlife and wildlife products is explicitly recognised with a requirement for “innovative strategies and increased

intergovernmental cooperation" in light of this. The Resolution also recognises the important work of the ICCWC in providing technical assistance to member states (See: Role of ICCWC). It requests the UNODC to collaborate with Member States to continue and strengthen collection of information on patterns and flows of illicit trafficking in wildlife and report them biennially. Information collection on cybercrime and online trade is not explicitly referenced. However, CITES published a number of decisions specifically directed towards tackling cybercrime after its 17th Conference of the Parties in 2016 (See: CITES Decisions Combating Wildlife Cybercrime 2016). Grouped under the theme "Combating Wildlife Cybercrime" decisions included the formation of "a working group on wildlife cybercrime that includes both producer and consumer countries and those with large internet companies, non-governmental organizations with expertise, lawyers, and other relevant experts". This group was constituted in 2017 and is due to report back to CITES on progress in October 2018 (CITES 2017) (See: CITES 2017 69th Meeting of Standing Committee).

In the UK, from where the data used in my research is drawn, events such as the imminent UK Conference on Illegal Wildlife Trade in October 2018 position illegal wildlife trade as a serious crime under the conference's aim of "Tackling IWT as a serious organised crime, Building coalitions and Closing markets" (UK Government 2014); see: London Conference on the Illegal Wildlife Trade 2018. Themes of enhanced collaboration, harnessing technology and innovative solutions feature within conference objectives.

The UK Government aims to strengthen regulation of the UK ivory trade by introducing a Bill to implement a virtual ban on the trade. The intent is to show leadership and contribute towards global efforts to combat the illegal trade in ivory and threats to elephant populations through poaching to supply the trade (UK Government 2018); see: UK Government Ivory Bill 2018. However, experience in other regions suggests that trade rapidly moves online in response to a ban, where it is both more difficult to detect and may reach new consumers, thus increasing demand. Examples to date include the USA (TRAFFIC, 2017) and China (IFAW, 2014; TRAFFIC, 2018). In the USA, research

indicates a reduction in ivory for sale through physical retail outlets, but a marked increase in ivory for sale online since the retail ban (TRAFFIC, 2017). In China, studies indicate a shift away from selling wildlife products via online marketplaces towards private online forums and social media platforms (IFAW, 2014). Post-ivory ban, so-called “Millennials”, characterised as having hyper-social connectivity (i.e. a high number of online contacts and interactions) exhibited the highest ivory purchase index score of all tested groups, indicative of persistent ivory purchasing, and bought ivory online significantly more than other consumer groups (TRAFFIC, 2018). The trade bans in the USA and China may therefore have had unintended (criminogenic) consequences (see Lavorgna et al., 2018) which may similarly affect the UK ban, when implemented

Globally, enforcement agencies such as the International Criminal Police Organization (ICPO-INTERPOL) recognise that a high proportion of wildlife crime, including trade, is carried out by organised criminal networks, attracted by the area’s typically low risk and high profit nature (ICPO-INTERPOL, 2015; also see Wittig, 2016). A principal impetus driving formal recognition of wildlife crime as a serious crime is the pressing need to improve the effectiveness of counter-measures (Challender and MacMillan, 2014; Lavorgna et al., 2018). A precursor to this is improved understanding of the illegal wildlife trade so that enforcement measures may be formulated, prioritised and targeted appropriately. As emphasised, areas where more clarity is needed include understanding the extent of trade, whether this takes place face-to-face or online and how this balance might be shifting.

The illegal online wildlife trade is not just a conservation issue; it is multi-faceted in nature in terms of traded commodities, trading actors and motivations, global extent and potential impacts. As such, it demands a suitably aligned, interdisciplinary approach towards improving understanding of key aspects (St John et al., 2010; Pooley et al., 2013; Bennet et al., 2017). To date, a number of studies have attempted to measure the trade’s extent but with varying degrees of success and accuracy. A cohesive picture is still elusive, due to the complexities involved in measuring a typically covert trade, often further

camouflaged by the larger trading volume of legitimate goods. The online environment, given its global reach and the particular challenges in monitoring and regulation it presents, amplifies these challenges still further.

1.6 Mark-recapture applied to monitor online trade

The online marketplace is available “24/7”, worldwide which makes continuous monitoring to detect illegal online wildlife trade impractical, given limited resources together with current technological and legal constraints. Methods are therefore required to allow information to be gathered on key population parameters based on non-continuous monitoring. A number of methods exist to measure population characteristics indirectly through drawing inferences from a suitable population sample. Mark-recapture is one such method that has been used extensively in ecology, but has its roots in the social sciences (demography). It shows potential for application to the study of trading populations, including those trading legally and illegally in wildlife. Mark-recapture (MRC) has been applied in a range of fields to estimate total population size (Böhning, 2008) and/or to estimate demographic parameters of interest from an observed sample (Lebreton et al., 1992; Amstrup, McDonald and Manly, 2005). Its use in estimating the size of cryptic, including criminal, populations has been recognised in a number of sociological contexts including illicit drug use or supply (Bouchard, 2007; Vaissade and Legleye, 2009), the illegal drug and arms trades (Bloor, 2005) and estimation of victim numbers from acts of terrorism (Murphy, 2009). As far as we are aware MRC has, however, never been used to investigate illegal online trades, although others (e.g., Lavorgna, 2015; Vida et al., 2016) have applied it to attempt to provide an understanding of online trade dynamics.

1.7 A review of the literature on non-ecological application of mark-recapture

As context to Chapters 2 and 3 of this thesis, I review the literature on non-ecological (social science) adoption and application of MRC and provide a brief overview of MRC concepts. Since social science application of MRC is a relatively new discipline (Böhning and van der Heijden, 2008; Böhning et al., 2017) I focus on its uptake in the social

sciences from approximately the mid twentieth to early twenty-first centuries. Publications are selected from the latter portion of this timeframe (i.e. 1990-2018) to illustrate contemporary sociological application of MRC; 38 papers are identified to illustrate MRC applied to research cryptic human populations including those involved in illicit behaviours (Table 1-1).

Table 1-1: Number of published papers per social science area of research for the period 1990-2018 where MRC has been applied to estimate population demographics (Source: Google Scholar accessed September 23rd, 2018)

MRC Application Area	Number of publications (1990-2018)
Acts of terrorism	1
Casualties through conflict	1
Illegal firearms	1
Physical anthropology – comingled human remains	1
Homelessness	2
Illegal immigrants	2
Prostitution	3
Criminal population size	4
Drug use	23
Total	38

Of the identified papers, the majority (n=23) researched aspects of illegal drug use, either in isolation, or in combination with other areas such as homelessness, prostitution or illegal immigration. Three papers researched prostitution; 1 with estimating casualties through conflict; 4 with estimating criminal population size; 2 with estimating homelessness; 1 estimated illegal firearms; 2 estimated illegal immigration; 1 estimated comingled human remains (e.g. from conflict) and 1 estimated casualties from an act of terrorism.

Böhning and van der Heijden (2008) suggest that “Discrete mixture models offer a wide and flexible modelling framework to cope with heterogeneity in the parameters representing capture–recapture probabilities”. The authors also comment that “mixture model estimates should be seen in the context of other estimators”. It is also observed that, when selecting models for mixtures, the Bayesian Information Criterion (BIC) was

found to be a better choice than the Akaike Information Criterion (AIC) (See also Kuha, 2004).

Bouchard et al. (2010) reviewed MRC as a potential method to estimate the size of illicit drugs markets in Canada and support Zelterman's truncated Poisson estimator as a robust means to estimate population size for illegal populations, where the assumptions of the Poisson distribution may be violated. The authors explain that Zelterman's estimator is robust in such applications because "its logic is based on the idea that the projected rate of capture for those individuals not yet captured more closely resembles the rate found for those individuals captured only once or twice".

The diversity of MRC application is illustrated by inclusion of physical anthropology, war and terrorism casualty references which serve to highlight MRC as a means to quantify the victims of crime, in contrast to the "supply and demand", producer and end-user process dynamics present in covert trades such as the illegal drugs trade, or prostitution. Illegal firearms possession forms the focus of one paper.

1.8 Origins and development of MRC

Recognition of the need for indirect methods to measure demographic parameters of human populations has a long history. In Western Europe, it may be traced back to the seventeenth century where John Graunt (1662) is recorded as having measured the population of London, England using a method similar to that commonly known as mark-recapture (MRC) today (Bloor, 2005). Subsequently, in 1786, Pierre Simon Laplace applied MRC principles to estimate the population of the country of France (Pollock, 1991). A number of synonyms exist for MRC in the social sciences, including contact-recapture; dual-list estimation; dual-record estimation and multiple list system. Given its earliest reported origins in the field of social science (demography), it is interesting to note that the next, major uptake and application of MRC occurred in the discipline of ecology, approximately 100 years after the work of Laplace (Pollock, 1991). In the late nineteenth and early twentieth centuries the potential value of applying MRC to infer the population

size of a non-human population from an observed sample was recognised by Petersen (1889 and 1894), studying fish populations, and Lincoln (1930), studying wildfowl.

Dating from the late twentieth century, MRC has been applied to estimate population size in a wide, and expanding, variety of non-ecological (social science) areas including epidemiology, alcoholism, illegal drug use, the illegal drug and arms trades, illegal immigration, people trafficking and prostitution (Bloor, 2005; Böhning, 2008).

In the mid-twentieth century, MRC was applied to estimate births, deaths and registration completeness in a landmark paper by Sekar and Deming (1949). MRC was also applied during this period to estimate birth registration completeness using census data (IWGDM, 1995, citing Shapiro, 1949) and, under the designation “dual record system” or “dual system estimator” applied to estimate census undercount from the mid twentieth century (IWGDM, 1995).

Wittes (1968) is credited with having been instrumental in recognising the potential for application of MRC to epidemiology, and in championing its use in this area in the mid 1960’s (IWGDM,1995). However, adoption of MRC did not proceed rapidly and there was a lag of some thirty years (i.e. until the mid-1990’s) before MRC became more established (IWGDM, 1995). Subsequently, application of MRC in epidemiology has become more widespread, and its use in this area is relatively well accepted. However, it is pertinent to note that there are recent examples of continuing debate over its value in this field. For example, Jarvis et al. (2000), assessing health event outcomes in an epidemiological study, comment that:

“Very little can be deduced accurately about the scale or characteristics of an unobserved group by the use of mark/recapture applied to two overlapping health event registers.”

However, in a subsequent study in a similar research area (i.e. injury research) Morrison and Stone (2000) observe that:

“CRC (MRC) is a potentially useful method of evaluating the completeness of data sources and identifying biases within datasets. However, ascertainment corrected rates

should be viewed with caution. A number of requirements of the capture-recapture technique are unachieved in this study of injury in the human population."

These, disparate, contemporaneous views illustrate the evolving nature of MRC application in relatively new fields such as epidemiology and how case and context-specific use of MRC as an evaluative or analytical tool may be. Further, it appears that the process of trans-disciplinary adoption described by LaPorte (1994) is exemplified by the application of MRC in epidemiology, whose use continues to be debated and developed over forty years from first reported application in this area.

LaPorte (1994) set out a compelling case for "assessing the human condition" using MRC techniques, drawing on Sekar and Deming's 1949 study, together with more recent studies on prostitution and HIV infection (Bloor et al., 1991; McKeganey et al. 1992), homelessness and mental illness (Fisher et al., 1994). More philosophically, LaPorte (1994) citing Hall (1992) extends his consideration of MRC to the process by which techniques may be shared, to positive effect, across the artificial boundaries of scientific disciplines. Pertinent reference is also made to possible barriers to the translation of ideas and methods across disciplines, such as the pull exerted by established practice and the prevailing culture which surrounds it. Set against this is the challenge of validating new ideas in the face of established practice, such as gaining acceptance of the value of extrapolation to estimate population size, rather than relying on so-called "complete count" data (LaPorte, 1994).

From areas of relatively well-established non-ecological use, such as human census and epidemiology, MRC continues to be applied in an expanding, diverse spectrum of novel areas. These include particle physics (Sanathanan, 1977) and linguistics (Efron and Thisted, 1976; Meara and Olmos Acoy, 2010; Racine, 2011). MRC has also been applied to estimate victim numbers from terrorist events (Murphy, 2009) or war crimes (Ball et al., 2002; Stone, 2002; Zweirzchowski and Tabeau, 2009; Manrique-Vallier et al., 2011). In the latter case, data generated using MRC was used as pivotal evidence in the trial of

Slobodan Milosevic for war crimes (Stone, 2002: “Statistical Analysis Provides Key Links in Milosevic Trial”).

Since MRC has been applied in different disciplines for varying lengths of time, with no obvious, active cross-disciplinary collaboration[1], it may be anticipated both that a differentiated knowledge base exists across these disciplines, and that the maturity of MRC methodology might vary similarly. Review of the literature is broadly supportive of this point, with notably more papers on methodological development existing in ecology than in the social sciences. Also, the confidence and method familiarity developed over 100 years of experience with MRC has provided a foundation for research into novel approaches in ecology, versus other disciplines, such as the recent application of Bayesian statistics (McCrea and Morgan, 2014).

MRC is not equally applicable to all datasets, since specific model assumptions must be met by the subject data in order for MRC to yield meaningful results. Hence, MRC does not necessarily translate directly between disciplines, given the structural differences in “typical” datasets associated with each discipline. For example, in ecology, data might comprise a series of presence/ absence observations whereas, in demography or epidemiology, data tend to take the form of single (or multiple) lists. It is essential that models appropriate to the data under consideration are used to ensure that results are meaningful, and to avoid so-called “misguided inference” due to the use of inappropriate models (Johnson and Omland, 2004). Selecting an appropriate MRC model is therefore key, and is the subject of much literature. The contemporary approach of model selection predominates in contemporary MRC analysis, and has been described as “a tool for making inference about unobserved processes based on observed patterns” (Johnson and Omland, 2004).

Given the array of complex statistical analyses which exist for post-hoc analysis of MRC data, it is important not to overlook the fundamentally important point of data suitability. That is, the fitness for use of input data, linked to the design of the study which yielded it.

[1] In ecology, the Euring initiative exists as a forum for collaborative MRC co-development by statisticians and ecologists

Lindberg (2010) observes that “design is the most influential element in the pathway to statistical inference” and comments on the necessity to ensure study design fundamentals, e.g. suitable sample size, are ensured to mitigate against study failure through design flaws. Commentators including Otis (1978) and Pollock (1982) also acknowledge the importance of appropriate study design. Lindberg (2010) suggests that a collective reaction to poor study design and associated assumption violations has been to focus on the identification of downstream analytical solutions, when efforts might be more effectively directed towards ensuring appropriate study design.

In summary, debate continues on the utility of MRC in certain fields, whilst, simultaneously, it is actively explored and applied as a technique in novel areas. Based on this observation, non-ecological MRC application may be viewed as an active and expanding area of research which offers significant potential for future studies.

1.9 Comparative perspective: sociological versus ecological application of MRC

From its recorded late nineteenth to early twentieth century adoption as an ecological tool, MRC has continued to be applied extensively in ecology to assess populations (Agresti, 1994; Böhning, 2008). In addition to this, MRC has also been adopted, or re-adopted, for application in a variety of social science and allied fields including demography (census undercount), epidemiology and to assess the extent of illicit behaviours, such as prostitution, and illicit drugs use (Pollock, 2000; Böhning and van der Heijden, 2008).

To place use of MRC within the social sciences in broad context compared to its use in ecology, search results from Google Scholar using the search term “mark recapture” in conjunction with each of the separate terms: ecology; conservation; biodiversity; drug abuse; alcoholism; sociology; epidemiology; homelessness; criminology and prostitution yielded the results presented in Table 1-1. Note that synonyms including “dual list estimator” are used in the social sciences to denote MRC, so different numbers of papers identified per discipline may result according to which synonyms are used as search terms. These results are intended to provide an illustrative snapshot, only, of the activity within and between different social science disciplines where MRC is applied. The

disciplines selected are intended to represent the main social science areas where MRC is applied, informed by prior research in this area (Yeo, 2010 (MSc thesis)).

The results presented in Table 1-2 and Figure 1-1 illustrate that MRC has been applied most extensively in ecology, and less so in the social sciences. Uptake of MRC use in epidemiology appears highest, followed by a deliberately broad bracket of "sociology" and then specific areas involving social science research of cryptic populations associated with drug abuse, prostitution, homelessness and alcoholism.

Table 1-2: Number of published papers identified using the listed search terms via Google Scholar (accessed September 23rd, 2018)

Search term (part 1)	Search term (part 2)	Results returned (n papers)
"MARK RECAPTURE" AND	"ECOLOGY"	29400
	"CONSERVATION"	24500
	"BIODIVERSITY"	15000
	"EPIDEMIOLOGY"	3400
	"SOCIOLOGY"	628
	"CRIMINOLOGY"	131
	"DRUG ABUSE"	97
	"PROSTITUTION"	93
	"HOMELESSNESS"	84
	"ALCOHOLISM"	51

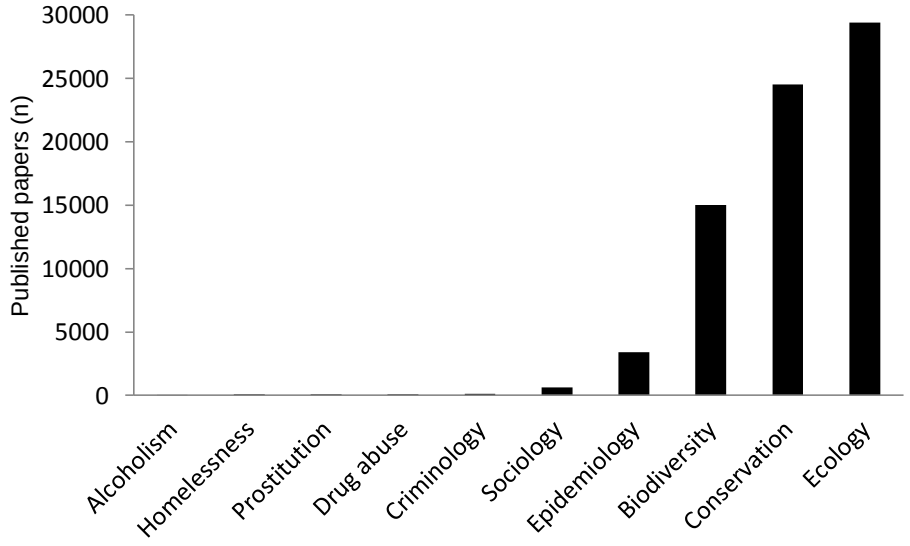


Figure 1-1: Graphical representation of the results presented in Table 1-2

2.0 Outline of MRC methodology

A comprehensive overview of MRC models and data analysis methods may be found in McCrea and Morgan (2014). To frame MRC content of later chapters, an outline of major MRC models and methods is included here:-

MRC models fall into two, broad categories, according to the assumptions integral to model design and operation. These two categories are known as closed-population models, and open-population models.

Closed population models

Closed population models are those where the population under assessment is assumed to be constant throughout the period during which it is being studied, i.e. its size, in terms of the total number of individuals, is not changing due to births, deaths, immigration or emigration (or, in non-biological settings, their analogues). This assumption of closure forms one of the three cornerstone assumptions of closed population models, which are:-

a) That the population is closed to additions or deletions, i.e. it remains of constant size during the study period

b) That all animals are equally likely to be captured in each sample

c) That marks are not lost or overlooked

In ecology, early applications of MRC assumed that populations were “closed” (Amstrup et al., 2005) so its use here is long-established. Whilst it is acknowledged that, in reality, most populations are not truly closed, it is sometimes found that population changes over the time period of interest are so minimal that the assumption of closure is “a reasonable approximation” (Amstrup et al., 2005) such that study outcome is not adversely affected by violation of this assumption. Closed population models are therefore of continuing use, and interest, in the study of populations and are, themselves, the subject of ongoing research to refine and develop new models and methods of data analysis.

Key steps in the evolution of closed population models include the development of the two sample method, where one sample of a population is taken and “marked”, then “released”. A second sample is then taken, and the number of previously “marked” individuals counted; data from the first and second sampling occasions can then be used to estimate the total population size. A further development from this, two-sample method is attributed to Schnabel (1938) and concerns taking three, or more, samples from a population. Individuals from the first sampling occasion are “marked” and “released”. Numbers of “marked” individuals that are “re-captured” on subsequent sampling occasions are noted, with the study being conducted over a time period where an assumption of population closure is presumed. Overall population size can then be estimated from the data gathered, with the opportunity to apply diverse models (guided by model suitability) to achieve this aim (Amstrup et al., 2005).

As previously mentioned, assumption violation can compromise experimental outputs (i.e. population size estimates) yielded by MRC models and complying with the assumption of equal catchability may be especially challenging. This is because variability in capture probability of individuals may exist (capture heterogeneity) which may be due to age, gender, or other factors. There may also be variation in individuals’ catchability based on their response to initial capture (termed “trap response”). Individuals may behave in a “trap-happy” or “trap-shy” way post initial capture, which may introduce bias to population estimates. Trap-happy individuals are more likely to be captured, since they become attracted to traps due to (in an ecological setting) presence of food, or some other attractant. In contrast, trap-shy individuals actively avoid traps through prior experience which has conditioned them to become trap-shy (averse).

Since the 1990’s, there has been an increase in research into MRC methods in ecology to refine them to better represent situations in the field. Principal developments include a Bootstrap Method (to obtain variance estimators); improved interval estimation using log transformation; a Maximum Likelihood Estimator for model M_{tb}; a Jackknife Technique for model M_{bh}; Log-linear or Generalised Linear Models; Bayesian methods; models

incorporating covariates, and model selection, model uncertainty and model averaging (Amstrup et al., 2005). A need to move away from the restrictive requirement for nested models in early methods for model selection has led to current model selection approaches which largely rely on the Akaike's Information Criterion (AIC). Here, model selection involves defining a set of candidate models which may be most suitable for the data under analysis, fitting the models to the data and then calculating each model's AIC value and considering these relative to each other (Amstrup et al., 2005).

Open Population Models

Open populations are those which are, or could be, changing during the time they are being assessed due to one or more of the following events: births, deaths, emigration or immigration (or, in non-biological settings, their analogues). Open population models, therefore, are those designed to operate according to these assumptions and, since ecological populations often vary according to the reasons for change listed above, are used extensively in ecology and have been since the early 20th century (Amstrup et al., 2005). Key steps in the evolution of open population MRC models have included the introduction of maximum likelihood estimation in the 1960's leading to the development of the Cormack-Jolly-Seber (CJS) and the Jolly-Seber (JS) models (Amstrup et al., 2005). The CJS model permits survival and capture probabilities to be estimated; is based on recapture of marked individuals. In contrast, the JS model permits population size to be estimated, in addition to survival and capture probabilities, since it is takes account of ratios of marked to unmarked individuals. In order for the JS model to be valid, a number of assumptions must be made, i.e.:-

Equal catchability per individual

Equal survival chance of marked individuals

Retention of marks and consistent observation of marks per individual

Short sampling periods

All emigrations from the population are permanent

(After Amstrup et al., 2005)

In addition, unlike the closed MRC models, the JS model does not allow for unequal catchability of individuals due to heterogeneity or trap response (Amstrup et al., 2005).

Recently, computer-based analysis has facilitated the development of more complex open population models, and also elevated the importance of model ranking and selection procedures. Computer-based analysis may involve the application of numerous models to the same dataset, so model ranking, supported by knowledge of the situation in which the models are being applied (i.e. their relevance) must be used to discern the most appropriate outcome from the study in question. Model development, in ecology, has been prompted by the desire to make models more relevant to the ecological populations to which they were being applied. Developments stem from refinements of the CJS and JS models and permit, for example, estimation of population growth rate (reverse-time modelling); estimation of population size assuming that unmarked individuals are randomly sampled; models where both survival and recruitment probabilities are included and the “Robust Design” model which involves sampling over two temporal scales (Amstrup et al., 2005).

2.1 Summary

The relatively small number of papers identified on the subject of social science application of MRC to research cryptic or illicit populations (Table 1-1) suggests that this area is relatively novel. At the same time, the presence of recent publications indicates that it is still dynamic and evolving so offers potential for novel research into the illegal wildlife trade. A comprehensive overview of MRC methods for the social and medical sciences may be found in Böhning et al., 2017.

Principal challenges from sociological studies applying MRC are reported to include population definition, source (sample) heterogeneity, sample independence and population movement. Böhning and van der Heijden (2008) suggest use of discrete mixture models to address mark-recapture probability parameter heterogeneity. Bloor (2005) comments that MRC methods have potential as useful population estimation tools, but face challenges including “ethical identification of matches, sample independence,

population movement, population definition, and sample heterogeneity". Bloor suggests that the first three of these problems may be readily addressed, but that the last two are more intractable; here, appropriate selection of datasets or combining MRC methods with a screening instrument is offered to address the population definition issue, whilst separate modelling of different constituent sub-populations is suggested to address sample heterogeneity.

Consideration of prior reviews of MRC, focussing on its evolution, indicates that the tendency for sociological studies is to treat MRC populations as open, in contrast with ecological studies, which tend to treat them as closed (Bloor, 2005). Further, that "most of the techniques for modelling open population estimates have only recently been developed and are still under appraisal" (Bloor, 2005, citing Borchers et al., 2002). Consideration of this pivotal aspect, i.e. delineation of study populations as open, or closed, is key to selecting appropriate MRC models.

Based on this evaluation of MRC application in ecological and sociological contexts we conclude that the method demonstrates suitability for application to assess population parameters associated with the (illegal) online trade wildlife. I therefore apply MRC to model online postings related to the trade in elephant ivory in the U.K. to increase understanding of the illegal online wildlife trade.

To provide context regarding use of the online environment for illegal wildlife trade to inform the results of chapters 3 and 4, I apply sensitive method techniques (see Nuño and St John, 2014) to evaluate face to face versus online transactions. The growth in availability and adoption of the online environment prompts questions around how human behaviour may vary according to whether interactions occur face to face (F2F) or online, especially where behaviour may be illegal. From the origins of the Internet (ca. 1960's) and the World Wide Web (ca.1982) human interactions mediated via these related entities have continued to expand rapidly and to diversify. The study of human behaviour online versus F2F is now an active and expanding area of anthropological (psycho-social and philosophical) research (Blažun Vošner et al., 2016).

Human behaviours can deviate from established norms when interactions occur online (Suler, 2004; Ploug, 2009) and this may manifest as constructive, supportive behaviour or tend towards more destructive extremes (Christopherson, 2006). Online environmental attributes including perceived anonymity, physical invisibility, asynchronicity, textuality and personality-linked factors may engender the "online disinhibition effect" (Suler, 2004; Joinson, 2003, 2007) where psychological restraints that usually act to moderate behaviour to lie within societal norms are reduced (Joinson 2003, 2007; Suler, 2004). The concept of online disinhibition builds on Zimbardo's (1969) deindividuation theory, where an observed increase in expression of usually inhibited behaviour (i.e. the administration of electric shocks to fellow study subjects) was ascribed to the "deindividuated state" (Zimbardo, 1969).

When researching sensitive topics, such as illegal behaviour, use of conventional surveys can result in biased response data and diminish the validity of results. However, a number of methods, or models, developed specifically to investigate sensitive topics and behaviours can be applied to mitigate this risk. These "sensitive question models" (Chaudhuri and Christofides, 2013) are designed so that it is not possible to link individual respondents with indications of illicit behaviour. Instead, this may only be inferred at group level by statistical analysis of all responses submitted for both sensitive and non-sensitive content. The premise is that surveys incorporating sensitive question models may yield less biased response data since respondents are more likely to respond truthfully through the anonymity offered by the methods (Nuño and St John, 2015). The act of researching sensitive topics online, rather than F2F, may also enhance generation of valid responses through a reduction in social desirability bias (Kays, 2012) and potentially the online disinhibition effect (Suler, 2004; Joinson, 2003, 2007).

2.2 Research Focus

The research focus of this thesis is on contributing to address a key area of unmet need for counter-illegal wildlife trade measures, i.e. enhanced understanding of the nature of the illegal online trade. As context, research is framed under the United Nations Office on

Drugs and Crime Report (2016) as a member of the ICCWC and as the organisation tasked by the UN with “strengthening collection of information on patterns and flows of illicit trafficking in wildlife”. The Report specifies 3 key areas of unmet need for counter-wildlife trafficking (trade) measures, i.e.-

1. Informational

2. Legislative

3. Operational

The report states that “This report has documented the great lengths to which traffickers go to exploit loopholes in the international controls. This is a testament to the strength of the international controls. But it has also highlighted several significant gaps that, if addressed, could dramatically reduce the negative impact trafficking is having on wildlife. These gaps can be categorized under three headings.”(UNODC, 2016)

This research aligns under unmet need 1: Informational which, if addressed, would support the bridging of gaps 2 (legislative) and 3 (operational).

2.3 Thesis Aims and Objectives

My principal aim is to explore novel methods to increase understanding of the online, illegal trade in wildlife using the UK online ivory trade a case study. In addition, to improve understanding of purchasing propensity for (illegal) wildlife trade items by engaging with purchasers more directly using an online survey incorporating sensitive question models.

Specific aims and objectives

Chapter 2: To assess the suitability of MRC as a method to assess key population parameters associated with the illegal, online trade in wildlife by means of a method validation study.

Chapter 3: To apply MRC to assess key population parameters associated with the illegal, online trade in wildlife and to elucidate those parameters.

Chapter 4: To assess the suitability of multi-state open robust design MRC to evaluate time-separated online trade encounter histories and potentially model data from discrete online wildlife trade monitoring studies

Chapter 5: To undertake a methodological comparison applying sensitive question models (including a novel model) to evaluate buying propensity and trends associated with items of illegal wildlife trade.

Chapter 6: To evaluate research outcomes versus thesis objectives and within the UNODC framework of bridging an informational knowledge gap.

2.4 Thesis Outline

Chapter 1:

I start by reviewing the method of mark-recapture (MRC) for application to assess key demographic parameters for human populations engaged in illegal (online) wildlife trade. A description of main MRC concepts is provided, and its application to study cryptic human populations reviewed. To date, the most extensive use of MRC has been in ecology, conservation and biodiversity studies, despite the method's origins in the study of human population demography (population size). However, it is currently applied in diverse disciplines, including epidemiology, criminology and the study of drug and alcohol abuse to evaluate human populations.

In subsequent chapters I first validate MRC as a method to assess key population parameters associated with the (illegal) online wildlife trade (Chapter 2). I then explore two approaches to assessing illegal online wildlife trade and the behaviours associated with it. These are: a). "Measurement" (modelling) of online trade postings by application of two different MRC models to downloaded encounter history data (Chapters 3 and 4) and b). "Asking" people who may be involved with illegal (online) wildlife trade to share this information through online survey incorporating sensitive question models (Chapter 5).

Chapter 2:

I validate MRC as a method to assess (illegal) online wildlife trade by first undertaking a sensitivity study then conducting two modelling studies, respectively in the presence and absence of parameter heterogeneity. I assess MRC model performance across a range of parameter values representative of those associated with the online trade in ivory using encounter history data from my research as the basis for analysis. I produce summary statistics to permit assessment of model performance for a range of parameter values.

Chapter 3:

In my first MRC study, I build on prior research into online trade in CITES-listed species (Yeo, 2011) to evaluate population parameters associated with (illegal) online trade in ivory. I assess MRC study outcomes to identify supportable population parameter inferences. Based on these, I indicate future opportunities for MRC application to enhance understanding of the illegal, online trade in ivory and, potentially, other wildlife commodities.

Chapter 4:

In my second MRC study, I apply the complex, multi-parameter multi-state open robust design (MSORD) model to time-separated sets of encounter histories of online trade items described as “ivory”. My objective is to assess whether MSORD shows potential for modelling data from discrete, snap-shot online wildlife trade monitoring studies. If so, it may enable maximum value to be derived from the hard-won data these studies represent hence add to the wider knowledge base on the illegal online wildlife trade.

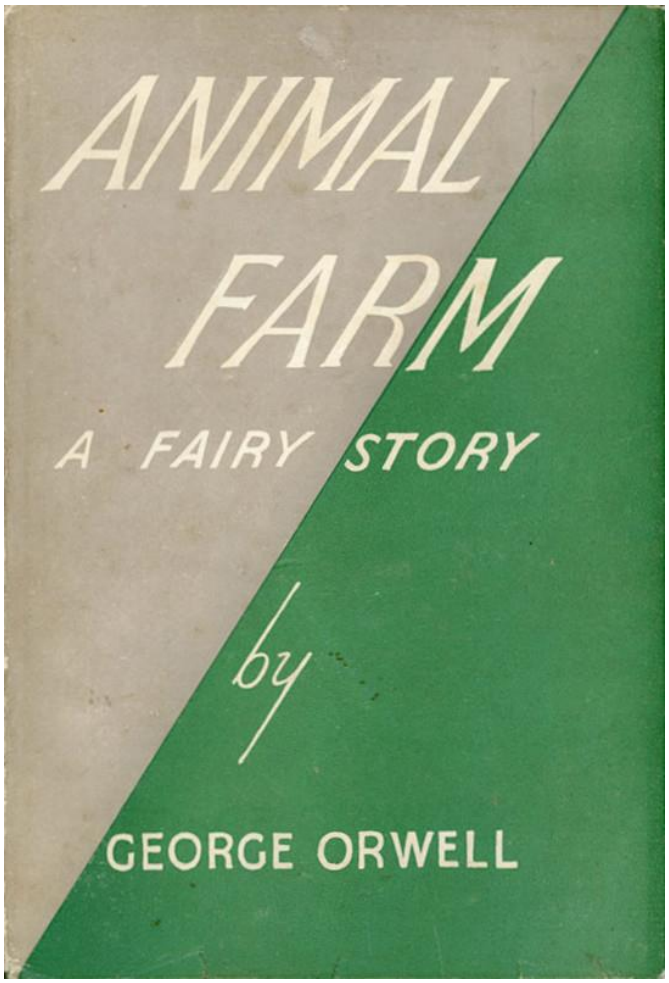
Chapter 5:

Moving towards engaging with people “directly” about potential involvement in the illegal wildlife trade, as well as knowledge of CITES as context, I apply 3 sensitive question models and direct questioning to investigate potentially sensitive purchasing behaviours. I evaluate purchasing prevalence for reptiles of questionable legal origin either face to face,

or online and over a ±1-year time frame relative to survey completion date in each case. Statistically significant results are discussed in the context of the reptile trade and recommendations made for future research. The complexity of sensitive question models is highlighted and reasoned suggestions for future research made based on study outcomes.

Chapter 6:

I evaluate the main outcomes from Chapters 3, 4 and 5, supported by Chapter 2 (Method Validation) and within the context of thesis aims and objectives (Chapter 1). I describe key findings and opportunities for future research to help bridge the illegal (online) wildlife trade information and knowledge gap.



"All animals are equal, but some animals are more equal than others."

Animal Farm: A Fairy Story. George Orwell, August 1945

Chapter 2: Method validation study

2.1 Objective

The objective of this study is to assess the suitability of MRC to model population parameters for an online trading population representative of illegal online wildlife trade. Suitability is assessed by means of three studies (a-c) reported in this chapter -

a) Population size estimation with reference to a population of known size using incremental reduction in observations to evaluate model performance for different detection probabilities (sensitivity analysis).

b) A simulation study using modelling in the absence of heterogeneity in parameter probabilities to assess MRC (Jolly Seber) model performance hence suitability under this condition

c) A simulation study using modelling in the presence of heterogeneity in parameter probabilities to assess MRC (Jolly Seber) model performance hence suitability under this condition

2.2 Study (a): Sensitivity analysis

2.2.1 Objective

The objective of this study is to assess the suitability of MRC to model population parameters for an online trading population representative of illegal online wildlife trade. Assessment is made by estimating population size with reference to a population of known size using incremental reduction in observations to evaluate model performance for different detection probabilities. This suitability assessment precedes a more extensive study where population size will be unknown. The model is fitted to a data set of downloaded “ivory” transactions taking place within the U.K. on eBay U.K. Model robustness is assessed for the full (100%) encounter histories, and also for a randomly generated 50% set derived from this. For each of these two data sets observations are randomly removed to simulate “missed” observations and estimates of population size (N) assessed relative to the missed observations.

2.2.2 Method

In order to develop our observation dataset of known size we first constructed a search term to retrieve relevant online advertisements, or postings. The search term “Ivory; Antique; UK only” was specified and used to extract items posted for sale on the generalist online trading site eBay UK. A broad search term of “ivory” was chosen to secure a dataset of suitable size for analysis. Postings for items of ivory colour (e.g. soft furnishings) as well as items made from the material ivory (e.g. elephant ivory) or substitute (e.g. resin) were therefore retrieved and used as a basis for analysis. For each item, we recorded in Excel the Seller Identification details, i.e. the “mark” required to undertake MRC analysis. This mark was selected as a reasonable analogue to the mark used in ecological MRC. Information responsive to the search term was recorded once an hour over a 12 hour period from 0830 until 2030, inclusive, on a selected weekday (Friday

2nd June, 2014). Earlier research had shown that data collection on a Friday coincided with a peak in the number of items of interest being posted, so presented an optimal sampling window (Yeo, 2011).Thirteen capture events were collected in this way and then combined to form a master sighting matrix containing a virtually complete observation record for the postings, presenting a data set with near perfect capture.

The Jolly-Seber (JS) model was fitted to these data to explore how well it was possible to estimate parameters for varying levels of detection. In order to vary the levels of detection, we varied parameter alpha (α), which denotes the proportion of observations missed, such that the higher the value of α, the lower the detection probability. Alpha (α) was varied from 10% to 90% in increments of 10% and the sampling and model fitting was repeated 100 times for each value of (α). Of particular interest was the estimation of the population size parameter (N) , which we found to be especially challenging to achieve in difficult to observe populations such as those involved in the illegal ivory trade (Yeo et al., 2017).

A second set of data was derived from the master sighting matrix by randomising sighting matrix records and removing 50% of them. The JS model was then fitted to these data and the same analysis protocol applied to this, randomly reduced data set as had been applied to the virtually complete encounter history. The objective was to investigate the effect upon parameter estimability of reducing (i.e. halving) the size of the observation record data initially available for sampling and model fitting.

2.2.3 Results

Model output (Estimated N) for the 100% and 50% “Sellers” encounter histories is presented in Figures 2-1 and 2-2.

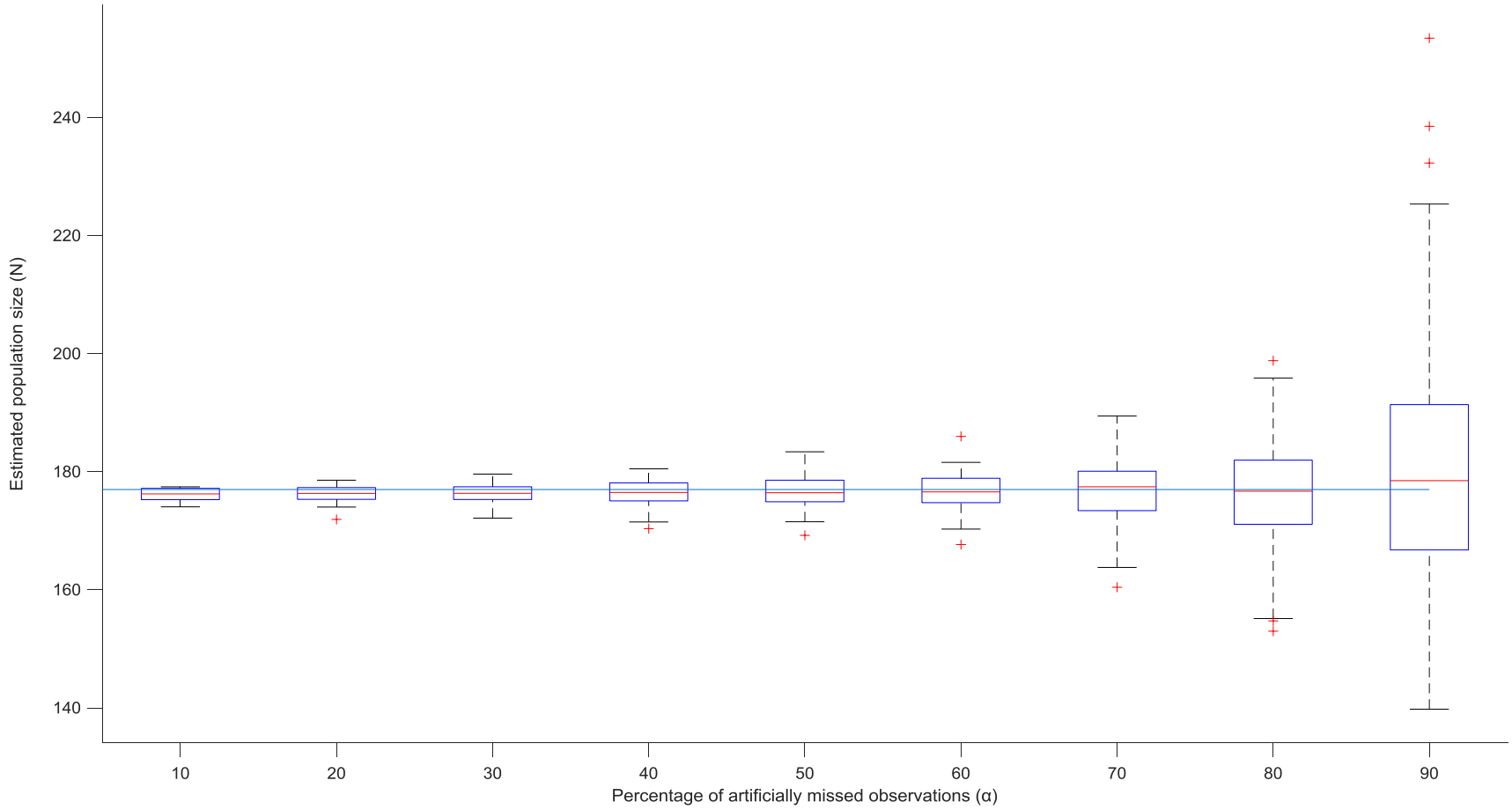


Figure 2-1: Sellers data (100%) Population size estimates (N) at α=10-90% (TrueN = 177)

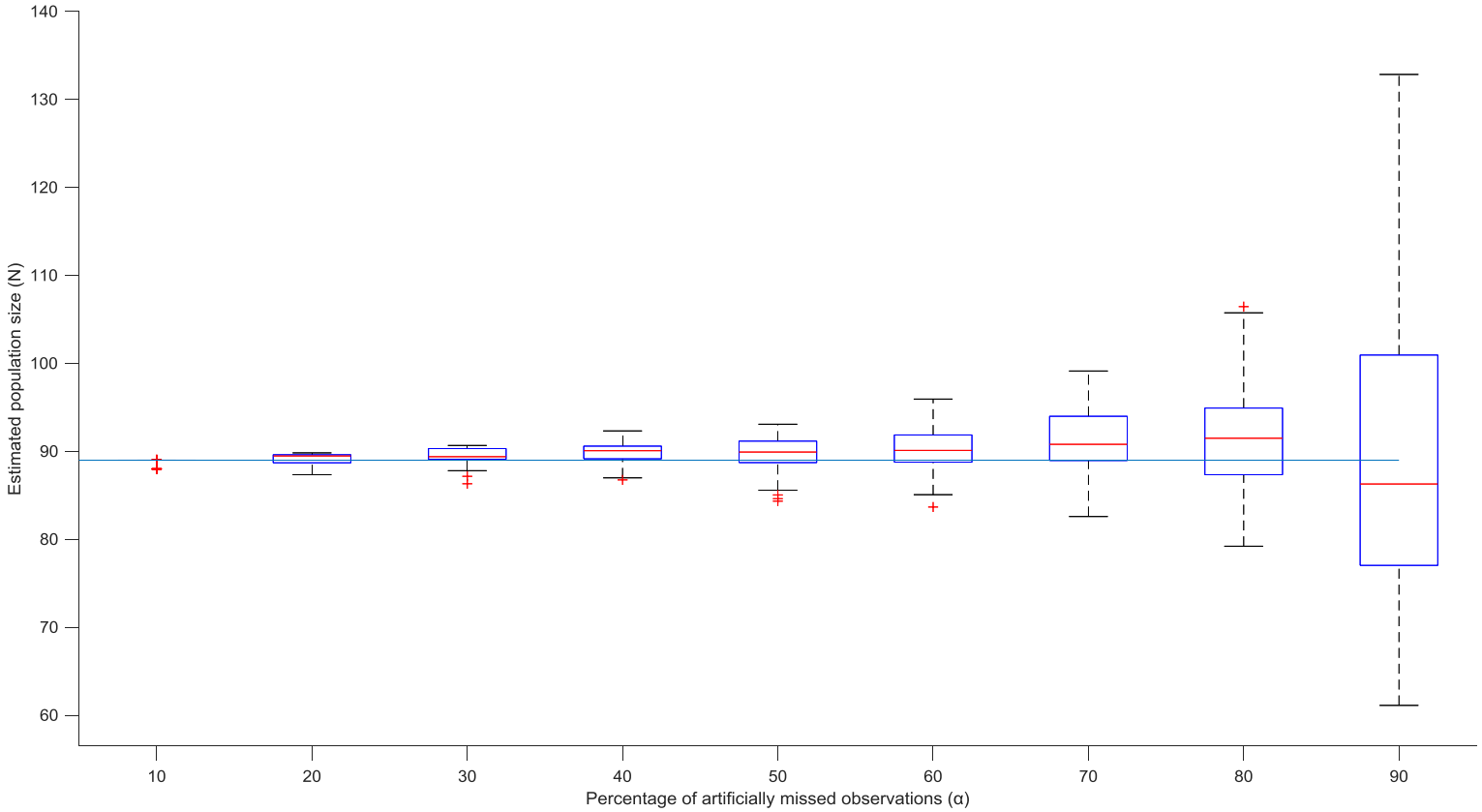


Figure 2-2: Sellers data (50%) Population size estimates (N) at α=10-90% (TrueN = 89)

Figures 2-1 and 2-2 illustrate that the range of estimated N values widens (i.e. variability increases) with increasing α, as would be expected. However, the ranges of estimated values per α (%) include the known “True N” value in all cases. At α = 90% (100% dataset) (Figure 2-1) the mean estimated N value is slightly higher relative to True N = 177. In contrast, for the 50% encounter history dataset at α = 90% the mean estimated N value is slightly lower relative to TrueN = 89, however the interquartile range of the estimates of population size overlap the true value of population size. Estimate variability per α (%) relative to TrueN appears more marked in the 50% encounter history dataset, culminating in a decrease versus TrueN at α=90%. A similar trend in increasing variability is evident for the 100% encounter history dataset, but variability appears less marked and culminates at α = 90% in a mean estimated N value that is marginally higher than TrueN.

2.2.4 Conclusion

The estimates of population size were generally unbiased for both the larger and smaller data sets and for all values of alpha (α). Based on this model performance we conclude that the Jolly Seber model is capable of estimating population size for this expected range of parameter values hence suitable for use in a larger scale modelling study to assess population parameters associated with the online wildlife trade.

2.3 Study (b): Simulation study in the absence of heterogeneity in parameter probabilities

2.3.1. Objective

The objective of this simulation study is to assess the suitability of mark-recapture as a method to model population parameters for an online trading population representative of (illegal) online wildlife trade in the absence of heterogeneity in parameter probabilities (covered in Section 2.4 of this chapter).

2.3.2 Method

The population parameters listed below were evaluated in this study -

BetaS: Number of individuals present from start of study

BetaN: Proportion of population present at start of study

p: Capture probability

N: Population size

Phi: Survival probability

Parameter values for BetaS, p, N and Phi were specified as input data for a series of simulations coded in Matlab (Table 2-1). Input values for Phi (survival probability) and p (capture probability) reflected real value ranges from research into the online ivory trade (Yeo et al. 2017; Table 3). For parameter N (population size) real population size values from the near complete encounter history data provided by 4 days' intensive download data were used as input data (see Chapter 4, 4.3 Method for details). Parameter BetaS input values were specified as approximately 50% and 100% of the actual population size values (N).

Six sets of input parameter values were specified for each of the population marks of Sellers, Items and Descriptions (Table 2-1) and two hundred simulations run for each set.

The Jolly-Seber (JS) model was fitted to the directly produced parameter estimates for parameters p, N, Phi and BetaN. Model performance was assessed by consideration of summary statistics i.e. mean, standard deviation (sample) (SD*s*) and mean standard error (MSE).

Table 2-1: Parameter values specified as input data for Matlab simulations run for Sellers, Items and Descriptions marks

Parameter	**Definition**	**SELLERS**						**ITEMS**						**DESCRIPTIONS**					
BetaS	Number present from start of study	160	80	160	80	160	80	450	230	450	230	450	230	480	240	480	240	480	240
p	Capture probability	0.2	0.2	0.5	0.5	0.7	0.7	0.2	0.2	0.5	0.5	0.7	0.7	0.2	0.2	0.5	0.5	0.7	0.7
N	Population size	177	177	177	177	177	177	465	465	465	465	465	465	517	517	517	517	517	517
Phi	Survival probability	0.85	0.85	0.85	0.85	0.85	0.85	0.4	0.4	0.4	0.4	0.4	0.4	0.75	0.75	0.75	0.75	0.75	0.75
Simrun	Simulation runs (n)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Simulation reference		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

2.3.3 Results

Table 2-2: Parameter estimate summary statistics for simulations 1-18

Param.	Definition	Statistic	Sellers						Items						Descriptions					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BetaN	**Proportion present at start of study**	Mean	0.90	0.46	0.90	0.46	0.90	0.45	0.97	0.50	0.97	0.49	0.97	0.49	0.92	0.47	0.93	0.46	0.93	0.46
		SD *s*	0.09	0.09	0.03	0.04	0.02	0.03	0.02	0.06	0.01	0.03	0.01	0.02	0.05	0.05	0.02	0.03	0.01	0.01
		MSE	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p	**Capture probability**	Mean	0.20	0.20	0.50	0.50	0.85	0.70	0.21	0.21	0.50	0.51	0.70	0.70	0.20	0.20	0.50	0.50	0.70	0.70
		SD *s*	0.03	0.03	0.02	0.02	0.01	0.02	0.05	0.06	0.04	0.06	0.03	0.04	0.02	0.02	0.02	0.02	0.01	0.01
		MSE	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	**Population Size**	Mean	175.92	178.92	177.22	176.78	176.67	176.66	473.23	478.34	469.55	464.15	464.35	464.95	518.84	519.44	514.08	515.41	515.73	515.71
		SD *s*	15.86	16.07	6.16	5.75	3.61	3.85	126.45	120.90	34.61	38.87	18.61	21.85	37.03	39.18	13.07	14.26	8.14	8.67
		MSE	251.60	260.77	37.79	32.98	13.11	14.85	15977.36	14721.84	1212.52	1503.77	345.01	475.06	1367.45	1533.07	178.35	204.96	67.63	76.49

Phi	**Survival probability**	Mean	0.85	0.85	0.85	0.85	0.85	0.85	0.39	0.40	0.40	0.40	0.40	0.40	0.75	0.75	0.75	0.75	0.75	0.75
		SD *s*	0.02	0.03	0.01	0.01	0.01	0.01	0.04	0.06	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
		MSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Key:
SD *s*: Standard deviation (sample)
MSE: Mean square error
BetaN forecast values for MSE calculation = BetaS/N

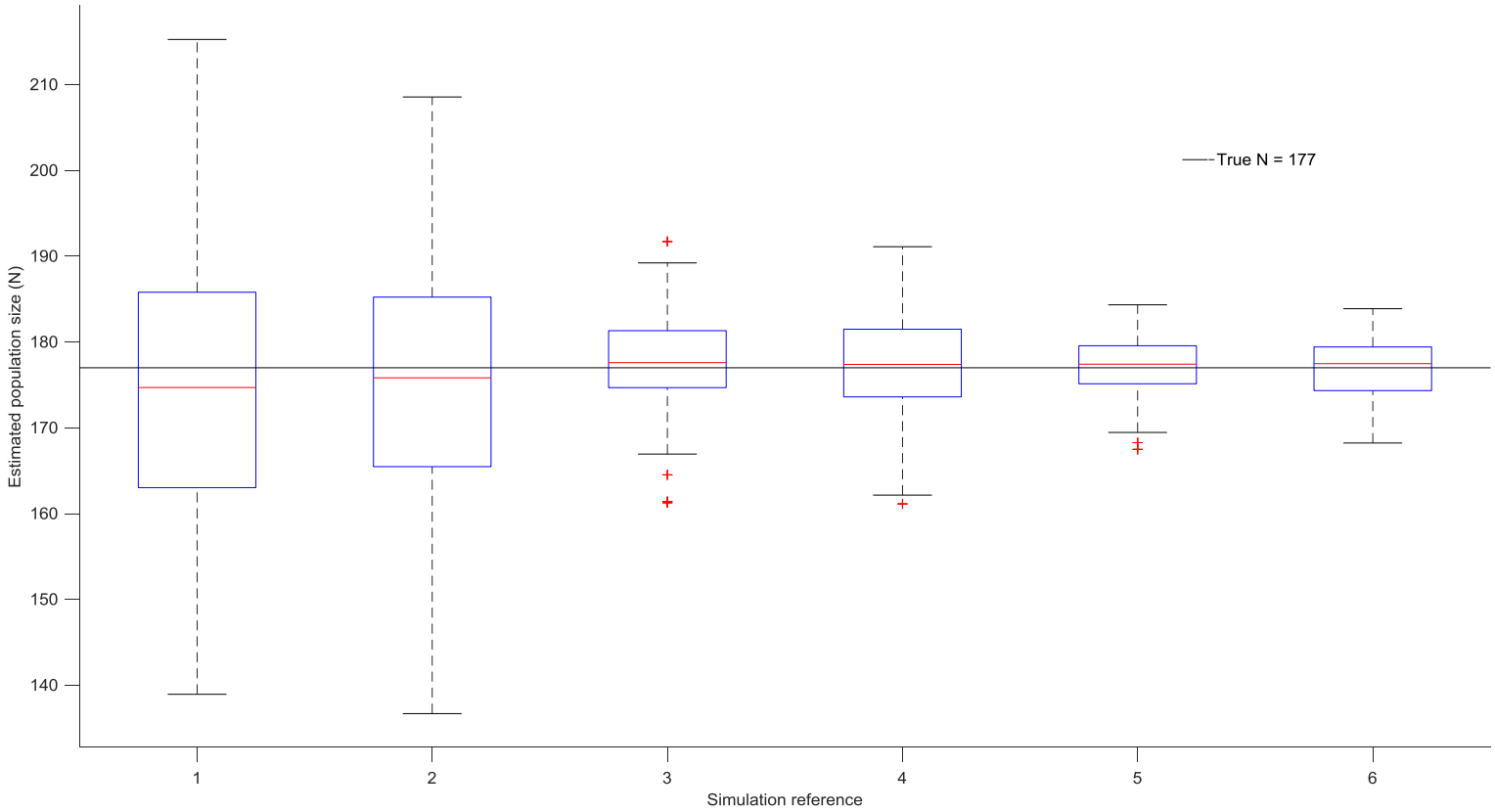


Figure 2-3: Estimated population size (N) from simulations 1-6 (specified in Table 2-1)

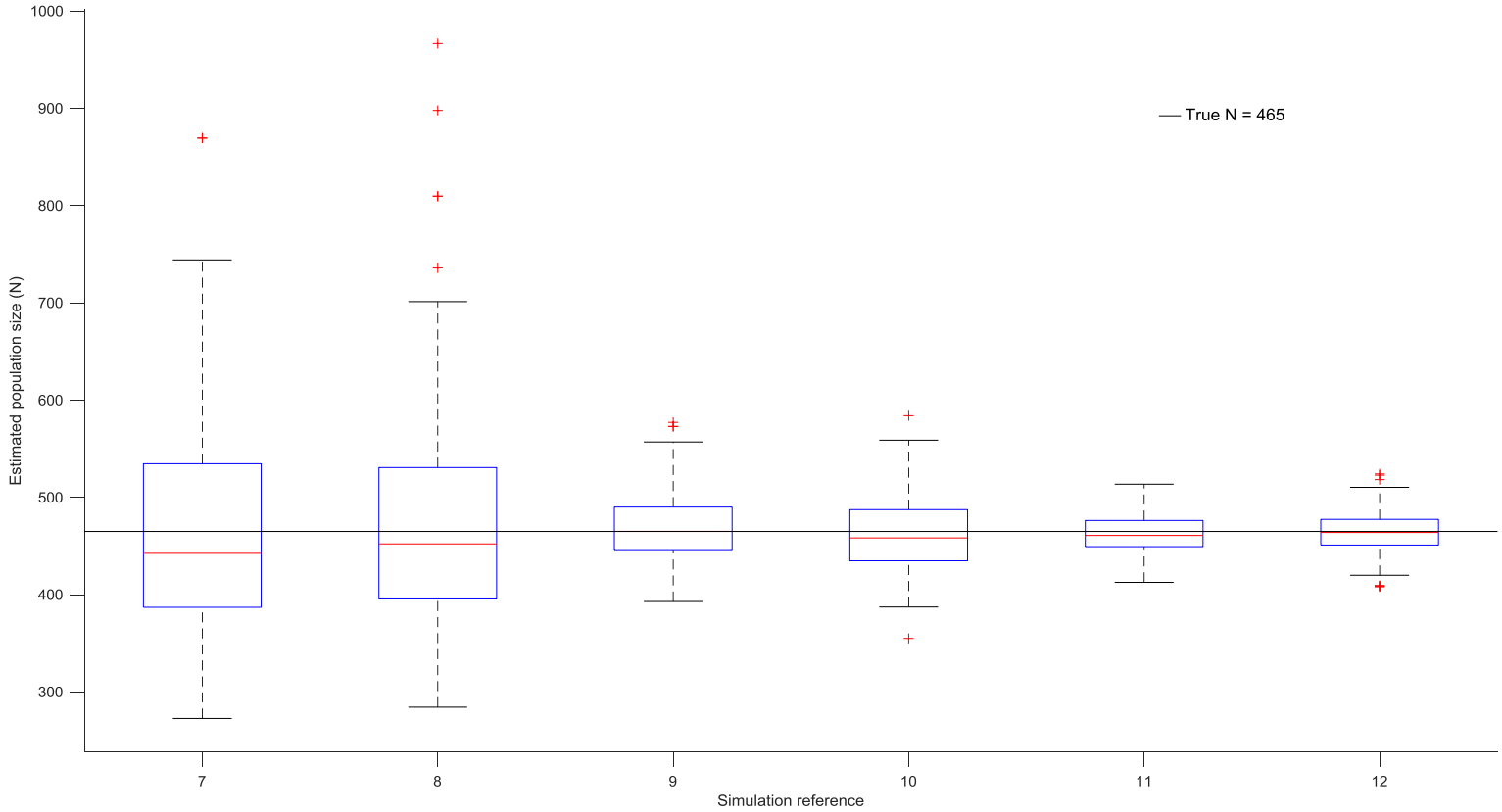


Figure 2-4: Estimated population size (N) from simulations 7-12 (specified in Table 2-1)

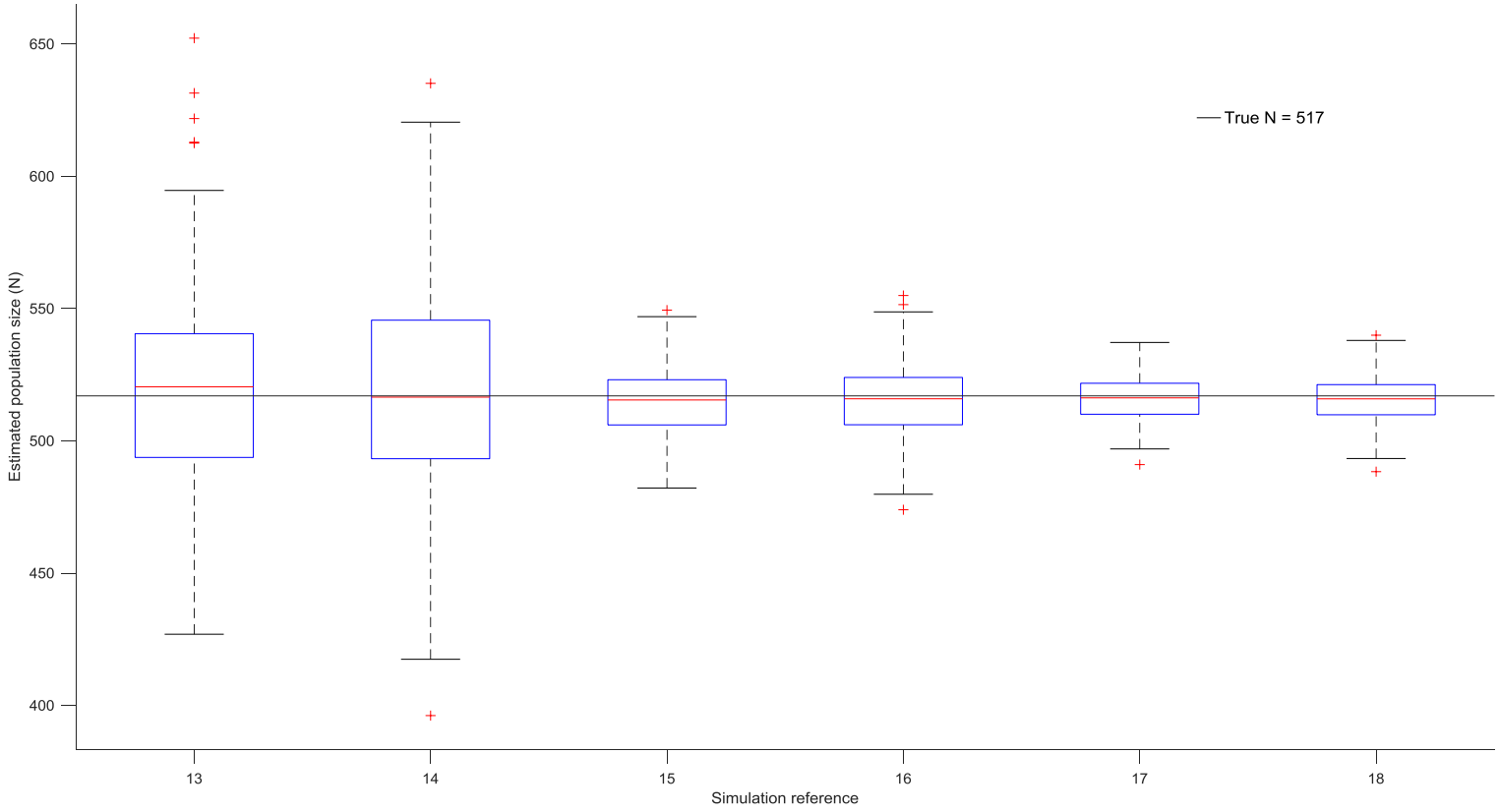


Figure 2-5: Estimated population size (N) from simulations 13-18 (specified in Table 2-1)

An assessment of summary statistics for the parameter estimates produced by simulations 1-18 (Table 2-2 and Figures 2-3 to 2-5) indicates the following -

BetaN (Proportion of population present at start of study): there is good agreement between modelled and real parameter estimates.

p (Capture probability): there is good agreement between modelled and real parameter estimates.

N (Population size): Population size estimates are in good agreement with real values. Markedly higher SD*s* and MSE values are associated with population size estimates for simulations 7, 8, 9 and 10 (Items mark) and 13 and 14 (Descriptions mark) (Table 2-2). In both cases, SD*s* and MSE values are highest where capture probability is lowest (p=0.2) and decrease with increasing capture probability (p). Although similar decreases in SD*s* and MSE values with increasing capture probability (p) across simulations 1 to 6 can be seen in the Sellers data (Table 2-2) values here are generally lower, of the order $1*10^2$ compared to $1*10^3$ for the Descriptions and Items marks. In all cases (i.e. simulations 1-18 and all three marks) population size estimates are unbiased (Figures 2-3 to 2-5) and the few outliers that drive the larger MSE values in the Items and Descriptions data may be seen in Figures 2-4 and 2-5.

Phi (Survival probability): there is good agreement between modelled and real parameter estimates.

2.3.4 Discussion

An assessment of the model performance inferred by summary statistics (Table 2-2 (all parameters) and Figures 2-3 to 2-5 (parameter N)) indicates that the Jolly Seber model is capable of producing estimates for parameters and value ranges representative of the (illegal) online wildlife trade. Estimation of population size (N) is known to be challenging where capture probability (p) is low (see, for example, p. 45 of McCrea and Morgan, 2014) and trends in our data reflect this. However, the JS

model still produced unbiased (N) parameter estimates for low values of (p) that were in good agreement with real values.

2.3.5 Conclusion

The suitability for use of mark-recapture (specifically, the Jolly Seber model) as a method to research population parameters representative of (illegal) online wildlife trade is indicated.

2.4 Study (c): Simulation study in the presence of heterogeneity in parameter probabilities

2.4.1 Objective

The objective of this simulation study is to assess the suitability of mark-recapture as a method to model population parameters for an online trading population representative of (illegal) online wildlife trade. This study incorporates heterogeneity in probability for parameter (p) (capture probability) to explore model performance in terms of parameter recoverability under this condition.

2.4.2 Method

The population parameters listed below were evaluated in this simulation study. Two sub-populations were considered, E1 and E2, to represent a binomial mixture model.

BetaN: Proportion of population present at start of study

Phi: Survival probability

p1*: Capture probability of population E1

p2: Capture probability of population E2

* Coded such that p1 is always set as the smaller of these two probabilities and Alpha (see below) is estimated directly.

Alpha: Proportion of population in group E1

N: Population size

Parameter values for BetaN, Phi, p1, p2 and TrueN were specified as input data for a series of simulations coded in Matlab (Table 2-3). Input values for Phi (survival probability) and p (capture probability) were based on real value ranges from research into the online ivory trade (Yeo et al. 2017; Table 3) and experimental results from Part 1 of this simulation study where parameter probabilities in the absence of heterogeneity were modelled. For parameter N (population size) real population size values from the near complete encounter history data provided by 4 days' intensive download data for the "Descriptions" mark (TrueN = 517) were used as input data (see Chapter 4, 4.3 Method for details). A total TrueN value of 2*517=1034 was specified for each of simulations 1-6 and the different contributions

towards this from sub-populations E1 and E2 varied as different E1:E2 proportions per simulation (Table 2-3).

Six sets of input parameter values were specified using this approach for the population mark “Descriptions” (Table 2-3) and two hundred simulations run for each set. The Jolly-Seber (JS) model was fitted to the directly produced estimates for parameters alpha, p1, p2, N, Phi and BetaN. Model performance was assessed by consideration of summary statistics i.e. mean, standard deviation (sample) (SD*s*) and mean standard error (MSE).

Table 2-3: Parameter values specified as input data for Matlab simulations (Descriptions mark)

Simulation reference	Parameters and definitions					Proportion TrueN E1:E2
	BetaN	Phi	p (as p1 and p2 where p1<p2)	TrueN	Associated sub-population	
	Proportion of population present at start of study	Survival probability	Capture probability	True population size		
1	0.5	0.8	0.08 (p1)	104	E1	10:90
	0.5	0.8	0.8 (p2)	932	E2	
2	0.5	0.8	0.08 (p1)	777	E1	75:25
	0.5	0.8	0.8 (p2)	259	E2	
3	0.5	0.8	0.08 (p1)	932	E1	90:10
	0.5	0.8	0.8 (p2)	104	E2	
4	0.5	0.8	0.5 (p1)	104	E1	10:90
	0.5	0.8	0.8 (p2)	932	E2	
5	0.5	0.8	0.5 (p1)	777	E1	75:25
	0.5	0.8	0.8 (p2)	259	E2	
6	0.5	0.8	0.5 (p1)	932	E1	90:10
	0.5	0.8	0.8 (p2)	104	E2	

2.4.3 Results

Note that one simulation (91 of 200 for Run 3, specified in Table 2-3) produced spurious estimates for all parameters. These results were removed from the output data prior to statistical analysis. The nature of the spurious estimates was as follows -

Alpha: estimate = 1 (suggesting a boundary error)

BetaN: gross underestimate vs. known starting value

p1: gross underestimate vs. known starting value

p2: estimate = 1 (suggesting a boundary error)

N: gross overestimate vs. known starting value

Table 2-4: Parameter estimate summary statistics for simulations 1-6

Parameter	Definition	Statistic	Simulation reference					
			1	2	3	4	5	6
Alpha	**Proportion of population belonging to group E1**	Mean	0.15	0.75	0.90	0.18	0.74	0.82
		SD *s*	0.16	0.03	0.01	0.21	0.10	0.20
		MSE	0.00	0.00	0.00	0.00	0.00	0.00
BetaN	**Proportion of population present at start of study**	Mean	0.50	0.50	0.51	0.50	0.50	0.50
		SD *s*	0.01	0.02	0.04	0.01	0.01	0.02
		MSE	0.00	0.00	0.00	0.00	0.00	0.00

p1	**Capture probability group E1**	Mean	0.15	0.08	0.08	0.34	0.50	0.48
		SD *s*	0.17	0.01	0.01	0.18	0.03	0.06
		MSE	0.03	0.00	0.00	0.05	0.00	0.00
p2	**Capture probability group E2**	Mean	0.81	0.80	0.80	0.81	0.80	0.79
		SD *s*	0.03	0.02	0.03	0.04	0.05	0.11
		MSE	0.00	0.09	0.09	0.00	0.00	0.01
N	**Population Size**	Mean	1045.76	1049.94	1050.91	1037.14	1034.54	1037.92
		SD *s*	82.48	114.05	117.59	10.12	15.51	18.11
		MSE	6906.85	13197.51	13972.97	111.82	239.52	341.52

Phi	**Survival probability**	Mean	0.80	0.80	0.80	0.80	0.80	0.80
		SD *s*	0.01	0.01	0.02	0.01	0.01	0.01
		MSE	0.00	0.00	0.00	0.00	0.00	0.00

Key:
SD *s*: Standard deviation (sample)
MSE: Mean square error

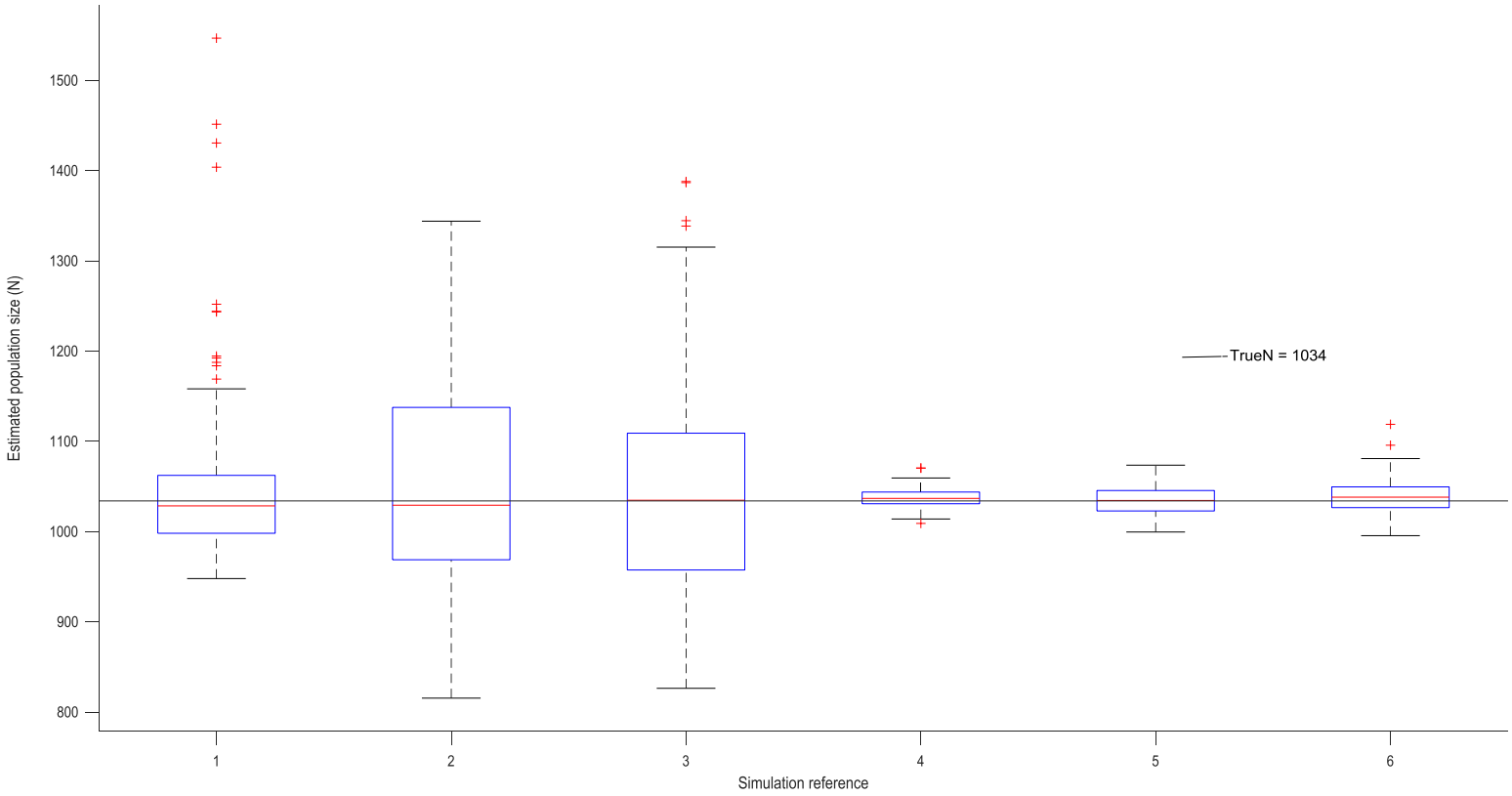


Figure 2-6: Estimated population size (N) from simulations 1-6 (specified in Table 2-3)

An assessment of summary statistics (Table 2-4 and Figure 2-6) for the parameter estimates produced by included data (i.e. estimates from all simulations except Run 3, simrun 91) indicates the following -

Alpha (proportion of population belonging to Group E1): There is generally good agreement between modelled and real parameter estimates. Slight overestimates versus known E1 are produced where known E1 (alpha) = 0.1 (runs 1 and 4 (Tables 2-3 and 2-4) and a slight underestimate where known E1 = 0.9 (Run 6, Tables 2-3 and 2-4).

BetaN (Proportion of population present at start of study): There is good agreement between modelled and real parameter estimates.

p1 (Capture probability E1): There is generally good agreement between modelled and real parameter estimates. Slight overestimates versus known p1 are produced where known p1 = 0.08 (runs 1 and 4 (Table 2-4)) and the overestimate is greater for Run 4.

p2 (Capture probability E2): there is good agreement between modelled and real parameter estimates.

N (Population size): There is good agreement between modelled and real parameter estimates and unbiased estimates are produced in all cases. Variance is greatest where simulations incorporate a low value of p1 (p1= 0.08; Runs 1-3; Tables 2-3 and 2-4).

Phi (Survival probability): there is good agreement between modelled and real parameter estimates.

2.4.4 Discussion

An assessment of model performance inferred by summary statistics (Table 2-4 (all parameters) and Figure 2-6 (parameter N)) indicates that the Jolly Seber model is

capable of producing estimates for parameters and value ranges representative of the (illegal) online wildlife trade in the presence of heterogeneity in capture probability (p). One set of spurious results was produced for the modelling conditions specified in Run 3 (Table 2-3) which involved modelling a low capture probability (p=0.08) for the larger sub-population (E1=0.9). Boundary estimate errors together with gross over- and under-estimates were produced in this single case which represented 1/200 for Run 3 conditions, or 1/1200 for all Run conditions. Results for this simulation suggest modelling at the edge of the probability space and the estimates generated were omitted from summary statistic calculations. In terms of estimation of population size, N, unbiased estimates were produced in all cases. A trend of greater variance in estimates of N was evident where lower values of capture probability (p) were modelled, especially when this applied to the greater part of the population (i.e. the higher of E1 or E2) (Table 2-4 and Figure 2-6). Estimation of population size (N) is known to be challenging where capture probability (p) is low (see, for example, p. 45 of McCrea and Morgan, 2014) and trends in our data reflect this. However, overall, the JS model produced unbiased parameter estimates across a range of representative input parameter values for the parameters modelled.

2.4.5 Conclusion

The suitability for use of mark-recapture (specifically, the Jolly Seber model) as a method to research population parameters representative of (illegal) online wildlife trade in the presence of heterogeneity in capture probability is indicated.

2.5 Overarching conclusion - studies (a), (b) and (c)

Consideration of the outcomes from studies (a), (b) and (c) reported under sections 2.2, 2.3 and 2.4 of this chapter indicates that mark-recapture (the Jolly Seber model)

is suitable for use as a method to research population parameters representative of (illegal) online wildlife trade.

The Economist: Eat or be eaten

With a wave of consolidation in prospect, America's big internet firms look set to divide into predators and prey

Attribution: The Economist, May 9th 2015, SAN FRANCISCO

Chapter 3: A novel application of mark-recapture to examine behaviour associated with the online trade in elephant ivory

3.1 Abstract

The illegal trade in elephant ivory is driving the unlawful killing of elephants such that populations are now suffering unsustainable reductions. The internet is increasingly being used as a platform to conduct illegal wildlife trade, including elephant ivory. As a globally accessible medium the internet is as highly attractive to those involved in the illegal trade as it is challenging to regulate. Characterising the online illegal wildlife (ivory) trade is complex, yet key to informing enforcement activities. We applied mark-recapture to investigate behaviour associated with the online trade in elephant ivory on eBay UK as a generalist online marketplace. Our results indicate that trade takes place via eBay UK, despite its policy prohibiting this, and that two distinct trading populations exist, characterised by the pattern of their ivory sales. We suggest these may represent a large number of occasional (or non-commercial) sellers and a smaller number of dedicated (or commercial) sellers. Initial focus of resource to significantly reduce or eliminate occasional sales, such as through education, would enable subsequent focus to be directed towards characterising the extent and value of the illegal, “commercial” online ivory trade. MRC has the potential to characterise the illegal trade in ivory and diverse wildlife commodities traded using various online platforms.

3.2 Introduction

Globally, environmental crime, including the illegal wildlife trade, is estimated to be worth $91-258 billion p.a. (UNEP, 2016), making it the fourth most lucrative class of crime after the drugs trade, counterfeiting and human trafficking. Further, its value is estimated to have increased by 26% between 2014 and 2016 (UNEP, 2016). As a specific category of environmental (wildlife) crime, the illegal wildlife trade is estimated to be worth $7-23 billion per annum (UNEP, 2016).

Since 2012 there has been a growing momentum towards recognition of wildlife crime, including illegal wildlife trade, as a serious crime requiring a response commensurate with its gravity. A series of events at national, regional and global levels have taken place to further this aim (CITES, 2015) including the UK Conference on Illegal Wildlife Trade in 2014 and subsequent conference in Kasane, Botswana in 2015. Both events produced statements of intent consolidating next steps for aligned, anti-illegal wildlife trade activities, i.e. the London Declaration, 2014 (UK Government, 2014) and the Kasane Statement (UK Government, 2015). At the United Nations Congress on Crime Prevention and Criminal Justice in Doha, Qatar in 2015 a landmark development was achieved in the first tabling of wildlife crime as a Congress agenda item and its inclusion within the Doha Declaration adopted at that Congress (UNODC, 2015a). Shortly afterwards, the first United Nations Resolution to recognise the illegal wildlife trade as one of the largest transnational criminal activities, comparable to trafficking in drugs, arms and people, was adopted by the United Nations General Assembly (UNGA, 2015). This signalled heightened political concern over the adverse impacts of poaching and the illegal wildlife trade upon species, ecosystems and local communities as well as the need to counteract these (UNODC, 2015b).

Globally, enforcement agencies such as the International Criminal Police Organization (ICPO-INTERPOL) recognise that a high proportion of wildlife crime, including trade, is carried out by organised criminal networks, attracted by the area's typically low risk and high profit nature (ICPO-INTERPOL, 2015; also see Wittig 2016). A principal impetus driving formal recognition of wildlife crime as a serious crime is the pressing need to improve the effectiveness of counter-measures (Challender & MacMillan, 2014).

African elephant populations, from which the majority of traded ivory is sourced, are suffering unsustainable reductions as a result of illegal killing to supply the ivory trade (Anon., 2013a; Anon., 2013b; Wittemyer et al., 2014; Chase et al., 2016).The rate of killing now exceeds the growth capacity of the species, placing the African elephant population in net decline (Wittemyer et al., 2014). Further, the ability of depleted populations to withstand additional stressors, such as habitat loss, or environmental effects resulting from climate change, is likely to be compromised (Brook et al., 2008; Barnosky et al., 2011).

The past two decades have seen a rapid increase in the online trade in wildlife, both legal, and illegal (IFAW, 2005; Beardsley, 2007; IFAW, 2008; Izzo, 2010; Shirey & Lamberti, 2011; Lavorgna, 2014). Since the Internet extends globally and is both readily accessible and challenging to regulate it has the potential to attract both legal and illegal traders. Research indicates that the Internet is being used as a medium to conduct illegal trade in wildlife (de Magalhães & São-Pedro, 2012; Alves et al., 2013; Lavorgna, 2014) with adverse impacts upon traded species (IFAW, 2005; IFAW, 2008; Izzo, 2010; Shirey & Lamberti, 2011). It is widely acknowledged that there is a need for effective means to address the threat to biodiversity posed by Internet-mediated illegal wildlife trade (Wylar & Sheikh, 2008; Bennett, 2011; Felbab-Brown, 2011; Shirey & Lamberti, 2011; ICPO-INTERPOL & IFAW, 2013; ICPO-INTERPOL & IFAW, 2014).

The Internet is a conduit for a significant volume of trade in elephant ivory, including illegal trade (IFAW, 2008; IFAW, 2011; ICPO-INTERPOL & IFAW, 2013). In response to lobbying, online trading sites, such as eBay, have banned the sale of ivory. However, the trade still continues (IFAW, 2008; IFAW, 2011; ICPO-INTERPOL & IFAW, 2013). Research into the online trade in ivory is needed to determine the scale of the problem and monitor activity; however, this is challenging. Since the word “ivory” describes a colour, as well as an organic material, online searches for ivory items will result in postings for ivory coloured items, and also items made from ivory. The number of postings for ivory coloured items (e.g. curtains, rugs and furniture) tends to far exceed that for items made from ivory, making the latter difficult to distinguish within the overall trading volume. In addition to this linguistic camouflage derived from using the word ‘ivory’, deliberate devices, such as describing elephant ivory as a physically similar but legitimately traded material (e.g. horn or bone) may be used to actively conceal illicit postings (Harrison et al., 2016). Consequently, the process of detecting online elephant ivory postings is complex and implicitly resource-intensive. Further, since law enforcement officers are currently unable to monitor internet sites continuously, and check every item they detect for sale, they are likely to detect only a fraction of the illegally traded ivory that is actually for sale (ICPO-INTERPOL & IFAW, 2013; Hernandez-Castro & Roberts, 2015). Accurate knowledge of the extent of the illegal trade and the traders involved is key to informing and prioritizing intervention activities to curb illegal trade. Research indicates that anticipated shifts in the preferred Internet medium for illegal wildlife trade from the open, or surface, web to the so-called “dark web” have not, so far, occurred (Harrison et al., 2016). This, coupled with the increasing volume of illegal wildlife trade conducted via the surface web, suggests that it remains an attractive medium for illegal trade and may indicate a lack of effective enforcement measures applied to counter this trade (Harrison et al., 2016). Therefore, using current monitoring techniques the observed trade is likely to only represent the tip of

the iceberg. Statistical methods are therefore required to provide an understanding of the trading population.

Mark-recapture (MRC) has been applied in a range of fields to estimate total population size (Bohning, 2008) and/or to estimate demographic parameters of interest (Lebreton et al., 1992; Amstrup et al., 2005) from an observed sample. Its use in estimating the size of cryptic, including criminal, populations has been recognised in a number of sociological contexts; illicit drug use or supply (Bouchard, 2007; Vaissade, 2009), the illegal drug and arms trades (Bloor, 2005) and estimation of victim numbers from terrorism (Murphy, 2009). As far as we are aware MRC has, however, never been used to investigate illegal online trades, although others (e.g. Lavorgna, 2015; Vida et al., 2016) have attempted to provide an understanding of the dynamics. In this paper we apply MRC to a novel situation to explore behaviours associated with the illegal, online trade in elephant ivory conducted via eBay UK. Specifically, we employ three different marks, i.e. item number, item description (or title) and seller username (or "ID"), to explore demographic parameters of interest that may be indicative of illicit trading in terms of detection probability.

3.3 Method

Figure 3-1, below, outlines the process used for data specification, acquisition and assessment for this study which is described in more detail following the flow chart.

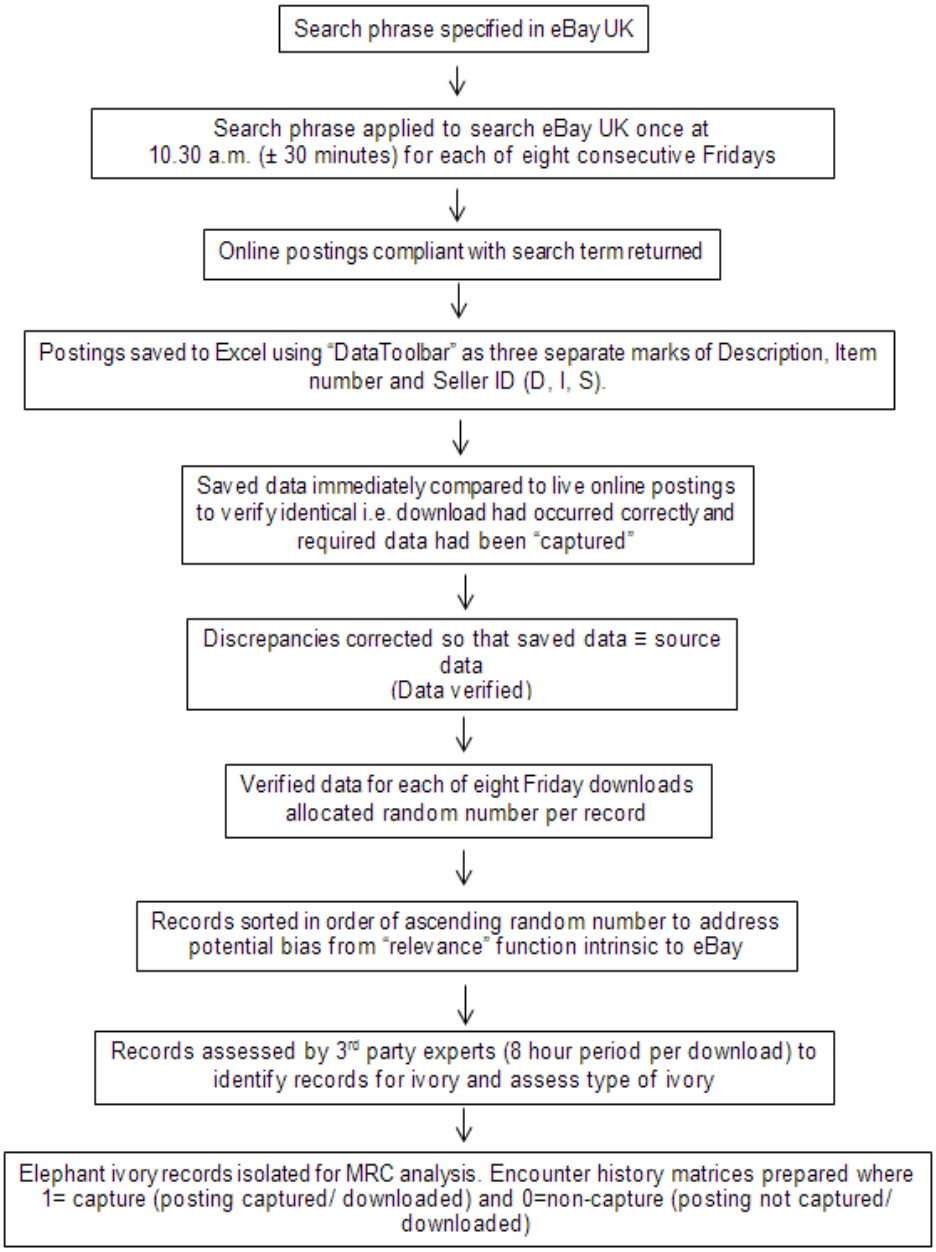


Figure 3-1: Data specification, acquisition and assessment process for weekly downloads over an eight week period with downloads each Friday at 10.30 a.m. (±30 minutes))

Data specification and acquisition

The study design was approved by the University of Kent, School of Anthropology and Conservation's Research and Ethics Committee. We defined a single data point as an advertisement (posting) on eBay UK for an item for sale within the UK which results from the search terms of "Ivory; Antique; UK only". For each item, we recorded its Description (Title), Item Number and Seller Identification details (username). This information was recorded once per week for an eight-week period, starting on 28th March 2014. Data were collected on the same weekday and at approximately the same time of day (i.e. Fridays at 10.30 a.m. ±30 minutes). Prior research based on an intensive survey had identified this data collection period as the weekly peak in the number of items of interest being posted and therefore represented an optimal sampling window (Yeo, 2011).

Data assessment: identification of ivory items

Two former law enforcement experts examined postings to assess whether items comprised, or contained, ivory and, if so, the likely origin of that ivory (i.e. its category). We defined categories of ivory as: elephant, hippo, walrus, ox/cow-bone, man-made, other or unknown. A period of approximately 8 hours was allowed for assessment of each week's set of recorded data, to reflect a standard working day; in essence the two experts replicated their previous roles in wildlife enforcement in terms of sifting items that would be taken forward for subsequent investigation. This period delimited the total number of items which could be assessed from each of the eight (Friday) downloads. It should be noted that prior to the experts being provided the list of items, item records were randomised to prevent bias associated with how the eBay "Relevance" sort function generates the order of search results.

Data analysis: open population model

Encounter history matrices consisting of 1s, denoting captures, and 0s, denoting non-captures, were constructed for each of three categories of data associated with the downloaded elephant ivory postings,

1. Description: the title description of the posted item, which was assumed to be unique per item due to the low probability of using the same words in the same order,
2. Item (number): the unique item number associated with each posting, and
3. Seller: the unique user identification name associated with each posting

An open population mark-recapture model was fitted to these data. The model used was the POPAN form of the Jolly-Seber (JS) model (Schwarz & Arnason, 1996) which permits the estimation of population size whilst allowing the population to be open. Nineteen models within the JS framework were fitted to the encounter history matrices. The models encompassed constant (.), time-dependent (t) or heterogeneous (h) variants of the parameters listed here,

N: population size,
p: capture probability,
β: probability of arrival in the population,
ϕ: retention (or survival) probability

Heterogeneity was modelled as a mixture of two binomials such that proportion π of the population has the capture probability of p1 and proportion $(1-\pi)$ has the capture probability of p2. The issue of model selection, i.e. how best to choose the most appropriate number of mixture components to support unbiased parameter estimates and correct model selection, is both fundamental and complex. In this study, the choice of number of mixture components to model heterogeneity in capture probability (p) was based upon consideration of relevance to the study population, feasibility and recommended practice (see Pledger et al., 2003 & 2010; Cubaynes et al., 2012). The four options considered, and outcomes, are summarised below -
1. Modelling including no heterogeneity: potentially appropriate, but ruled out by testing
2. A two binomial mixture: potentially appropriate, based on consideration of eBay data

3. A beta-binomial (continuous) mixture model: code is available for closed populations (see Morgan and Ridout 2008) but not open populations and coding is outside the scope of this study

4. A three binomial mixture: data hungry, so not suitable

Based upon the above evaluation, option 2 (the two binomial mixture model) was selected.

Since capture probability (p) was a parameter of key interest for this research, and it seemed plausible, based upon assessment of eBay data, that there may be heterogeneity in capture probability across different cadres of seller (where some sellers were associated with multiple items for sale, and appeared more persistently, whereas others seemed to be linked to few or one items, and sporadically) it was an appropriate parameter for such modelling.

Ranking of candidate models was undertaken using ΔAIC (Cubaynes et al., 2012) and models inferring heterogeneity in capture probability were supported for the Sellers and Descriptions marks.

Closed population models were considered as constrained versions of the JS model. Models with no new arrivals are denoted by $\beta(=1)$ and models with no departures are denoted by $\phi(=1)$. ΔAIC was used as a tool for model selection and applied to rank the models (Burnham & Anderson, 2002). When appropriate, we used AIC weights to produce model-averaged estimates which account for model uncertainty.

In order to investigate the heterogeneity within capture probability further, the open population Cormack-Jolly-Seber (CJS) model (which conditions on the first capture and hence does not allow estimation of population size) was fitted to the Sellers data to assess the significance of an individual covariate - the average number of items associated with each Seller over the study period. This allowed investigation of whether capture probability (p) was significantly related to the number of items an individual has for sale (Table 3-6). The individual covariate could not be incorporated into the JS model due

to the unseen individuals having unknown values of individual covariate (see chapter 7 of McCrea & Morgan, 2014).

3.4 Results

Between 528 and 633 postings were recorded from eBay UK, per week, for the eight-week study period. Between 349 and 419 (c. 68%) of these postings were randomised and then assessed each week by two third party enforcement experts, according to how many items could be assessed in approximately 8 hours. In total 7% were found to concern elephant ivory, which equated to 42-67 items per week, based on Item Number. Elephant ivory items ranked second after “Other” items (i.e. non-material ivory items), however it should be noted that “Unknown” items (i.e. those that could not be identified) ranked third (Figure 3-2).

As context to this summary, tables 3-1 to 3-3 (below) provide further details on the number of elephant ivory records identified versus total number of records retrieved and examined (Table 3-1), the weekly rate of observation (capture) per mark (Table 3-2) and mean, minimum and maximum residence times per mark (weeks) (Table 3-3).

Table 3-1: Ivory records as a percentage of total records (a) retrieved and (b) examined over eight week study period

Study week	a) Records retrieved	b) Records examined in ~ 8h	Elephant ivory records identified over 8 week study period	Elephant ivory records as % total records retrieved
1	539	399	314	6.8
2	528	349		
3	555	414		
4	553	399		
5	633	419		
6	621	356		
7	628	405		
8	561	417		
Total	4618	3158		

Table 3-2: Weekly rate of observation (capture) per mark*

Mark	**Number of times mark observed (captured) (n)**								**Σ (n)**
Sellers	66	15	11	6	8	2	1	1	110
Items	253	65	5	10	0	0	0	0	333
Descriptions	229	35	5	5	5	1	0	0	280
Week	1	2	3	4	5	6	7	8	N/A

* If mark captured multiple times in one week this is recorded as 1 for MRC analysis so table content does not reflect summed observations (captures)

The general trend is for the majority of all marks to be observed (captured) for one week out of a possible maximum of eight, then a general decline in rate of capture with increasing number of weeks to a minimum rate of one observation (capture) occurring for seven and eight weeks out of a potential maximum of eight (Sellers mark). The most frequent residence time (all marks) is therefore inferred to be one week; residence times of two to eight weeks are less frequent and frequency declines across this range to a minimum at seven and eight weeks out of eight (Table 3-2).

Table 3-3: Mean, minimum and maximum residence time per mark (weeks)

Mark	Residence time (weeks)		
	Mean	Minimum	Maximum
Sellers	2.0	1	8
Items	1.3	1	4
Descriptions	1.3	1	6

Mean values indicate a residence time of between one and two weeks per mark and the maximum residence time per mark varied between four and eight weeks (Table 3-3).

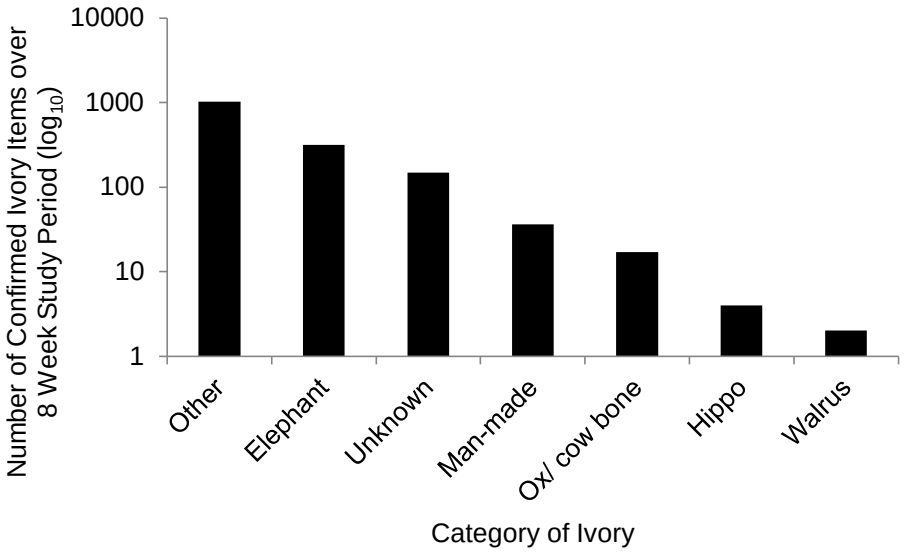


Figure 3-2**:** Histogram illustrating absolute and relative amounts of categorised ivory items identified by visual assessment of online postings over the eight week study period (unique values only)

Table 3-4 presents the top 10 models (as ranked by ∆AIC) for each of the data sets -

Table 3-4 Open population mark-recapture POPAN form of the Jolly-Seber model: model ranking and selection using ∆AIC

Sellers	**k**	**∆AIC**	**Items**	**k**	**∆AIC**	**AIC weight**	**Descriptions**	**k**	**∆AIC**
N(.),β(.),p(h), ϕ(.)	6	0.00	N(.),β(.),p(.),ϕ(t)	10	0.00	0.59	N(.),β(.),p(h),ϕ(.)	6	0.00
N(.),β(.),p(.),ϕ (.)	4	19.42	N(.),β(t),p(.),ϕ(t)	16	1.02	0.35	N(.),β(.),p(.),ϕ(.)	4	21.67
N(.),β(t),p(.),ϕ(.)	10	24.45	N(.),β(t),p(t),ϕ(.)	17	5.81	0.03	N(.),β(.),p(.),ϕ(t)	10	26.51
N(.),β(.),p(t),ϕ(.)	11	25.69	N(.),β(.),p(t),ϕ(t)	17	7.54	0.01	N(.),β(.),p(t),ϕ(.)	11	28.56
N(.),β(.),p(.),ϕ(t)	10	29.30	N(.),β(.),p(.),ϕ(.)	4	8.91	0.01	N(.),β(t),p(.),ϕ(.)	10	29.17
N(.),β(t),p(t),ϕ(.)	17	33.98	N(.),β(t),p(t),ϕ(t)	23	9.66	0.00	N(.),β(t),p(.),ϕ(t)	16	35.83
N(.),β(t),p(.),ϕ(t)	16	34.67	N(.),β(t),p(.),ϕ(.)	10	10.62	0.00	N(.),β(.),p(t),ϕ(t)	17	37.38
N(.),β(.),p(t),ϕ(t)	17	35.74	N(.),β(.),p(h),ϕ(.)	6	12.91	0.00	N(.),β(t),p(t),ϕ(.)	17	38.05
N(.),β(t),p(t),ϕ(t)	23	44.66	N(.),β(.),p(t),ϕ(.)	11	15.12	0.00	N(.),β(t),p(t),ϕ(t)	23	47.95
N(.),β(=1),p(t),ϕ(.)	10	60.50	N(.),β(t),p(t),ϕ(=1)	16	177.70	0.00	N(.),β(.),p(t),ϕ(=1)	10	82.75

Key: N: population size; (.): constant; (t): time dependent; (h): heterogeneity; p: capture probability; β: probability of arrival in the population; ϕ: retention (or “survival”) probability; k: number of parameters; ∆AIC: Measure of each model relative to model of best fit by AIC

It is clear that the models incorporating capture heterogeneity, p(h), are strongly supported by the sellers and descriptions data sets (∆AIC to next best model of 19.42 and 21.67 respectively). There was no evidence of capture probability heterogeneity from the Items data set and the ∆AIC of the top-ranked models are much closer. AIC weights showing the relative plausibility of each of the models are displayed for the item data. These weights were used to produce model-averaged estimates which are displayed in Table 3-5. There was no support for the closed population models for any of the three data sets.

Table 3-5**:** Open population mark-recapture POPAN form of Jolly-Seber model: maximum likelihood estimates (MLE) and corresponding standard errors (SE). Note that the MLEs for the items data are model-averaged estimates from the top two models as ranked by AIC.

Parameter	**Sellers**		**Items**		**Descriptions**	
	MLE	**(SE)**	**MLE**	**(SE)**	**MLE**	**(SE)**
β_1	0.67	(0.10)	0.10	(0.02)	0.31	(0.05)
β_2	-	-	0.13	(0.02)		
β_3	-	-	0.11	(0.01)		
β_4	-	-	0.13	(0.02)		
B_5	-	-	0.13	(0.02)		
β_6	-	-	0.11	(0.02)		
β_7	-	-	0.13	(0.02)		
p1	0.54	(0.05)	0.77	(0.07)	0.06	(0.02)
p2	0.02	(0.04)	-		0.58	(0.08)
π	0.09	(0.13)	1*		0.95	(0.02)
ϕ_1	0.88	(0.03)	0.35	(0.08)	0.74	(0.05)
ϕ_2	-	-	0.38	(0.09)	-	-
ϕ_3	-	-	0.24	(0.06)	-	-
ϕ_4	-	-	0.30	(0.07)	-	-
ϕ_5	-	-	0.45	(0.08)	-	-
ϕ_6	-	-	0.47	(0.08)	-	-
ϕ_7	-	-	0.11	(0.05)	-	-
N	710.00	(1125.00)	360	(27.11)	1614.00	(539.00)

Key: π: proportion of individuals with capture probability p1*; β: probability of arrival in the population; p: capture probability; ϕ_j: time-dependent retention (or "survival") probability; N: population size; *π is not estimated in the case of no heterogeneity

The maximum-likelihood estimates from the sellers and descriptions analysis (Table 3-5) indicate the existence of two groups of individuals with markedly different capture probabilities. Proportion 0.09 of the sellers population has capture probability 0.54, whilst the remaining proportion of the population has capture probability 0.02. The model-averaged estimates for the items data demonstrate some suggestion of time-dependence in both arrival and retention probabilities, and this may be linked to items being re-posted with a new item number during the study.

AIC model selection from fitting the CJS model to the sellers data strongly supported the model with capture probability depending on the average number of items a seller has listed (Table 3-4).

Table 3-6: Open population Cormack-Jolly-Seber mark-recapture model: covariate model selection

Model	**∆AIC**	**k**
ϕ(.),p(covariate)	0.00	3
ϕ(.) p(.)	22.65	2
ϕ(.) p(t)	30.49	8
ϕ(t) p(.)	33.00	8
ϕ(t) p(t)	39.68	13

Key: ϕ: retention (or "survival") probability; (.): constant; p: probability of capture, logit (p)=α_{0+} α_1 × covariate; (covariate): individual covariate, i.e. average number of items for sale; (t): time dependent; k: number of parameters

The maximum-likelihood estimates (Table 3-7) indicate that as the number of items a seller has listed increases, so does the probability of capture of an individual seller ($\alpha 1$ = 0.68, SE = 0.19).

Table 3-7: Maximum likelihood estimates (on the logistic scale), corresponding standard errors and 95% confidence limits from fitting the Cormack - Jolly - Seber model to the Sellers data

Parameters	MLE	SE	Lower 95% point	Upper 95% point
ϕ (survival)	1.43	0.22	0.99	1.86
α_0 (intercept)	-1.34	0.34	-2.01	-0.66
α_1 (slope)	0.68	0.19	0.30	1.06

Key: ϕ: retention (or "survival") probability; α_0: intercept in logistic regression; α_1: coefficient of covariate value in logistic regression

It is clear from Table 3-5 that the estimates of population size, N, are estimated with very poor precision and therefore it is impossible to draw any conclusions from them. It is known that when capture probability is very low it is very difficult to obtain meaningful estimates of population size (see for example p. 45 of McCrea and Morgan, 2014). If capture probability of the less detectable population could be increased then the precision of estimates might improve, however such an approach would require greater resources for identifying occasional sellers of illegal ivory online.

3.5 Discussion and conclusions

Our results indicate that an online trade in elephant ivory is being conducted via eBay UK, despite the existence of eBay's User Agreement and Animal and Wildlife Products Policy (AWPP) policies and in contravention of these. Under its AWPP (eBay, 2015a), described by eBay as reflective of international trade restrictions and treaties banning the sale of ivory, eBay prohibits the sale of ivory with the limited exception of antiques that contain 5 percent or less of real ivory and were made before the year 1900. None of the elephant

ivory postings we identified complied with the terms of the AWPP, so all constituted prohibited sales.

Further, sellers were acting in contravention of eBay's User Agreement (eBay, 2015b), which is framed as a contractual arrangement and stipulates seller responsibilities, including compliance with eBay's Prohibited and Restricted Items Policy (eBay, 2015c) and AWPP.

According to our categorisation of the types of ivory traded, elephant ivory forms the second largest group after "Other" (i.e. ivory coloured items such as textiles and furniture) (Figure 3-1).

Our data infer that two elephant ivory trading populations are active on eBay UK characterised by their trading patterns and associated capture probabilities. One, inferred population has a relatively high capture probability ($p = 0.54$, SE 0.05) whereas the other population has a relatively low capture probability ($p = 0.02$, SE 0.04). Capture probability is, as one would expect, positively related to the number of items that a seller has listed (i.e. the more items that a seller has listed, the more "catchable" they are). The population with a relatively high capture probability sells elephant ivory persistently, and tends to have multiple items advertised for sale simultaneously. This trading pattern may be suggestive of dedicated (or commercial) sellers. In contrast, the population with a relatively low capture probability tends to sell elephant ivory items only occasionally, and as single items. We suggest that this sporadic, lower-volume sales pattern may be associated with occasional (or non-commercial) sellers. Relatively few sellers are trading persistently in multiple items of ivory, with high catchability, and a comparatively large number of sellers are trading sporadically and typically in single items, with low catchability (Figure 3-3). However it is worth noting that items categorised as "Unknown" (i.e. those that could not be identified) ranked third (Figure 3-2) and therefore creates a level of uncertainty as one would expect when making decisions based solely on the available online attributes of an item.

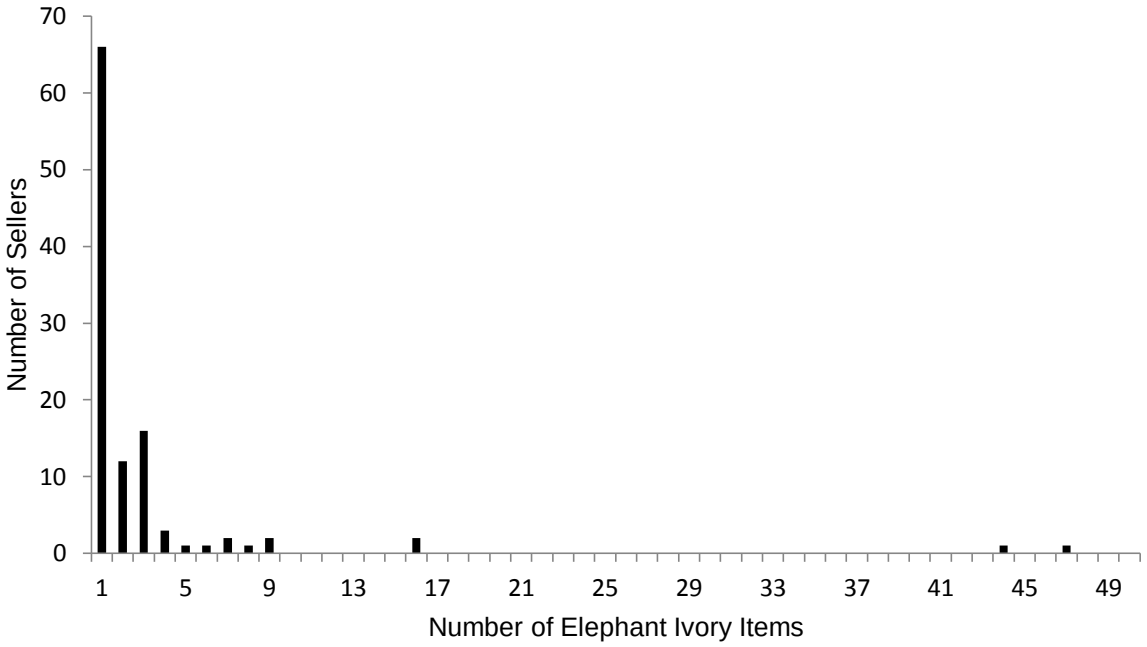


Figure 3-3: Histogram illustrating the number of observed, confirmed elephant ivory items for sale per observed seller during the 8-week study period

Catchability may also vary according to whether a seller is using the “Auction” or “Buy it Now” option to sell items. Items posted using “Buy it Now” are likely to have a longer residence time and are therefore more likely to be detected. Such items may be associated with dedicated (commercial) sellers, trading in larger volumes of ivory. In contrast, items posted for sale using the “Auction” facility are likely to have a shorter residence time, making them more difficult to detect. Items posted in this way may be associated with the “less catchable”, occasional (non-commercial) sellers. Such differences in residence time may also be seen in the use of item descriptions and item number as ‘marks’ during the mark-recapture analysis. We suggest that using “Description”, rather than Item Number would provide a more robust “mark” for future studies. We found that the latter changes during relisting of an unsold item, whereas we found “Description” largely remained unchanged except in a few cases where “New listing” was added to the item description.

The existence of the two, inferred populations has implications beyond the suggestion of two potential classes of online (i.e. eBay UK) ivory seller. The observed pattern of relatively few, persistent, higher-volume sellers and relatively numerous, occasional, lower-volume sellers leads to the high standard errors reported for population size (N) (Table 3-5).

The pattern of high number of single offence, versus individuals engaged in multiple offences is likely to be seen in other area of environmental crime. This makes it difficult for law enforcers both to estimate the total population of offenders, and to identify the most persistent offenders from within this population.

Since one would imagine that a lower likelihood of prosecution is associated with single offences, resource-driven priorities mean that enforcement focus tends to be directed towards multiple offenders. This has two effects: firstly, a single offender population tends to persist and, secondly, the relatively high volume of single versus multiple offenders complicates overall (offender) population size estimation. However, if law enforcers are mainly interested in persistent offenders then an analysis focusing on individuals with a high probability of capture may be of interest and may result in a more robust estimate of this specific population.

We see potential opportunities, resulting from this study, for actions to address the online trade in elephant ivory. For example, should the many, sporadic, single items sales actually be associated with occasional sellers, then this might indicate a lack of understanding of trading requirements, rather than deliberate offending; it would be interesting to see whether these individuals use code words such as “ox bone” often used to disguise the sale of elephant ivory (Harrison et al., 2016) which may indicate a level of intent. If it is a case of lack of understanding on the part of the sporadic, single item sellers, education to raise awareness and understanding of legal and policy requirements surrounding the trade in ivory may be of value. Should compliance subsequently increase, then the twin benefits of a reduction in the volume of sporadic, online trade and a

lessening of the confounding effect of this trading pattern upon overall trading population size (and value) estimation may result. In our example, reducing the number of sporadic, less catchable sellers should allow more focus to be placed upon detection and characterisation of persistent, higher volume sellers. Reduction of the high standard errors associated with the sporadic seller trading pattern should better enable estimation of the total, online trading population size, and its monetary value. Such evidence may assist enforcement agencies in directing their resources towards persistent, higher volume sellers with a greater potential for successful prosecution. However, absolute estimates of the size of the market activity may not be required, as relative size may be adequate if prioritizing worst offenders or monitoring the efficacy of schemes to reduce offending rates is the goal.

An assessment of the speed with which elephant ivory postings appear, and then disappear from eBay UK prior to this study yielded very few with a residence time on the site of ≤1 hour (Yeo, 2011). Posting items very briefly is sometimes used as a mechanism by those engaged in illegal trade to highlight the availability of illegal items but avoid detection by the authorities. However, the fact that we did not detect evidence for this phenomenon does not mean that offline discussion of posted ivory items to conclude sales is not occurring. We have been informed that this phenomenon has also been seen in China (pers. comm. Anon.); however, there the items are reposted under a different username. This activity was not observed in this study.

Our research was confined to the eBay UK online market, for transactions taking place within the UK, and indicates that MRC may be applied to gain a clearer understanding of the online ivory trade when sampling is not continuous. MRC exhibits potential for scaled up research into the online ivory trade across a wider area of cyberspace. Further, since trade in elephant ivory takes place via other electronic (social) media, MRC may also offer a means to research and characterise trade conducted via those media and the degree to which trading platforms overlap.

Research into the electronically-mediated wildlife trade is still in its infancy with the number of peer-reviewed studies slowly increasing. At the same time, the pressing need for enhanced understanding of its key characteristics, especially to elucidate illegal trade, is a conservation priority. The illegal, online trade in wildlife commodities, including elephant ivory, is a serious and growing issue that presents a significant conservation threat. Despite a groundswell in international intent to stem the illegal wildlife trade there will, necessarily, be a time lag between planning and execution of impactful intervention measures. Further, it is unlikely, given the desire for items of wildlife that demand for them will disappear in the near-term (Courchamp et al., 2006; Hinsley et al., 2015). Given this, the application of MRC offers a flexible and resource-efficient means by which to assess, more accurately, key facets of the illegal online trade in wildlife, as well as other criminal activity (see Wittig, 2016). The enhanced understanding that this approach brings may usefully inform regulatory and intervention measures to support delivery of wider conservation imperatives.

This is the whole point of technology.

It creates an appetite for immortality on the one hand.

It threatens universal extinction on the other.

Technology is lust removed from nature.

- Don DeLillo, *White Noise*

Chapter 4: Application of the multi-state open robust design model for the evaluation of populations associated with online (illegal) wildlife trade

4.1 Abstract

The illegal, online trade in wildlife is increasing and constitutes a significant and pernicious threat to biodiversity. Currently, trade is poorly monitored and our understanding relies mainly on limited duration, snapshot studies since continuous monitoring is not possible through a lack of suitable technology. As a consequence of imperfect detection, snapshot studies are unlikely to detect all trading activity. Mark-recapture provides a means to enhance understanding of online trade, even where monitoring is not continuous. We apply multi-state open robust design (MSORD) modelling to assess its suitability for evaluating demographic parameters of interest for illegal online wildlife trade. We demonstrate compatibility between MSORD and our collected online data and draw statistically significant inferences, with good precision, for key population parameters including those that may indicate illegal trade. We conclude that MSORD demonstrates potential for application to assess the illegal, online wildlife trade especially given its facility for estimating state transition probabilities which can infer illegal trade. Recommendations are made for future research to evaluate MSORD effectiveness compared to simpler MRC models in delivering desired outcomes for online illegal wildlife trade monitoring. A structured feasibility study would consider time, cost and model complexity as part of this assessment.

4.2 Introduction

The illegal online wildlife trade is increasing. However, it is currently poorly monitored and our understanding of its extent and nature is based mainly on “snapshot” studies (e.g. IFAW 2005, 2013, 2014, 2017; TRAFFIC 2017, 2018). This largely involves manual searches of websites and as such is time-consuming and expensive, making continuous monitoring untenable. Reported outcomes from snapshot studies often do not account for the fact that, even during periods of intensive monitoring, the internet is not been

monitored continuously so it is unlikely that all trading activity will have been detected (imperfect detection) (Yeo et al., 2017).

The method of mark-recapture (MRC) offers a means to evaluate online trade even when monitoring is not continuous. In a novel study, MRC was applied to examine behaviour associated with the online trade in elephant ivory (Yeo at al., 2017). Study outcomes indicated not only the presence of online ivory trade, as would be expected from a snapshot study, but also MRC enabled the identification of differentiation within the trading population (i.e. a small number of dedicated, or commercial, sellers and a large number of occasional, or non-commercial, sellers). The potential of MRC for future application to characterise illegal wildlife trade across diverse online platforms was indicated.

The periods of intensive, although not continuous or “perfect”, monitoring associated with online wildlife trade studies are often time-separated. It is important to be able to derive maximum benefit from these hard won but discrete sets of data, and MRC provides a potential means to do this. MRC can be applied to understand population behaviour (demography) that occurs during periods of intense monitoring, and during the interim periods where monitoring does not occur. Essentially, this is achieved by incorporating both open and closed population assumptions into an evaluative model framework. As context to our study, we provide a short review of open and closed population models and their development.

MRC is applied extensively in ecology and conservation to investigate key population parameters, such as natality, mortality, movement (i.e. emigration and immigration) and population size (McCrea and Morgan, 2014). Classically, population ecology employs two, main methods of MRC, “Open population” methods, and “Closed population” methods.

Open populations exhibit natality, immigration, mortality and emigration. Here, long-term MRC data have historically been analysed using the Jolly-Seber (JS) method (Pollock et al., 1990) or one of its variants. The JS method is based on one capture occasion per period of interest, but this apparently single occasion may actually consist of data pooled from a number of sampling occasions according to whether an individual was captured at

least once during those events. Further, the JS method assumes that samples are collected instantaneously, which rarely happens in practice in ecology. However, the collection of a sample non-instantaneously (i.e. over a longer period) does not bias parameter estimates providing the population dynamics remain static for that sampling effort period (Seber, 1982, pp.196-132).

In contrast, where it is reasonable to assume that a population is not subject to natality, immigration, mortality and emigration throughout the time period over which it is being sampled, it is defined as “closed” (McCrea and Morgan, 2014). Here, a set of methods other than the JS method is required in order to estimate abundance, or detection probability (Otis et al., 1978). In these, closed population studies a series of samples is taken during a time period where, considering the traits of the specific population being evaluated, an assumption of closure may reasonably be made.

In 1982, Pollock proposed that the application of open population, JS methods and closed population methods might usefully be combined to make overall population analyses more robust to heterogeneity (Pollock 1982). Pollock’s proposal was to apply closed population methods (for abundance estimation) to analyse data from within a sampling period, i.e. one compliant with population closure assumptions, whilst also applying open-population, JS methods (for survival rate) to analyse data from a number of these periods, i.e. all of those occurring within a given study. A combination of closed population and JS estimators was proposed to estimate recruitment. Using this approach, inherent tendencies within open and closed population methods could be balanced to achieve more efficient and less biased outcomes, resulting in Pollock’s “Robust Design Method” (RDM).

The closed population sets of observations within a study of this type are termed “secondary samples” which are themselves grouped into separate sets of “primary samples” (or periods) between which open population model assumptions apply (Figure 4-1).

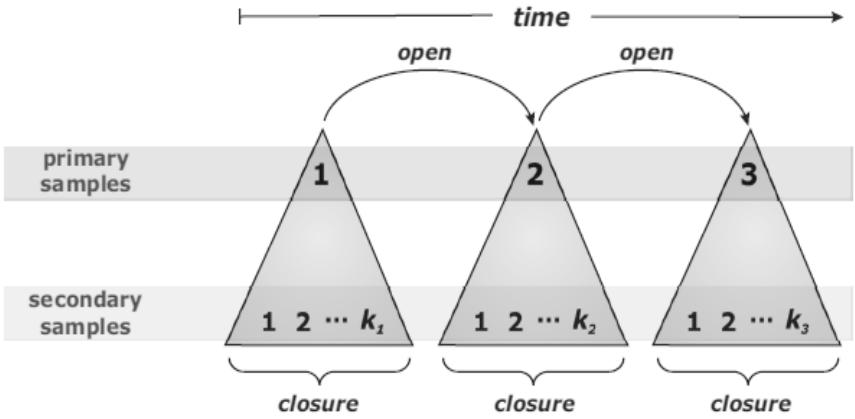


Figure 4-1: Sampling structure of “classical” Pollock’s robust design (closed) (MARK, 2018)

Subsequent to Pollock’s original RDM proposal, Kendall et al. (1995) developed models capable of interrogation of within- and between- sampling period data simultaneously, instead of separately, for cases where detection probability varies only by time, or trap response. Trap response describes a potential source of capture probability heterogeneity where a study subject may be more (i.e. trap-happy) or less (i.e. trap-shy) predisposed towards “capture”, or encounter. Kendall et al. (1995) demonstrated that, using this approach, survival rate estimators are more precise than under JS. This development also encompassed a change from the *ad hoc* approach to modelling ascribed to Pollock’s original concept to a likelihood based approach (Williams et al., 2002). The *ad hoc* approach is typified by independent modelling of data from the primary and secondary periods, whereas a likelihood based approach models both types of data simultaneously within a single likelihood (Williams et al., 2002). Likelihood based modelling offers advantages over the *ad hoc* approach, including yielding estimators that possess a number of optimal properties, examples of which are listed below (Williams et al., 2002).

1. The maximum likelihood estimator $\hat{\theta}$ has an approximately normal distribution for large sample sizes. Also, its distribution converges asymptotically to a normal distribution as sample sizes increase.

2. Although $\hat{\theta}$ may be biased, it is asymptotically unbiased since the expected value of $\hat{\theta}$ converges to parameter θ as sample sizes increase.

3. The variance of estimator $\hat{\theta}$ is asymptotically minimum since it has the least variance of all unbiased estimators of parameter θ when sample size is large.

4. It is possible to approximate the variances and covariances of maximum likelihood estimators directly from the likelihood function (see Williams et al., 2002, Appendix F (Information Matrix)).

In 1999, Nichols and Coffman described the multi-state closed robust design model (MSCRD) intended to offer more flexibility than either of its constituent models since both multiple states (a refinement of the robust design model) and multiple secondary capture occasions (building on the multi-state model) could be considered (Nichols and Coffman, 1999; MARK, 2018, pp.15-28-15-37). In tandem with the flexibility offered by this combinatorial approach, an increase in model complexity occurs.

The open robust design (multi-state) model (MSORD) is a development of the RDM (closed) and MSCRD models and represents an increase in flexibility and complexity compared to them. MSORD permits arrivals into and departures from the sampled population within the primary periods, violating the assumption of closure. Unbiased parameter estimates may be generated under this relaxed closure assumption (Schwarz and Stobo, 1997; Kendall and Bjorkland, 2001; Kendall and Nichols, 2002). Two states between which the probability of transition may be estimated are integral to the MSORD model, i.e. the observable state and the unobservable state. Temporary emigration (and return) involves transitions to and from an unobservable state. For example, in biological systems, the unobservable state may be that of “non-breeder”, i.e. an individual not available at a study site at time of survey but still a member of the wider (or super-) population (Kendall and Nichols, 2002).

MSORD employs the following parameters:

S_t^r (Survival probability between primary periods): Survival from primary period *t* to *t+1* for those occupying state *r* during primary period *t*

ψ_t^{rs} (Transition probability between primary periods): Probability an individual in state *r* at primary period *t* is in state *s* in primary period *t+1*, given it survives to period *t+1*

pent_{tj}^{s} (Entry probability within primary periods): Probability that an individual in state *s* in primary period *t* is a new arrival (within that primary period) to the study area for that state at capture occasion *j*

φ_{tja}^{s} (Survival probability within primary periods): Probability that an individual in the study area associated with state *s* at capture occasion *j*, who first arrived in the study area *a* capture occasion previous , is still in that study area at capture occasion *j+1*

p_{tj}^{s} (Capture probability): Probability that an individual in the study area for state *s* at capture occasion *j* is captured.

Although a relatively new approach, MSORD is increasingly being applied in ecology and conservation to study the population dynamics of diverse species (e.g. Muths et al., 2010; Prince and Chaloupka, 2012; Ruiz-Gutierrez et al., 2016), especially those whose ecology means that accounting for unobservable states is particularly relevant. Failure to take account of unobservable states can result in severe biases in demographic parameters derived from MRC models, whereas application of appropriate models including MSORD can reduce or eliminate such biases (Bailey et al., 2009). MSORD is finding particular utility in the study of marine species, such as hawksbill turtles (Prince and Chaloupka, 2012), loggerhead turtles (Pfaller et al., 2013), humpback whales (Franklin, 2015), green sea turtles (Piacenza et al., 2016), grey seals (den Heyer and Bowen, 2017), sperm whales (Boys et al., 2018) and sea turtles (Kendall et al., 2018). In addition, MSORD has been applied to the study of boreal toads (Muths et al., 2010), migratory birds (Ruiz-

Gutierrez et al., 2016) and the impact of dogs upon protected wildlife (Paschoal et al., 2016).

Here, we apply MSORD to evaluate online wildlife trade using data from time-separated periods of intensive, but imperfect, monitoring to assess population parameters both within and between sampling periods. We select online postings for “ivory” items as our case study and, to secure a suitable sample size for analysis, we include all items responsive to the search term “ivory”. Our data therefore includes, but is not limited to, items of animal-origin ivory. Examples of potential non-animal origin “ivory” items include faux ivory objects, and items of clothing or furnishing that are ivory in colour (Yeo et al., 2017). Whilst all MSORD probability parameters are considered (i.e. survival within and between primary periods; transition between observable and unobservable states; entry probability and capture probability) particular focus is upon patterns of arrival into the population, survival within and between primary periods, and any inference of temporary emigration.

We hypothesise that arrival probability ($\mathrm{pent}_{\mathrm{tj}}^{\mathrm{s}}$) trends could identify peaks in posting activity, which may be of demographic interest for future monitoring studies. Survival probability between days ($S_{\mathrm{t}}^{\mathrm{r}}$) may provide a useful indication of population residence time; again, of potential use for planning monitoring studies. Survival probability within a day ($\varphi_{\mathrm{tja}}^{\mathrm{s}}$) may infer times of day when listings might end and transition probability ($\psi_{\mathrm{t}}^{\mathrm{rs}}$), associated with temporary emigration, can suggest de-listing and re-listing of an item which (for relevant items) may indicate illegal trade.

Our research presents a novel application of the MSORD mark-recapture model to evaluate online wildlife trade, especially illegal trade. Our objective is to assess the suitability of MSORD for analysis of data from time-separated online (illegal) wildlife trade studies. If suitable, MSORD may enable maximum benefit to be derived from the resource investment these studies represent, and the valuable data they yield. Prospectively, series of planned, short-duration studies, designed for analysis using

MSORD, might offer a resource sparing complement to real-time monitoring of online trading sites for diverse illegal wildlife trade commodities.

4.3 Method

Figure 4-2, below, outlines the process used for data specification, acquisition and assessment for this study which is described in more detail following the flow chart.

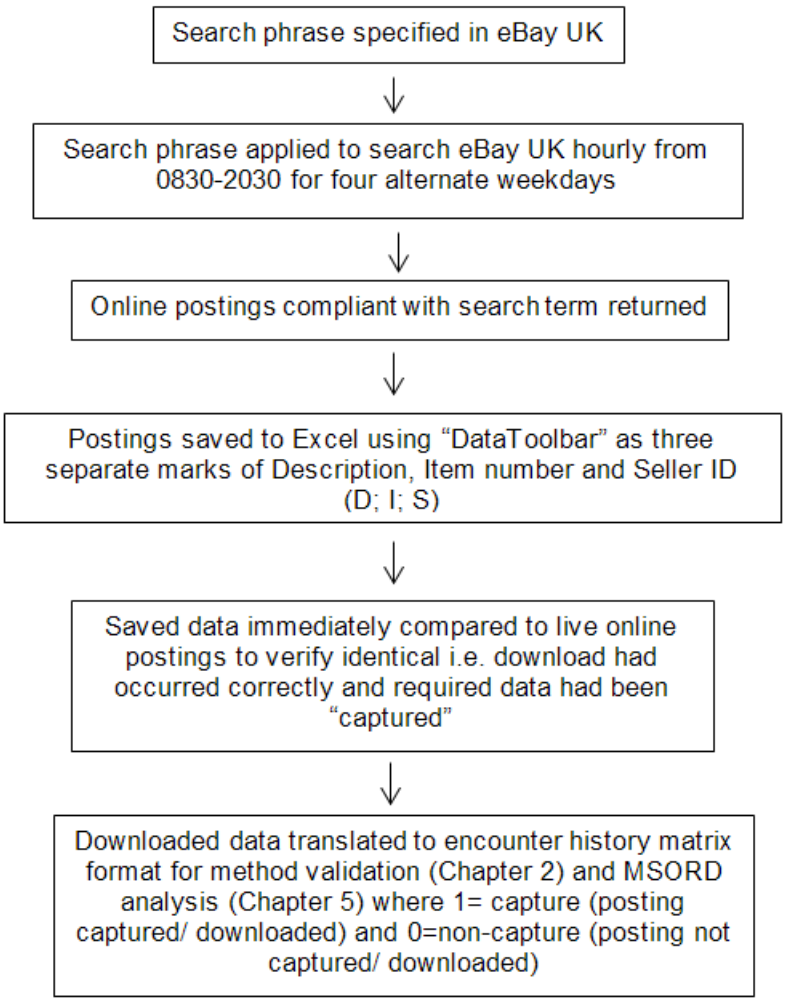


Figure 4-2: Data specification, acquisition and assessment process for hourly downloads 0830-2030 inclusive over four alternate weekdays

The study design was approved by the University of Kent, School of Anthropology and Conservation's Research and Ethics Committee.

Postings responsive to the search string "ivory; antique; UK only" were downloaded from the generalist online marketplace "eBay UK" at hourly intervals on four, successive weekdays. Specifically, from 0830 until 2030, inclusive, on Monday 2nd, Wednesday 4th,

Friday 6th and Sunday 8th June, 2014 in order to garner data from a trading week. Since a broad search term of “ivory” was selected to secure a suitable sample size for analysis, downloaded items included those comprising or containing animal-true ivory (e.g. elephant, hippo, walrus), synthetic “faux” ivory, vegetable ivory (i.e. tagua nut) and ox/cow-bone items. In addition, ivory-coloured items, including soft furnishings, clothing and furniture, predominated, which tends to be the case (Yeo et al., 2017).

Downloaded information per posting included: unique Seller Identification, unique Item Number & (presumed unique) Item Description-analogues to the more traditional “marks” used in ecological mark – recapture. Encounter history data for the “Descriptions” mark was isolated for analysis since previous research indicated that this mark provided a more stable mark than other alternatives, such as sellers (Yeo et al., 2017). The Descriptions encounter history was converted into the .INP format required for analysis using program MARK (White & Burnham, 1999).

This set of downloaded data (i.e. our encounter history) was assessed to guide selection of an appropriate model class for data evaluation and configuration of specific models within this class in terms of parameter/ covariate combinations.

We considered two aspects of our downloaded data for development of descriptive statistics -

1. Hourly variation in the number of encounters within each day (primary period) for insight into encounter patterns per primary period and to enable comparison between primary periods

2. Patterns suggestive of Descriptions temporarily emigrating from, then re-entering the population (i.e. transitioning to and from an unobservable state, parameter ψ_t^{rs}) was assessed by visual examination of downloaded data across all four sampling days (primary periods). Patterns of “0’s” appearing within a string of “1’s” was assumed to indicate temporary emigration, followed by immigration. We provide examples from our dataset that exemplify this pattern, within a single primary period (Figure 4-3).

Des.1	0	1	1	0	1	1	0	1	0	1	1	1	1
Des.2	1	1	1	1	0	1	0	0	1	1	1	1	1
Des.3	0	1	1	1	0	0	0	0	1	1	1	1	1
	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12	t13

Figure 4-3: Encounter histories illustrating potential temporary emigration and re-entry into the population (parameter ψ_t^{rs}) for individual descriptions (Des.1-3) within a single primary period at secondary sampling times t1-t13

Based on this evaluation, we judged that the most appropriate class of model to apply for analysis was multi-state open robust deign (MSORD) incorporating suitable parameter covariates (Table 1). In Table 1 we provide classical and study-specific definitions of MSORD states, parameters and covariates. With respect to our "Descriptions" population, the observable state ("*r*") equates to a listed Description, whereas the unobservable state ("*s*") equates to an item that is temporarily not listed (i.e. the Description is not available for download).

Table 4-1: MSORD classical and study-specific definitions

MSORD Parameter	**Classical definition**	**Study analogue**	**Shorthand & constraints**	**Parameter variants***
S_t^r	Survival from primary period *t* to *t+1* for those occupying state *r* during primary period *t*	Survival probability of observable/ listed descriptions between successive primary periods (i.e. download days).	Survival probability between days **Constrained to be constant**	S(c) or S(d)
ψ_t^{rs}	Probability an individual in state *r* at primary period *t* is in state *s* in primary period *t+1*, given it survives to period *t+1*	Probability a Description in state *r* (i.e. observable/ listed) at download Day *t* is in state *s* (i.e. unobservable/ temporarily unlisted) in download Day *t+1*, given the Description is still listed on download Day *t+1*	Transition probability from state O to state U, or state O to state U on successive download days. The probability of an item being de-listed (i.e. transition from observable to unobservable) or re-listed (i.e. transition from unobservable to observable). The probability an item remains listed is then the complement of the probability of it being de-listed (i.e. 1- probability of it being	phi (1,2) (c) phi (2,1) (c)

MSORD Parameter	Classical definition	Study analogue	Shorthand & constraints	Parameter variants*
			de-listed). Conversely, the probability an item remains de-listed is 1-probability of it being re-listed). **Constrained to be constant**	
pent_{tj}^{s}	Probability that an individual in state *s* in primary period *t* is a new arrival (within that primary period) to the study area for that state at capture occasion *j*	Probability that an observable (listed) Description within Day *t* is a new arrival (within Day *t*) to the study area for that state (i.e. observable/ listed) at capture occasion *j*)	Probability of entry into download day during hourly downloads (2^{o} period)	pent(t*d) pent(t)
φ_{tja}^{s}	Probability that an individual in the study area associated with state *s* at capture occasion *j*, who first arrived in the study area *a* capture occasions previous, is still in that study area at capture occasion *j+1*	Probability that a Description unobservable at download hour *j* is still listed at download hour *j+1*	Probability of survival <u>within</u> download Day	phi(c) phi(t) phi(t*d)
p_{tj}^{s}	Probability that an individual in the study area for state *s* at capture occasion *j* is captured	Probability that a Description observable at download hour *j* is captured.	Capture probability (observable/ listed state) **Constrained to be constant**	p(c)
p_{tj}^{s}	Probability that an individual not in the study area for state *s* at capture occasion *j* is captured	Probability that a Description unobservable at download hour *j* is captured	Capture probability (unobservable/ delisted state) **Constrained to be zero**	p=0

* Parameter variants:

(t) denotes time-dependence

(c) denotes a constant parameter

(d) denotes parameter dependence associated with primary periods (i.e. days)

(t*d) denotes parameter dependence associated with both time (i.e. hours within a primary period) and days (i.e. between primary periods/ days))

Four primary sampling periods i.e. weekdays Monday, Wednesday, Friday and Sunday were specified and within each primary period data was collected every hour for 13 hours. This gave 13 secondary sampling occasions. For modelling purposes, the time interval between hourly download occasions within the secondary sampling period was assumed to be zero.

Probabilities for pent, φ and p were constrained to zero for the unobservable state. In order to simplify parameter structure, parameters of survival probability between days (S_t^r), capture probability in the observable state (p_{tj}^s) and transition probabilities (ψ_t^{rs}) were constrained to be constant over time.

Twelve different movement models were configured for data analysis, based on all possible combinations of the parameter variants listed in Table 4-1 and informed by our prior assessment of the downloaded Descriptions data (Table 4-2). The movement model in all cases was Markovian, reflecting the assumption that the probability of a Description moving from a listed to an unlisted state between primary periods (days) (psi(1,2)) differed from the probability of one moving from an unlisted to a listed state (psi(2,1)). Differences in parameter estimates resulting from the 12 models therefore related only to the parameter structure, i.e. whether or not parameters were held constant (c), or allowed to vary over time (t), or day (d), or both (t*d).

Table 4-2: MSORD movement models to be fitted to collected data using Program MARK

Model Reference	Model configuration (parameter structure)
A	S(c), pent (t), p(c), phi(c), psi(1,2), psi(2,1)
B	S(c), pent (t), p(c), phi(t), psi(1,2), psi(2,1)
C	S(c), pent (t), p(c), phi(t*d), psi(1,2), psi(2,1)
D	S(c), pent (t*d), p(c), phi(c), psi(1,2), psi(2,1)
E	S(c), pent (t*d), p(c), phi(t), psi(1,2), psi(2,1)
F	S(c), pent (t*d), p(c), phi(t*d), psi(1,2), psi(2,1)
G	S(d), pent (t), p(c), phi(c), psi(1,2), psi(2,1)
H	S(d), pent (t), p(c), phi(t), psi(1,2), psi(2,1)
I	S(d), pent (t), p(c), phi(t*d), psi(1,2), psi(2,1)
J	S(d), pent (t*d, p(c), phi(c), psi(1,2), psi(2,1)
K	S(d), pent (t*d), p(c), phi(t), psi(1,2), psi(2,1)
L	S(d), pent (t*d), p(c), phi(t*d), psi(1,2), psi(2,1)

Program MARK is used to fit the data from MSORD models to collected data. It is necessary to configure parameter index matrices (PIMs) appropriate to the study in question in order to define models in MARK. Model selection is used to evaluate optimal parameter dependencies both across primary periods (for parameters S, ψ, pent, φ and p) and within primary periods (for parameters pent, φ, and p). A prerequisite to unbiased parameter estimation using MSORD is that an individual's state is fixed during a primary period, so for correct model functioning transitions between states may only occur between primary periods.

Parameter index matrices representing configurations A-L (Table 4-2) were therefore specified in Program MARK and the 12 candidate MSORD movement models fitted to the formatted (.INP) Descriptions data.

4.4 Results

4.4.1 Descriptive statistics

Summed encounters per hour (secondary samples) were plotted for each download day (primary period) to assess fluctuations in total numbers of listed descriptions over time. Variation was seen in terms of different summed encounters per hour within and between all 4 days (Figure 4-4).

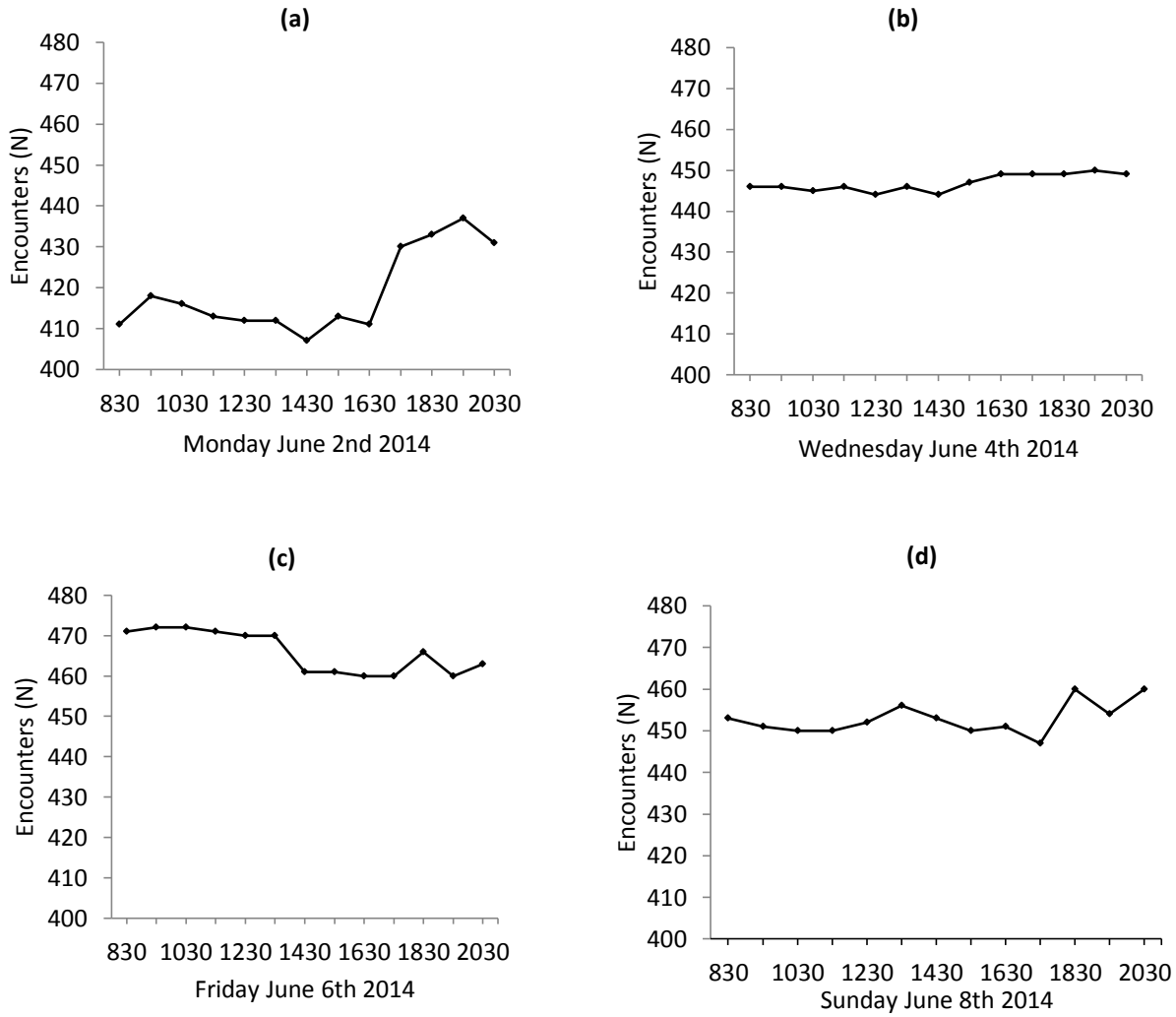


Figure 4-4: Hourly variation per day in summed encounters per hour of downloaded "Descriptions"; (a) Monday June 2nd 2014; (b) Wednesday June 4th 2014; (c) Friday June 6th 2014; (d) Sunday June 8th 2014

4.4.2 MSORD Movement Models

The results from fitting the twelve candidate MSORD movement models to the Descriptions data are presented in Table 3, ranked in increasing order of ∆ AICc.

Table 4-3: Results from fitting open robust design multi-state (MSORD) models to data collected at hourly intervals over four successive weekdays in June 2014. Models are specified by their parameters and ranked by AICc, and k denotes the number of estimable parameters. Here, (t) denotes time-dependence; (c) denotes a constant parameter; (d) denotes parameter dependence associated with primary periods (i.e. days) and (t*d) denotes parameter dependence associated with both time (i.e. hours within a primary period) and days (i.e. between primary periods/ days))

Model Rank	Parameter configuration	AICc	∆ AICc	AICc Weights	Estimable parameters (k)
1	**{S(d),pent(t*d),p(c),phi(t),psi(1,2),psi(2,1)}**	**8833.55**	**0.00**	**0.99**	**59**
2	{S(c),pent(t*d),p(c),phi(t),psi(1,2),psi(2,1)}	8842.45	8.90	0.01	57
3	{S(d),pent(t),p(c),phi(t),psi(1,2),psi(2,1)}	8872.59	39.04	0.00	29
4	{S(c),pent(t),p(c),phi(t),psi(1,2),psi(2,1)}	8888.11	54.55	0.00	0
5	{S(d),pent(t),p(c),phi(c),psi(1,2),psi(2,1)}	8958.73	125.18	0.00	16
6	{S(c),pent(t),p(c),phi(t*d),psi(1,2),psi(2,1)}	9018.19	184.63	0.00	55
7	{S(c),pent(t*d),p(c),phi(t*d),psi(1,2),psi(2,1)}	9021.22	187.67	0.00	86
8	{S(c),pent(t),p(c),phi(c),psi(1,2),psi(2,1)}	9035.96	202.41	0.00	0
9	{S(d),pent(t*d),p(c),phi(t),psi(1,2),psi(2,1)}	9126.28	292.73	0.00	46
10	{S(c),pent(t*d),p(c),phi(c),psi(1,2),psi(2,1)}	9197.90	364.35	0.00	42
11	{S(c),pent(t*d),p(c),phi(c),psi(1,2),psi(2,1)}	9199.91	366.35	0.00	43
12	{S(d),pent(t),p(c),phi(t*d),psi(1,2),psi(2,1)}	10861.30	2027.74	0.00	59

Of the 12 candidate models, ∆ AICc provides compelling evidence that Model K (Table 2), highlighted in bold in Table 3, is the model of best fit with respect to our data relative to the other 11 candidate models. Note that, since there is no model-specific method to measure absolute goodness of fit we assess relative goodness of fit only for this model (MARK, 2018). Ad-hoc bootstrap or comparison of observed and fitted values could be made, but would not diagnose specific departures from the basic model assumptions.

Normally, a ∆ AICc of ≤ 2 is evidence of models to be considered (Burnham & Anderson, 2002). The fact that the next ranked model had an AICc of 8842.453, equivalent in this case to a ∆ AICc of 8.900, indicates that the fit between Model 1 and our data was considerably more pronounced than that for the other models listed. It is therefore appropriate that we discuss demographic inferences from the output of Model 1, only.

Model 1 is configured as: **S(d),pent(t*d),p(c),phi(t),psi(1,2),psi(2,1)** which suggests the following in terms of the demographic parameters of our data -

Survival probability (S(d)) in the observable state is day dependent and so the probability of remaining listed differs between Days 1-4.

The probability of entry (immigration) into the population (Pent (t*d)) is associated with both within-days (hourly, i.e. secondary sampling times) and between-day (i.e. between primary periods) intervals. Entry probability is therefore time varying, within primary periods, and differs between the days, i.e. between primary periods so is both time and day dependent.

Survival probability within a primary period (download day) (Phi(t)) is time varying and differs across secondary sampling times within a day, so is time dependent.

Transition probability between the observable (listed) and unobservable (unlisted) states Psi(1,2), or the converse (Psi(2,1)), between days is inferred (Markovian; probability set as constant)

In order to evaluate Model 1 output in more detail, parameter estimates generated by Model 1 were either plotted or tabulated, for evaluation. Time varying pent (t*d) estimates were plotted for each the 4 primary periods and phi(t) estimates plotted across time “t” within a day. Day dependent estimates were tabulated, i.e. S(d) and psi(1,2) and psi(2,1).

It should be noted that -

1. Pent(t*d) parameter estimates associated with a standard error (SE) value of zero were omitted from the plots due to a boundary estimate errors potentially being associated with them. Similarly, pent (t*d) parameter estimates where confidence interval values spanned 0-1 were also omitted since parameter redundancy may have been indicated here (Cole et al., 2012a; Cole, 2012b). This accounts for the values that may appear to be missing from the real parameter estimates plots for pent(t*d) (Figures 4-5 and 4-6).

2. It is a feature of MARK MSORD modelling that entry probabilities within a primary period must sum to 1. Therefore, the real parameter estimate for pent (t*d) at t13 (our 2030 timepoint) equals one minus the sum of all the other entry probabilities within this primary period (i.e. those at t1 to t12, inclusive) and is not modelled.

3. In our study, the t1 estimate represents the probability that an item is already listed and the t1 value for each primary period is high. We have therefore plotted pent(t*d) real parameter estimates per day both with, and without this t1 value since including it has the effect of “suppressing” the plotted values for times t2-t12, making them difficult to discern. See Figure 4-5 for overlaid plots without the t1 estimate, and Figure 4-6 for overlaid plots that include the t1 estimate.

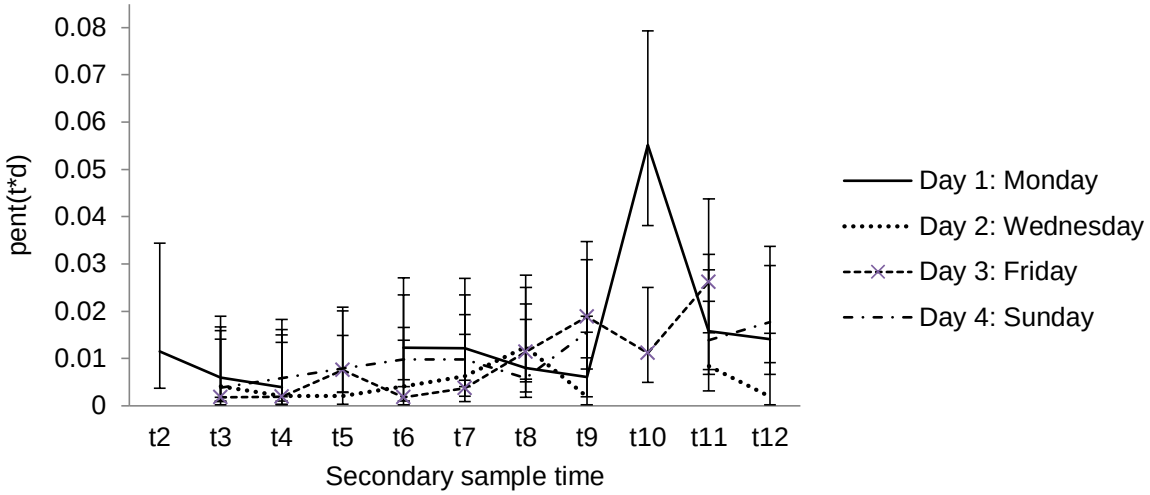


Figure 4-5: Real parameter estimates for pent (t*d) for secondary sample times (t2-t12) (95%CI)

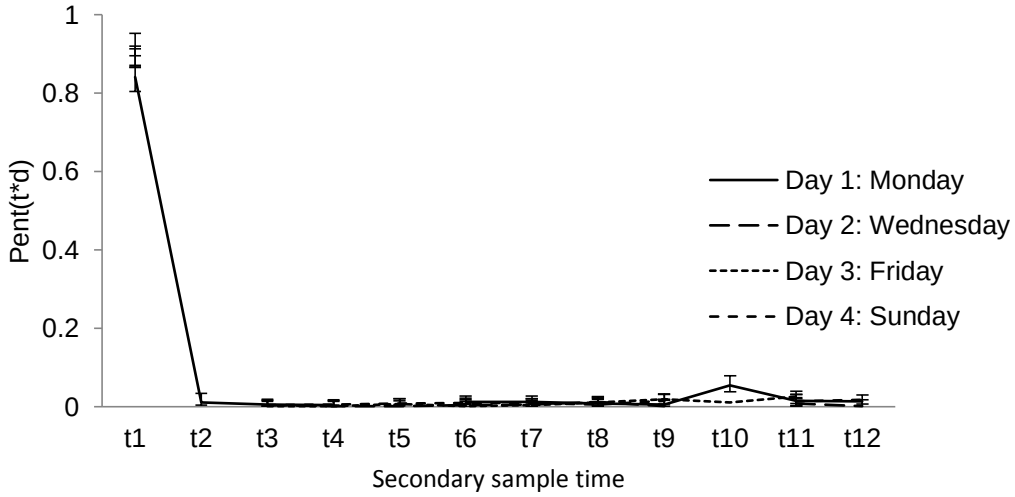


Figure 4-6: Real parameter estimates for pent (t*d) for secondary sample times (t1-t12) (95%CI)

A significantly higher estimate of pent(t*d) relative to other timepoints on that day for the probability of arrivals (Descriptions) into the population is apparent on Day 1 (Monday) at t10 (1730) (0.055 (95%CI 0.017-0.024)) (Fig.4-5).

No clear trend in arrival pattern is apparent from the pent (t*d) arrival probability estimates for Day 2 (Wednesday) (Fig.4-5).

Over Day 3 (Friday) there are indications of a general increase in arrivals across the day and the last non-zero parameter estimate, at t11 (1830), (0.026 (95%CI 0.011-0.018) is

significantly higher than the initial estimate, in this case at t3 (1030) (0.002 (95%CI 0.002-0.012) (Fig.4-5).

Across Day 4 (Sunday) there is a similar trend to that for Day 3 but with lower estimates per corresponding timepoint. Again, the last non-zero estimate at t12 (1930) (0.018 (95%CI 0.008-0.016)) is significantly higher than the initial estimate at t3 (1030) (0.004 (95%CI 0.003-0.012)) indicating a general increase in arrivals across the day (Fig.4-5).

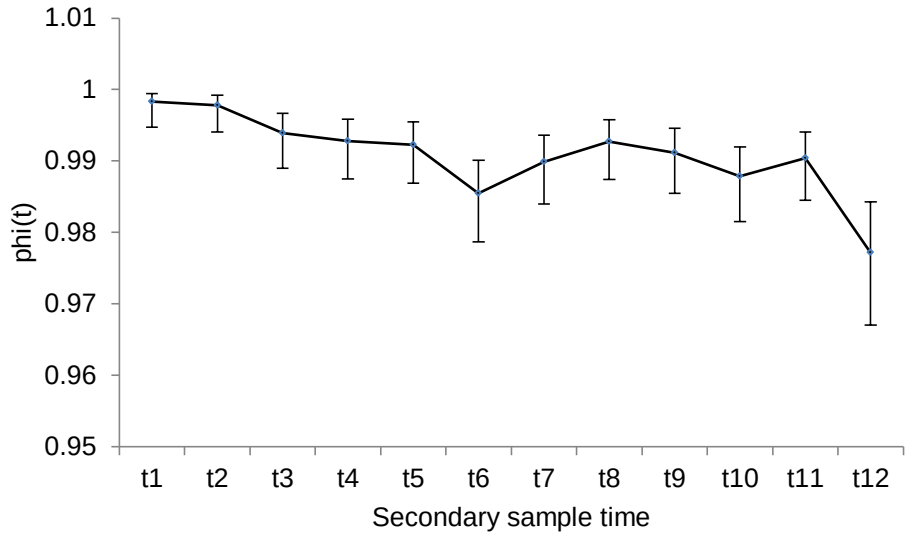


Figure 4-7: Phi(t): Survival probability parameter estimates within download day (95%CI)

Parameter Phi(t) (Survival probability within download day): The estimated parameter values indicate a significant decline in survival probability over time (Fig. 4-7), however generally the survival probability within a day is very high. There is a statistically significant difference between the parameter values at the initial (t1) (0830) (0.998 (95%CI 0.995-0.999)) and terminal (t12) (1930) (0.977 (95%CI 0.967-0.984)) timepoints. In addition, survival probability is indicated to be lower relative to that at other timepoints at t6 (1330) (0.985 (95%CI 0.979-0.990)) and t12 (1930) (0.977 (95%CI 0.967-0.984)).

Table 4-4: Real parameter estimates for day dependent parameters i.e. S(d) (survival probability in observable state) and transition probabilities Psi(1,2) (transition from observable to unobservable state) and Psi(2,1) (transition from unobservable to observable state).

Parameter	Estimate	SE	LCI	UCI
S(d) Mon-Weds: Listed	0.91829	0.02761	0.84530	0.95854
S(d) Weds-Fri : Listed	1.00000	0.00000	1.00000	1.00000
S(d) Fri-Sun: Listed	0.93498	0.02743	0.85589	0.97208
Psi 1 to 2	0.15443	0.01612	0.12541	0.18871
Psi 2 to 1	0.04862	0.01648	0.02479	0.09317

Parameter S(d): The probability of "survival" between days was day dependent. Estimated parameter values indicate that the probability of survival between Monday-Wednesday was 0.918 (95%CI 0.845-0.958) and between Friday-Sunday was 0.935 (95%CI 0.856-0.972). There was no statistically significant difference between these results. Results cannot be reported for survival probability between Wednesday-Friday since a standard error of zero is associated with this result because of the survival estimate lying on the boundary of 1.

Parameter Psi(1,2),Psi(2,1): There was a statistically significant difference between the probability of state transition from a listed to an unlisted state and vice versa between days. The probability of state transition from a listed to an unlisted state between days was 0.154 (95%CI 0.125-0.189). Conversely, the probability of state transition from an unlisted to a listed state between days was 0.049 (95%CI 0.025-0.093). Thus, the probability of transitioning from a listed to unlisted state was higher than the probability of re-entry into the population (re-listing).

Parameter p(c): An estimate of 0.989 (95% CI 0.988-0.990) was derived for capture probability parameter p(c) (constrained as constant).

4.5 Discussion

Our results clearly indicate temporal differences in the dynamics of the underlying population. The data we collected had a sufficiently large sample size to detect statistically significant differences across days and hours. We discuss below study outcomes including, for parameters of particular interest, versus our initial hypotheses.

A probability estimate of 0.989 (95%CI 0.988-0.990) resulted for parameter p(c), capture probability in the observable state. This indicates that capture was imperfect, which is unexpected since we used a web scraper to download "captures" and detection using this method might be expected to be perfect. A deliberately broad search term of "ivory" had been used to secure a dataset of suitable size for MSORD analysis. Therefore, postings for a diverse range of items, ranging from animal origin ivory to furniture and textiles, were downloaded. The objective of this study was to test the suitability of MSORD to evaluate online trading population parameters, rather than to focus on a detailed examination of parameters specific to elephant ivory. Therefore, the suggested absence of a small proportion of listed items is unlikely to have undermined study conclusions since the most likely impact of a smaller than anticipated dataset would have been to confound (complex) MSORD model functioning. This does not seem to have happened, given the production of statistically significant results. However, this anomaly should be investigated further in future studies to understand whether it is a persistent issue, and likely causes for it. Unexplained and potentially variable sub-100% downloading, or capture, could undermine future studies of (illegal) online wildlife trade, depending upon study objectives.

Survival probability between days (S_t^r) may provide a useful indication of population residence time, of potential use for planning monitoring studies.

Model output inferred that the probability of "survival" between days (S(d)) was day dependent. Parameter estimates suggest that there is no statistically significant difference between survival probability between Friday and Sunday (~93%) and that between Monday and Wednesday (~91%). Boundary estimate errors meant that it was not possible to estimate a survival probability between Wednesday and Friday.

Arrival probability ($pent_{tj}^{s}$) trends could identify peaks in posting activity, which may be of demographic interest for future monitoring studies.

A significantly higher estimate of pent(t*d), i.e. probability of "arrivals" to the population, or new Descriptions being listed, was inferred on Day 1 (Monday) at 1730 suggesting a peak in posting activity at this time, based on our data. Over Day 3 (Friday) there were indications of a general increase in arrivals across the day and the terminal parameter estimate was significantly higher than the initial estimate, supporting this observation. As a complement to Monday postings, which may suggest "re-stocking" (posting) of items by sellers after week-end purchase activity, this increase across Friday may suggest postings being added by sellers so that items are available for purchase over the week-end. Earlier research (Yeo et al., 2017) had indicated Friday to be a peak posting day for "ivory" items so our findings were in part aligned with this.

Across Day 4 (Sunday) a similar, general increase was observed but with lower estimates per corresponding timepoint. Again, the terminal estimate was significantly higher than the initial estimate, inferring a general increase in arrivals across the day.

Survival probability within a day (φ_{tja}^{s}) may infer times of day when listings might end

The estimated parameter values indicated a significant decline in survival probability over time since there was a statistically significant difference between the estimate at t1 (0830) and that at t12 (1930). In addition, survival probability appears to be lower relative to other timepoints at t6 (1330) and t12 (1930). These "dips" appear to coincide approximately with lunchtime and evening periods when more people are likely to be available to go online and make purchases resulting in an increase in listings ending.

Transition probability (ψ_{t}^{rs}), associated with temporary emigration, can suggest de-listing and re-listing of an item which (for relevant items) may indicate illegal trade

There was a statistically significant inference of temporary emigration from and re-entry into our case study population. The probability of transition from a listed to an unlisted

state between days was greater than the probability of transition from an unlisted to a listed state between days. Since our dataset was diverse, i.e. it was not restricted to elephant ivory items alone, it is inappropriate to suggest that this observation indicated actual instances of illegal trade. However, it does indicate that MSORD was capable of detecting a pattern that can indicate illegal trade, which merits further assessment. To expand, MSORD can be applied to infer population parameters that may be associated with or indicative of illegal online trade. For example, temporary emigration from and re-entry into a population of advertised online items (listings) can indicate illegal trade - posting items very briefly is sometimes used by those trading illegally to highlight the availability of illegal items but avoid detection by the authorities (Yeo et al., 2017). Study results infer temporary emigration from and re-entry into our case study population, which could be explored further as relevant to (illegal) online wildlife trade. In addition, application of novel research enabling direct estimation of trading population size (N) (Worthington et al., 2018) may provide an opportunity to apply MSORD to evaluate quantitative patterns associated with illegal trade, such as trading population size, amount of material traded and variations (e.g. temporal; geographic) in these.

Based upon the MSORD model's performance in our study, we suggest that it demonstrates potential for application to assess data from existing monitoring studies to derive maximum value from the resource invested in developing them. For example, between 2007 and 2013, the International Fund for Animal Welfare (IFAW) conducted three one-week studies, two two-week studies, one four-week study, two six-week studies and one nine-week study (IFAW 2007, 2008, 2011a, 2011b, 2012, 2013, 2014a, 2014b, 2015). From within this set a two-week study of online wildlife trade in Europe identified a total of 660 advertisements for ivory, with an advertised value of €649,688.90 and final, recorded sales value of €167,356.90 (IFAW, 2012). An additional three month study recorded online wildlife trade with an advertised value of US $3.87m (IFAW, 2008). The predominant class of wildlife material being traded was ivory, which was the subject of over 73% of the observed online trading activity (IFAW, 2008). Intensive snapshot studies

clearly enable detection of online wildlife trade and allow it to be quantified for the period over which trade is monitored, based on the observable trade, or imperfect detection.

To date, few studies have applied mark-recapture to evaluate the illegal wildlife trade, and existing studies have focused on seizure data, rather than online trade. For example, Baker et al. (2007) applied MRC to research illegal whaling; Raza et al. (2012) applied MRC to evaluate the illegal trade in leopard parts in India and Barber-Meyer (2010) proposed the application of the occupancy modelling form of MRC to develop more accurate illegal wildlife trade volume estimates from repeat (physical) market surveys.

Our study indicates that application of MSORD could allow further value to be derived data such as the cited IFAW online trade studies to derive maximum value from them and enhance understanding of the illegal online wildlife trade.

Current initiatives, galvanised by the urgent need to act to conserve biodiversity in the face of species' "annihilation" (Ceballos et al., 2017) aim to reduce online illegal wildlife trade by 80% by 2020 (CAWT, 2018). MSORD could be applied to model existing data, such as the cited IFAW studies, to develop an accurate baseline against which apparent reductions could be measured. In addition, MSORD modelling could be integrated into current monitoring activities to support development of more accurate and complete understanding of trade demographics.

4.6 Conclusions

Our dataset of downloaded Descriptions from time-separated primary periods was suitable for analysis using the complex, multi-parameter model MSORD. Interpretable output was obtained within the framework of the model, i.e. in terms of the demographic parameters and covariates selected as applicable to our data, and with good precision so that statistically significant inferences could be drawn. MSORD demonstrates potential for application to assess the illegal, online wildlife trade, especially given its facility for estimating state transition probabilities which can infer illegal trade. Estimates were derived based on discrete sampling periods (imperfect detection). The model's potential to

support enhanced understanding of trading population demographics between as well as during periods of intensive observation (monitoring) was therefore indicated.

Further evaluation of MSORD's potential utility should proceed along the lines of a structured feasibility study, designed to assess the relative merits of MSORD compared to other MRC models (e.g. JS model and its variants) when applied to analyse the online illegal wildlife (ivory) trade.

As context, prior research using a simpler, JS model and analysing data collected over a longer time period, indicated both the presence of online ivory trade, and differentiation within the trading population through modelling capture probability heterogeneity (Yeo et al., 2017). Although collected over a longer overall period (8 weeks), data for analysis in this study was collected via a single download on one weekday over those 8 weeks (i.e. a total of 8 instantaneous downloads). This compared to 13 hourly (instantaneous) downloads (i.e. secondary samples) over 4 weekdays (i.e. primary periods) for the MSORD study (a total of 52 downloads). Further, since we collected data for our MSORD study over 4 weekdays, only, it is possible that we may not have detected end times for standard 7 or 10 day listings. Were it necessary to extend our study, then similarly increased resource would be needed to collect, model and evaluate data. Further, if inclusion of modelling to consider heterogeneity was desirable, then this would make the MSORD modelling very complex and more parameter redundancy issues may result. A reasonable compromise might be to select one, or possibly two, weekdays for hourly data downloads for MSORD modelling, such as Friday and/or Sunday, to correspond with anticipated peak activity on the web-based auction site. In summary, it would be of value to conduct an in-depth study evaluating the feasibility of meeting the desired outcomes for online illegal wildlife trade monitoring by application of MRC.

This study and the prior research referenced have given an indication of model suitability (JS and MSORD) which could form the basis for future research. There is potential for a comparative methodology study to consider model performance, in terms of successful outcomes, together with the "cost" of this in terms of time and resource required, and the

complexity of modelling. One focus for MSORD, associated with its complexity, could be further scrutiny of underlying factors for apparent parameter redundancy and boundary estimate errors. In addition, novel research into enabling direct, rather than derived, estimation of population size (N) using MSORD (Worthington et al., 2018 (Submitted)) presents a highly useful extra dimension to future research. Trading population size estimation, combined with other demographic parameters, is a key focus for enforcement agencies and conservation practitioners to inform conservation policy, priorities and practice.

"On the Internet, nobody knows you're a dog."

Image attribution: The New Yorker

Chapter 5: Estimating the prevalence of participation in illegal wildlife trade through face to face versus online transactions using sensitive question models in a comparative methodology study

5.1 Abstract

Human behaviours can differ when interacting online versus face to face (F2F). Some individuals may perceive the relative anonymity and freedom from accountability of the online environment as conducive to aberrant behaviour. Socially undesirable behaviours, including cyber-bullying, trolling and cyber-stalking, may manifest online where they may not have occurred F2F.

Given the increasing use of the online environment as a medium for commerce, we explored behavioural approaches towards illegal transactions online versus F2F for items of wildlife trade. We applied an online survey incorporating 3 sensitive question models to achieve this, which allowed methodologies to be compared. The models selected were the Unmatched Count Technique (UCT), the novel Parallel Model (PM) and the Crosswise Model (CM) with Direct Questioning (DQ) acting as a comparator.

Response data from a special interest group involved with reptile keeping was analysed to compare sensitive purchasing behaviour prevalence estimates F2F or online and for a ± one year period relative to survey completion date to assess trends.

Results indicated a statistically significant prevalence for F2F transactions by survey participants during the past year (UCT and PM) and for next year purchases (UCT) but with a lower prevalence estimate. Notably, the novel PM yielded statistically significant results for prevalence of past year F2F purchase compared to DQ. The nature of the traded “commodity” (in this case, live reptiles) may drive F2F transactions. The higher prevalence estimates for a past year compared to next year timeframe may reference the unpredictability of a reptile of interest becoming available for sale or uncertainties over respondents’ future personal or financial readiness to purchase reptiles, i.e. competing priorities.

We conclude that further research into the utility of sensitive question models to improve understanding of the illegal online wildlife trade is warranted. We indicate the complexities of sensitive question models and the importance of considering aspects such as respondent receptivity and relative utility of DQ in study design.

5.2 Introduction

Globally, environmental crime, including the illegal wildlife trade, is estimated to be worth $91-258 billion p.a. (UNEP, 2016). This makes it the fourth most lucrative class of crime after the drugs trade, counterfeiting and human trafficking. Its value is increasing rapidly, and is estimated to have increased by 26% between 2014 and 2016 (UNEP, 2016). As a specific category of environmental crime, the illegal wildlife trade is estimated to be worth $7-23 billion per annum (UNEP, 2016). Elucidating key characteristics of this illicit trade, such as extent, dynamics and impact, is challenging and the wide range in estimated value references this uncertainty. However, a growing body of research is helping to elucidate key facets of the trade, especially which goods are being traded, and in what volumes (Blundell and Mascia, 2005; Blundell and Mascia, 2006; Wilson-Wilde, 2010a; Wilson-Wilde, 2010b; Wyatt, 2011, Pires and Moreto, 2016).

Mirroring trends in general commerce, the online environment is increasingly being used as a means to conduct legal and illegal wildlife trade (IFAW, 2005; Beardsley, 2007; Wu, 2007; IFAW, 2008; Izzo, 2010; Shirey and Lamberti, 2011; Lavorgna, 2015; IFAW 2018). The illegal online trade in wildlife is of significant conservation concern since it is a large and expanding market, trade is challenging to detect and characterise and regulation of internet trade, especially where global, is complex (IFAW, 2005, 2008, 2018; Wu 2007; Sajeva et al., 2013). Harms inflicted by illegal (online and non-online) trade range across compromised species' population viability (Flores-Palacios and Valencia-Dıaz, 2007; Loucks et al., 2007; Barry, 2011; Wyatt, 2011), habitat destruction (Sodhi et al., 2012) the introduction of alien species (Derraik and Phillips, 2010; Johnson, 2010; Kilkillus et al., 2012) the introduction of exotic diseases, including zoonoses (Shannon et al., 2007; Pavlin et al., 2009) and ecosystem imbalance (Myers et al. 2007; Hooper et al., 2012;

Lindsey et al., 2012). Associated harms to individuals, communities and economies proximate to (but not as perpetrators) trading activity constitute an additional, important adverse impact (Wyatt, 2013). Broadly, illegal wildlife trade constitutes a form of wildlife crime with a wide array of potential "victims" encompassing people, the state, non-human animals, plants and environments (Wyatt, 2013; Van Uhm, 2014, 2016).

E-commerce is fast becoming a principal and ubiquitous retail route (Howard 2017; ONS 2017; Statista 2018a). Consumer purchasing habits are changing, exhibiting a major shift to online transactions for diverse goods and services including fast moving consumer goods (FMCG's), banking and entertainment media (Kantar 2014; Howard 2017). Global, generalist online marketplaces such as Amazon, e-Bay and Alibaba act as "intermediaries" between consumers and suppliers, which may be linked to consumer perceptions of security (BEUC, 2017). An increasing trend for consumers to "buy across borders", i.e. outside the country in which they are domiciled, has led to considerations of consumer protection, especially where transactions do not occur through a "regulated" intermediary (BEUC, 2017). Examination of the rapid and sustained increase in revenue of generalist online marketplaces gives an indirect measure of consumer uptake of their services, and the extensive and diverse retail (and other, such as "Cloud" services) activity transacted through them (Howard, 2017; Forbes, 2018; Statista 2018b).

Access to the online environment is increasing rapidly, worldwide, including through targeted initiatives designed to provide "universal" internet access as a goal (UNESCO, 2017/ 2018). A United Nations initiative under the UN 2030 Agenda for Sustainable Development frames development discussions as "Connecting the Next Billions" (UN Internet Governance Forum IGF 2018). An aside from the early stages of this initiative is the evolution of its title from "Billion" to "Billions", acknowledging the project's expanding scale. In Europe, the EU Commission's "Digital Single Market Strategy" includes an imperative to secure better access for consumers and businesses to digital goods and services across Europe as one of its 3 main pillars (EC, 2015).

It is estimated that 58% of the world's population will have access to the internet by 2021, compared to 44% in 2016 (Cisco 2018). The use of mobile devices to access online services is outstripping that of PC's such that smartphones are predicted to account for 23% of all networked devices worldwide by 2021, compared to 5% for tablets and 3% for PC's (Cisco 2018). Smartphones can represent an aspirational commodity in source regions for illegal wildlife trade goods, which may drive poaching behaviours to provide local people with the means to buy these and other "desirable" electronic goods (MacMillan and Nguyen 2013; Challender and MacMillan 2014). Smartphones are also a ready means to access the online environment, including for (illegal) wildlife trade activities.

The growth in availability and adoption of the online environment prompts questions around how human behaviour may vary according to whether interactions occur face to face (F2F) or online, especially where behaviour may be illegal. From the origins of the Internet (ca. 1960's) and the World Wide Web (ca.1982) human interactions mediated via these related entities have continued to expand rapidly and to diversify. The study of human behaviour online versus F2F is now an active and expanding area of anthropological (psycho-social and philosophical) research (Blažun Vošner et al. 2016).

Human behaviours can deviate from established norms when interactions occur online (Suler 2004; Ploug, 2009) and this may manifest as constructive, supportive behaviour or tend towards more destructive extremes (Christopherson 2006). Online environmental attributes including perceived anonymity, physical invisibility, asynchronicity, textuality and personality-linked factors may engender the "online disinhibition effect" (Suler, 2004; Joinson 2003; Joinson 2007) where psychological restraints that usually act to moderate behaviour to lie within societal norms are reduced (Joinson 2003; Joinson 2007; Suler 2004). The concept of online disinhibition builds on Zimbardo's (1969) deindividuation theory, where an observed increase in expression of usually inhibited behaviour (i.e. the administration of electric shocks to fellow study subjects) was ascribed to the "deindividuated state" (Zimbardo 1969).

The spectrum of online behaviours generally seen as undesirable ranges from the relatively moderate, such as tele-cocooning (Habuchi 2005) and “phubbing” (Chotpitayasunondh and Douglas 2016) to more extreme and damaging behaviours including cyber-bullying (Li, 2007; Ploug 2009; Huang and Chou 2010; Notar et al. 2013), trolling (Coles and West 2016; Lopes and Hui 2017; Sest and March 2017) and cyber stalking (Smoker and March 2017). It may be the case that, if social interactions can tend towards aberrant extremes online (facilitated by the environment’s properties, and further influenced by online content depicting risky behaviours (Branley and Covey 2016) then behaviours such as online purchasing might be similarly affected. Individuals may exhibit more extreme purchasing behaviour online, manifested by buying illicit goods, than they would F2F. In the context of wildlife trade, purchasers might show an increased tendency towards engaging in illegal transactions online versus F2F.

Quantifying the prevalence of illicit behaviours directly is challenging, since rule breakers may not wish to identify themselves. When researching sensitive topics, such as illegal behaviour, use of conventional surveys can result in biased response data and diminish the validity of results. However, a number of methods, or models, developed specifically to investigate sensitive topics and behaviours can be applied to mitigate this risk. These “sensitive question models” (Chaudhuri and Christofides 2013) are designed so that it is not possible to link individual respondents with indications of illicit behaviour. Instead, this may only be inferred at group level by statistical analysis of all responses submitted for both sensitive and non-sensitive content. The premise is that surveys incorporating sensitive question models may yield less biased response data since respondents are more likely to respond truthfully through the anonymity offered by the methods (Nuño and St John 2015). The act of researching sensitive topics online, rather than F2F, may also enhance generation of valid responses through a reduction in social desirability bias (Kays, 2012) and potentially the online disinhibition effect (Suler 2004; Joinson 2003; Joinson 2007).

In our study, we use an online survey to apply direct questioning and the three specialised, sensitive question methods of the unmatched count technique (UCT) (Droitcour et al. 1991), the parallel model (PM) (Tian 2014) and the crosswise model (CW) (Yu et al. 2008) to estimate the prevalence of engagement in the illegal wildlife trade through F2F versus online transactions. Few comparative studies applying specialised sensitive question methods exist; however see Roberts and St John (2016) for a comparison of the unmatched count and crosswise models applied to estimate the prevalence of researcher misconduct in the UK. Of the methods we have selected, UCT has been previously applied in conservation (Nuño et al. 2013; Fairbrass et al. 2016, Hinsley et al. 2017) whereas CW has been little used, and not within the area of conservation (Roberts and St John 2016) while the PM has not, to our knowledge, previously been applied at all.

Our original objective was to evaluate the prevalence of online compared to F2F trade in potentially illegal wildlife trade commodities (i.e. those we define as being of "questionable origin") using survey response data from four Special Interest Groups (SIGs).The groups identified as having an area of interest of conservation (wildlife trade) relevance were: reptile keepers, orchid growers, taxidermy collectors (and/ or dealers) and antiques collectors (and/ or dealers). Due to pre-existing sensitivities, discussed later in this paper, only the reptile keepers' SIG agreed to participate in our survey. Response data was therefore collected for this SIG, alone.

We evaluate and compare the prevalence of purchase wildlife trade items of questionable origin online versus F2F to explore potential differences in purchasing behaviour. For both of these trading means we evaluate a recent past and immediate future timeframe (i.e. ± one year relative to survey completion date) to consider trends in purchasing behaviours.

5.3 Methods

Ethical approval for conducting the study was received from the School of Anthropology and Conservation, University of Kent, prior to the start of the study.

The study initially focussed on 4 UK-based SIGs whose area of interest was of conservation (wildlife trade) relevance, i.e. reptile keepers, orchid growers, taxidermy collectors (and/ or dealers) and antiques collectors (and/ or dealers). The online survey developed using SurveyGizmo (www.surveygizmo.com) was piloted pre-launch and content refined until clarity and utility comments were net positive. Data collection covered a three-month period starting 15th May 2017. Personalised e-mails explaining the study, introducing its authors and providing a URL link to the survey were sent to a contact point, or "gatekeeper", for each of the SIG's, for onward dissemination to each group. Reminder e-mails were sent at approximately monthly intervals to encourage an optimal response rate from each SIG.

Survey content was designed to support estimation of the prevalence of engagement in the illegal wildlife trade through F2F versus online transactions. A near-scale past and future timeframe was evaluated (i.e. prevalence of trading potentially illegally over a ± one year period versus survey completion date) to consider purchase route trends.

The survey comprised five sections, i.e. demographic questions followed by the three sensitive question models of unmatched count technique (UCT), parallel model (PM), crosswise model (CM) then Direct Questions (DQ) and finally a multiple response option question. Upon completion, an option to submit feedback on the survey was provided. (See Appendix 2 for a copy of the formatted survey downloaded from SurveyGizmo).

As discussed further within "Results", only the Reptile Keepers' SIG agreed to engage with our survey, so the following descriptions of detailed survey content relate to the survey developed specifically for this SIG.

We developed content to investigate potentially sensitive areas of reptile buying prevalence in line with study objectives. This translated into four variants, i.e.

Whether a respondent had bought a reptile of questionable legal origin over the past year F2F.

Whether a respondent had bought a reptile of questionable legal origin over the past year over the internet (aka online).

Whether a respondent was likely to buy a reptile of questionable legal origin over the next year F2F.

Whether a respondent was likely to buy a reptile of questionable legal origin over the next year over the internet (aka online).

This content was represented within our survey via the three sensitive question models, preceded by consent to complete the survey and demographic questions and succeeded by direct questions, a multiple response option question and an invitation to submit feedback on the survey. The multiple response option question was included to: 1) assess, together with DQ's, the extent to which purchase of reptiles of questionable legal origin was in fact a sensitive topic to respondents and 2) gain information on purchase routes for reptiles of questionable legal origin used by respondents.

After consenting to complete the survey, all subsequent questions were required and there was no facility either to go back to previous questions, or to skip questions. Our intention was to capture respondents' initial reaction to questions.

Survey content was not randomised across models since each model presents respondents with content that looks very different, which could have caused confusion and led to survey abandonment. In addition, since the unmatched count technique is considered to have low statistical power, it was presented to respondents first in an effort to maximise the number of UCT responses received.

5.3.1 Demographic Questions

In order to provide context to the purchasing behaviour research that was the main focus of our study we included 6 questions on demographic parameters. These included respondent gender, age, country of residence, how long they had kept reptiles for, whether they were a hobbyist or commercial keeper and their awareness of and views on the CITES Convention relative to their area of interest.

5.3.2 Unmatched Count Technique (UCT)

The first sensitive question model presented to respondents was the UCT. The UCT and its variants, including the list experiment or item count technique, have been applied by researchers for over 30 years to explore sensitive topics in diverse fields including health risk behaviours (Hubbard et al., 1989), attitudes towards race (Droitcour et al., 1991; Kuklinski et al., 1997) and illegal wildlife trade as an aspect of biodiversity conservation (Nuño et al., 2013; Hinsley et al., 2017)

UCT typically involves assigning participants randomly to either a control (i.e. baseline) or a treatment group. The control group receives a list of non-sensitive statements such as, in our study: “I am a member of only one reptile keeping group”. Respondents are then asked to specify how many statements they agree with from the list provided. Importantly, they are not asked to specify which statements they agree with so that, across analysis of control and treatment groups, it is not possible to link respondents with sensitive responses. The treatment group receives the same set of non-sensitive statements, but with the addition of a sensitive statement, such as: “During the last year I have purchased in person (face-to-face) a reptile of questionable origin”. Again, respondents are asked to indicate how many, but not which, statements they agree with.

Integral to the design of individual statements, and the way in which they are combined, is minimising the risk of “floor” and “ceiling” effects, which may compromise eliciting truthful answers from respondents (Kuklinski et al., 1997a, b). Floor effects occur when the control group’s statements result in most, or all, respondents replying in the negative to all

statements. Ceiling effects can occur when most, or all, treatment group respondents answer “yes” to all control statements and to the sensitive statement (Kuklinski et al., 1997a, b). An additional design refinement intended to reduce both sample variance and floor and ceiling effects is the inclusion of negatively correlated statements (that is, if a respondent has carried out one activity then they are unlikely to have carried out another) in order to reduce sample variance and increase statistical efficiency (Glynn, 2013).

Four treatments were developed with associated controls around the selected sensitive behaviours. Each control contained four non-sensitive statements of relevance to survey respondents (see Article 2 of Roberts and St John, 2014).

During the survey, respondents were randomly assigned to each question (i.e. to each of the four purchasing propensities being estimated) rather than being assigned to either the control or the treatment group from the outset. The objective of this was to reduce the likelihood of a respondent receiving all 4 sensitive treatments, risking survey abandonment.

The prevalence of a particular sensitive behaviour within the sampled population was calculated as the difference in the mean number of statements between the control and treatment groups (Glynn, 2013). Confidence intervals (± 95%) were calculated using the 2-sample approach.

5.3.3 Parallel Model (PM)

The PM (Tian, 2014), which we believe has not previously been applied, is a non-randomised version of the unrelated question model (Horovitz et al., 1967; Greenberg et al., 1969; Chaudhuri, 2011) which is itself an extension of the Warner (1965) randomised response technique (RRT). The PM was developed to address limitations in existing non-randomised crosswise (and triangular model (TM)) sensitive question models (Tian, 2014). It is framed as presenting a wider application range with greater efficiency than either the CM or TM methods (Tian, 2014). The PM requires the selection of two, non-sensitive dichotomous variates (termed U and W) that are mutually independent with

known q=Pr(U=1) and p=Pr(W=1). In our study, we chose the variates of U: birth month (over two, successive 6 month periods per question pair) and W: whether the final digit of the respondent's mobile phone number was odd, or even. We assumed that q≈0.5 and p≈0.5 (see also Discussion).

Four questions were constructed combining a sensitive element on purchase of wildlife trade items of questionable origin with non-sensitive elements based on the non-sensitive variates, U and W. It was then possible to estimate the unknown proportion of respondents exhibiting a sensitive characteristic (i.e. purchase of reptiles of questionable origin), π, where π = Pr(Y=1).

The MLE of π is: $\hat{\pi}_p = \frac{\hat{\lambda} - q(1-p)}{p}$ (± 95% CI)

5.3.4 Crosswise Model (CM)

The CM (Yu et al., 2008), also developed to research sensitive questions, has not been applied extensively (Roberts and St John, 2014). The method uses a comparative approach where a non-sensitive question of known probability distribution (the baseline) provides a reference distribution with which the probability distribution of the sensitive question responses is compared. Respondents are asked one sensitive and one non-sensitive (baseline) question simultaneously. They must indicate whether their answer is (a) Yes to both questions, or No to both questions, or (b) Yes to one question, and No to the other. In our study, the non-sensitive question of known probability distribution was month of birth (i.e. a randomised 3-month period with an assumed probability of 0.25 since, in this method, the non-sensitive response probability should not equal 0.5) and this was paired in turn with one of four sensitive questions concerning purchase of reptiles of questionable legal origin. Birth months were randomized prior to selection for inclusion in the non-sensitive questions to minimise bias.

The proportion of the sample (π) involved in the sensitive behaviour is calculated as:

$$\pi = \frac{\lambda + p - 1}{2p - 1} \text{ (±95\% CI)}$$

Where

λ = proportion of respondents that chose Y to both or N to both statements

p = proportion of population that would answer Y to the non-sensitive question

5.3.5 Direct questions (DQ)

Participants were asked to respond to the four sensitive questions (already presented to them via the three sensitive question models) directly, i.e.

1. In the past year, have you purchased a reptile of questionable legal origin from a seller face to face?

2. In the next year, are you likely to purchase a reptile of questionable legal origin from a seller face to face?

3. In the past year, have you purchased a reptile of questionable legal origin from a seller over the internet?

4. In the next year, are you likely to purchase a reptile of questionable legal origin from a seller over the internet?

Response options in each case were “Yes” or “No”. The objective of including these DQ’s was i) to provide a comparator for the UCT, CM and PM models in terms of relative utility in estimating sensitive behaviour prevalence, and ii) to assess the degree to which questions anticipated as being sensitive to respondents actually were sensitive to them.

5.4 Results

5.4.1 SIG participation

Results are presented for survey response data from the Reptile Keepers' SIG. Although we approached four SIG's, only the Reptile Keepers' SIG was willing to engage with our study. In discussion, other SIG's were uneasy about possible negative impacts upon their SIG's reputation linked to survey outcomes, since they felt a recent survey (see Cox, 2017) had damaged the groups' reputations (i.e. taxidermy collectors (and/ or dealers) SIG and antiques collectors (and/ or dealers) SIG). The gatekeeper for the orchid collectors' SIG felt that, since the group had recently taken part in surveys, then response rate would be low-perhaps an example of "survey fatigue" (Porter et al. 2004).

Due to the consequent small sample size, we analysed combined data for completed and partially completed surveys. This approach allowed respondent drop-off across time and survey section to be determined.

5.4.2 Respondent drop off across time and survey section

Eighty eight respondents from the Reptile Keepers' SIG participated in our survey which was open online from 15th May 2017 for 3 months. A total of 45.5% of respondents completed the entire survey including the direct questions and final multiple response option question. Considering survey sections, 87.5% completed the demographic questions section; 85.2% started and 71.6% completed the UCT (i.e. 13.6% drop-off across UCT); 68.2% started and 61.4% completed the PM (i.e. 6.8% drop-off across PM); 56.8% started and completed the CM; 56.8% started and completed the DQ and 45.5% completed the multiple response option question (Figure 5-1).

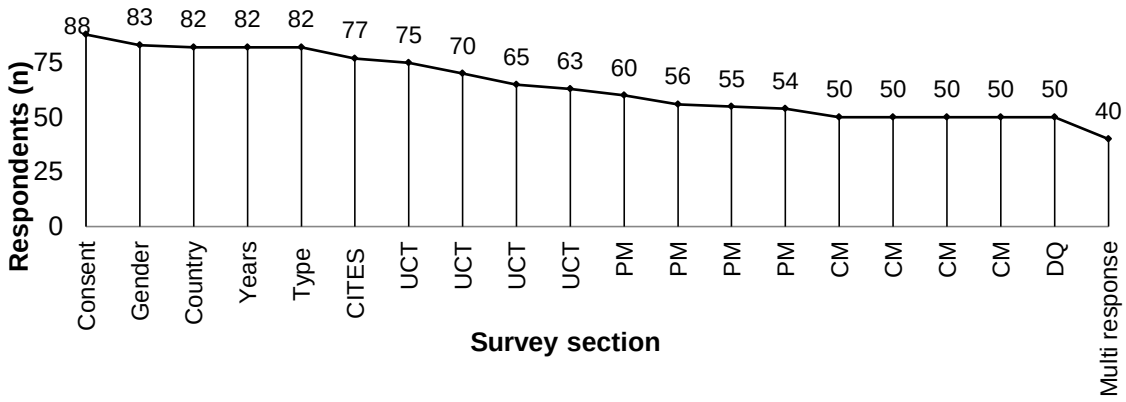


Figure 5-1: Respondent drop-off during the survey as number of respondents (n); UCT: Unmatched Count Technique; PM: Parallel model; CM: Crosswise model; DQ: Direct Questions

5.4.3 Demographic data and multiple response option question

Approximately two thirds of survey respondents were male (61.4%) and one third female (38.6%). The majority of respondents were in the age range 25-34 years (34.9%) followed by 35-44 years (22.9%), 45-54 years (20.5%), 55-64 years (9.6%) and 18-24 years (8.4%). Most respondents were UK residents (84.3%) with the rest being from other countries; ranging from 4.8% to 1.2%, from Germany, the Netherlands, Belgium, India, Madagascar, Spain, Switzerland and the USA. The majority of respondents had kept reptiles for over 20 years (36.1%) followed by, in rank order, 6-10 years (23.3%), 0-5 years (20.7%), and 11-20 years (19.4%). The majority of the respondents were hobbyist reptile keepers (92.8%) whilst commercial reptile keepers formed the minority (7.3%).

In response to questions on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) knowledge, understanding, importance and relevance, a high proportion of respondents either agreed (49.4%) or strongly agreed (42.9%) that they had knowledge of CITES and an understanding of its regulations. A marked increase in neutral responses, i.e. those that were scored as “3”, was evident for subsequent questions on the importance of CITES for a sustainable wildlife trade (neutral 31.3%), relevance of CITES to reptile keeping (neutral 24.7%) and the importance of CITES for reptile conservation (neutral 24.7%). However, the “agree” or “strongly agree”

categories were both more highly supported than “disagree” or “strongly disagree” for these three questions, i.e. 36.4%, 39.0% and 29.9%, respectively, for “agree”, and 26.0%, 27.3% and 29.9%, respectively, for “strongly agree”.

At the end of the survey, respondents were invited to indicate from where they had bought reptiles of questionable legal origin (choosing from multiple options) or to state that they had never bought any. The objective of this question was to provide additional perspectives on the sensitivity of purchasing reptiles of questionable legal origin to the respondents surveyed, and on preferred transaction routes. Forty-one individuals responded to this question; from these, 7 responses were removed, since the respondents had answered “yes” to all purchase routes, as well as “yes” to indicate that they had never bought a reptile of questionable legal origin. These responses could have been due to technical issues, or deliberate “spoilers”. A further 7 responses were removed since respondents had answered “yes” to some, but not all, purchase route options and “yes” to indicate they had never bought a reptile of questionable legal origin. This may have been due to their misunderstanding the question. This left a total of 27 responses for analysis. Of these, 13 (48.1%) respondents indicated that they had never purchased reptiles of questionable legal origin. Considering those respondents who indicated that they had bought reptiles of questionable legal origin, (n=14; 51.9%), the majority (71.4%) bought them from a private individual or residence. The next highest means of purchase was from shows and exhibitions (57.1%) followed by F2F transactions at a business (42.9%) and also a number of online sources (i.e. online classified advertisements (42.9%), general (42.9%) and specialist (42.9%) social media platforms). A further 28.6% bought reptiles of questionable legal origin from an online shop or business. Only one respondent selected Twitter, Instagram and WhatsApp, while this respondent and one other also selected the “Dark Web”; the second respondent who chose the Dark Web only selected this single option, therefore we believe that these two respondents may be spoilers as there is no evidence that reptiles beyond counterfeit leather goods of reptile origin are for sale on the Dark Web (see Roberts and Hernandez-Castro, 2016). However

they could have been referring to other sites that are not indexed such as Facebook closed groups

5.4.4 Sensitive question model and direct question results

Recognising that a number of comparisons between prevalence estimates could be made we clarify that our objective is to assess the prevalence of purchase of reptiles of questionable legal origin either online, or F2F and over a ±1-year timeframe in each case. Prevalence estimates (±95% CI, except for DQ) are presented in Figures 5-2 and 5-3.

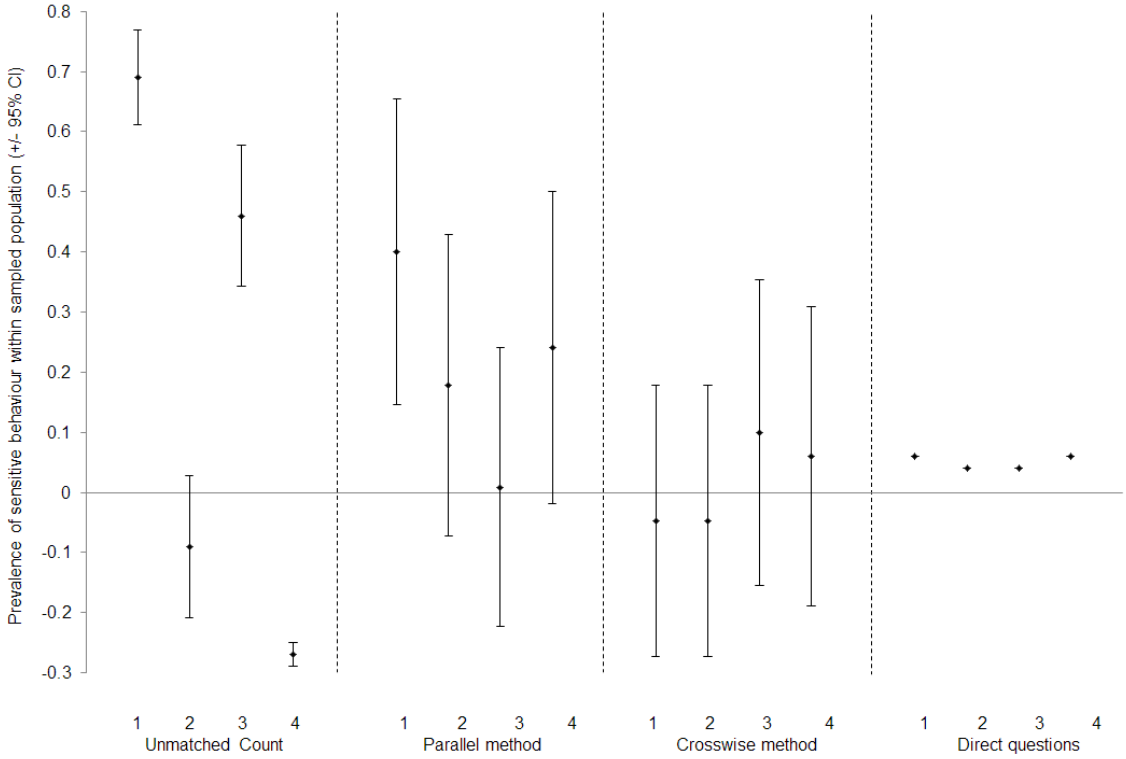


Figure 5-2: Group level estimates per sensitive question model and direct questioning for prevalence of sensitive behaviour within sampled population (±95% CI). 1=Past year F2F purchase; 2=Past year online purchase; 3=Next year F2F purchase; 4=Next year online purchase

UCT prevalence estimates for all four questions were statistically significantly different from each other. Of particular note was that F2F purchasing prevalence estimates were consistently higher than those for online purchase and previous year estimates consistently higher than those for the next year for both F2F and online routes.

UCT produced negative estimates which were statistically indistinguishable from zero for past year online purchases (-0.09 ±0.12) and negative estimates which were statistically distinguishable from zero for next year online purchases (-0.27 ±0.02).

For the parallel method (PM) there was no statistically significant difference between prevalence estimates from responses to any question and, apart from the first question, there is no significant difference between PM prevalence estimates and zero. Given this,

the prevalence estimate for F2F purchases in the past year was higher than that for both F2F purchases next year, and online purchases in the past year.

There was no statistically significant difference between prevalence estimates from the CM for any of the four sensitive questions. CM produced negative estimates, statistically indistinguishable from zero, for both past year F2F purchases (-0.05 ±0.23) and past year online purchases (-0.05 ±0.23). CM produced positive estimates, also statistically indistinguishable from zero, for next year F2F purchases (0.10±0.25) and next year internet purchases (0.06±0.25).

DQ resulted in small positive estimates for all four sensitive questions ranging from 0.04 to 0.06.

In summary, from a comparison of the prevalence of participation in the illegal wildlife trade through purchase of reptiles of questionable legal origin F2F or online indicated by 3 sensitive question models and DQ (Figure 5-2) there was a statistically significant difference between the UCT prevalence estimates for past year F2F (0.69 ±0.08) and next year F2F (0.46 ±0.12) purchases.

To allow comparison between prevalence estimates from each of the three sensitive question models and direct questions grouped by the four sensitive questions (rather than per model) used in this study an alternative presentation of the prevalence estimates is provided in Figure 5-3.

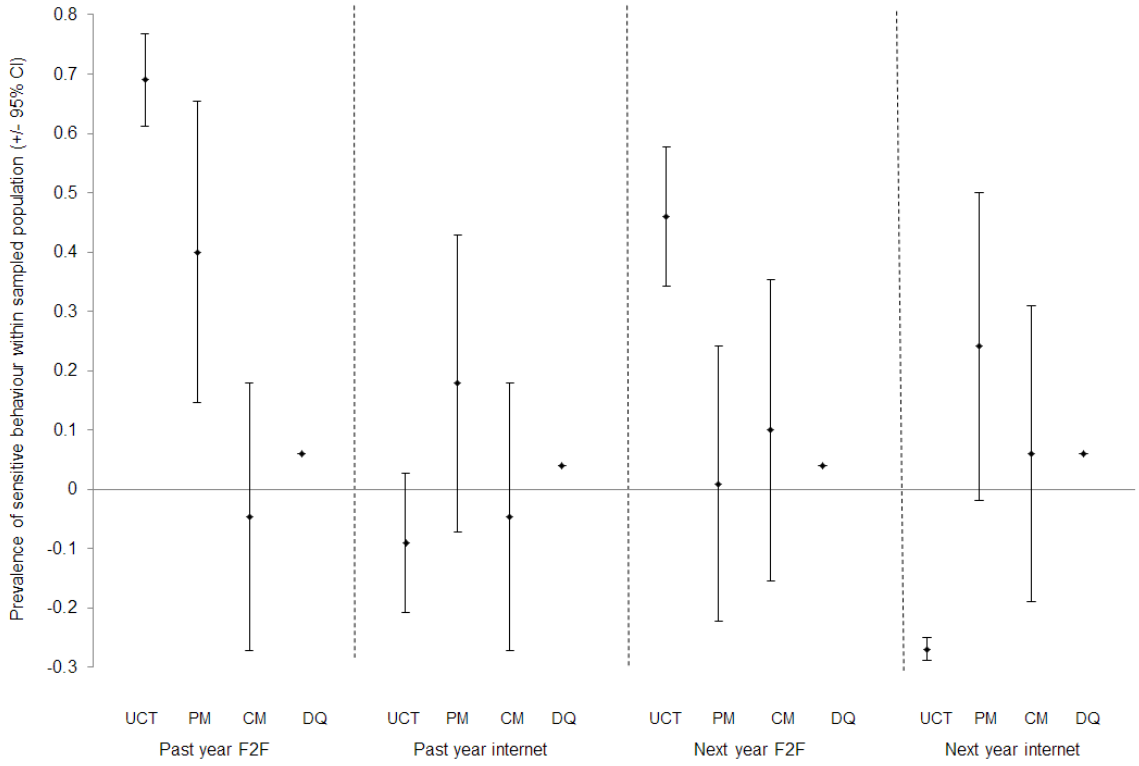


Figure 5-3: Group level estimates per sensitive question of prevalence of sensitive behaviour within sampled population (± 95% CI); UCT: Unmatched Count Technique; PM: Parallel model; CM: Crosswise model; DQ: Direct Questions

For past year F2F purchases there was a statistically significant difference between the estimates from UCT (0.69 ±0.08) versus CM (-0.05 ±0.23); UCT (0.69 ±0.08) versus DQ (0.06) and PM (0.40 ±0.25) versus DQ (0.06). However, the CM prevalence estimate was not significantly different from zero.

For past year online purchases only the UCT prevalence estimate was statistically significantly different from the DQ estimate and significantly lower than it. There was no other significant difference between prevalence estimates from other methods and no estimates were significantly different from zero.

For next year F2F purchases there was a statistically significant difference between estimates from UCT (0.46 ±0.12) and PM (0.01 ±0.23) and UCT (0.46 ±0.12) compared to DQ (0.04). The UCT prevalence estimate was also significantly different from zero. There

were no other significant differences and CM and PM estimates are not significantly different from zero.

For next year online purchases, the UCT prevalence estimate was significantly different from and lower than CM, PM and DQ estimates. It was also significantly different from and less than zero. There were no other significant differences between prevalence estimates and those from CM and PM are not significantly different from zero.

In summary, significant differences between prevalence estimates existed for past year F2F purchases between UCT (0.69± 0.08) and DQ (0.06) and PM (0.40±0.25) versus DQ (0.06). For next year F2F purchases, there was a significant difference between prevalence estimates from UCT (0.46±0.12) and DQ (0.04).

Results from the multiple response option questions (see 5.3, Method, for details) broadly aligned with those from the sensitive question models. Firstly, it is important to note that a high proportion (48.1%) of the respondents who completed this question indicated that they had never bought a reptile of questionable legal origin. Of the respondents who indicated that they had bought such reptiles (n=14; 51.9%) the majority (71.4%) bought them from a private individual or residence, i.e. F2F. The next highest means of purchase was shows and exhibitions (57.1%), so also F2F, followed by F2F transactions at a business (42.9%) or a number of online sources (i.e. online classified advertisements, general and specialist social media platforms) which each accounted for 42.9% of responses. A further 28.6% bought reptiles of questionable legal origin from an online shop or business.

5.5 Discussion

Sensitive question models are becoming increasingly used in conservation science; however, few undertake comparative studies between methods other than comparison with direct questioning (e.g. Robinson et al., 2015; Hinsley et al., 2017); although see Roberts and St John (2014) for a comparison between UCT, CM and DQ prevalence estimates for researcher misconduct in the UK). We applied three sensitive question

models (UCT, PM and CM) and direct questions (DQ) in a comparative methodology study to estimate the prevalence of engagement in the illegal wildlife trade through F2F versus online transactions over the recent past and immediate future (±1 year relative to survey completion). It should be noted that other models exist, including the popular Randomised Response Technique (RRT) (Warner, 1965). However, a key part of our model selection rationale was suitability for use in an online survey and since RRT requires the use of an extrinsic randomising device, such as a die, the method was not compatible with our online study. However, debate continues concerning the utility of sensitive question models, especially compared to DQ (see, for example Ozler, B. (2017). False positives in sensitive survey questions. World Bank Blogs).

Our respondent group was a reptile keepers' SIG, which was one of four SIGs we approached to take part in our survey and the only group that agreed to participate. The reason given for non-participation by the other three groups was either unease about possible negative impacts upon their SIG's reputation, linked to survey outcomes, or apparent survey fatigue. Our experience illustrates the challenges that can be faced when researching sensitive topics, even before a survey has been launched. Fundamentally, while sensitive methods encourage truthful responses by individuals, when a community feels threatened then "protection" (here, of anonymity) at an individual level may ultimately have no effect at wider group level.

Principal feedback messages from respondents included some confusion, frustration or mistrust by a minority over question structure for the sensitive question models. This was despite our attempt to frame the content appropriately at survey start via a brief, written introduction. It is perhaps indicative of the challenges associated with use of sensitive question models, which can appear "alien" (or hostile) through lack of familiarity, especially where they incorporate randomisation either through devices (such as RRT, not used in this study as discussed) or intrinsically through question structure (e.g. CM and PM as used in this study). A second notable feedback message from respondents was concern that survey results might negatively impact the reputation of reptile keepers. This

echoes the concerns of the other special interest groups and perhaps indicates the need for more preparatory work to be carried out with respondent groups (or gatekeepers) ahead of survey launch to the mutual benefit of participants and study outcome.

Consequences of limited participant engagement and reduced sample size may include power effects (see Ulrich et al., 2012 for a discussion of statistical power analysis of randomised response models, with equal reference to the essential issue of the psychological acceptance by respondents of RRT models). Due to our relatively small sample size (n=88) we therefore combined data from completed and partially completed surveys for statistical analysis.

5.5.1 Comparative model performance

In terms of model performance, negative UCT estimates were produced for 2 out of 4 sensitive questions posed, which may be linked to the small sample size, the number of statements and the relationship between statements included on the lists (Roberts and St. John, 2014). Negative estimates were also produced for 2 out of 4 CM sensitive questions, perhaps because respondents felt insufficiently protected since one of the paired questions asks about their birth month and appears unrelated to the sensitive question (Roberts and St. John, 2014). In addition, if the actual true prevalence (in this case, the prevalence of purchasing reptiles of questionable legal origin) is close to zero then small deviations in the non-sensitive statement prevalence estimate can significantly impact the estimate. For example, where the birth month probability p=0.30 rather than p=0.25 (Roberts and St. John, 2014). Also, where the probability of the last digit of a mobile phone number being odd, or even is other than $p \approx 0.5$ (see parallel model, PM). This could be due to individuals keeping a pre-existing number, or choosing a specific new one. However, it is interesting to note that the PM, which has not been applied previously in conservation, employed non-sensitive, “personal” questions (i.e. birth month and telephone number) in our study but did not yield corresponding negative estimates. The fact that the PM questions were placed ahead of the CM questions in the actual survey, so that respondents were still relatively fresh at this point and less likely to

abandon may be relevant since our analysis of respondent drop off during the survey (Figure 5-1) shows that 17% fewer respondents started the CM section than had started the immediately preceding PM section. Sample size for the CM was therefore reduced which could have affected results; Roberts and St John (2014) also produced negative estimates when applying the CM.

The results of our study show that the UCT (0.69±0.08) and PM (0.40±0.25) estimates were significantly greater than the DQ estimate (0.06) for F2F purchases (past year). For next year F2F purchases, there was a significant difference between the UCT (0.46 ±0.12) and DQ (0.04) estimates.

In summary, prevalence of purchase of reptiles of questionable legal origin was greater through F2F transactions, rather than online, and over the past year, rather than the next year.

5.5.2 The context of the reptile trade

To explain the observed results, which indicate that the F2F purchase route predominates, we consider the practicalities and dynamics of the reptile trade. Firstly, the trade is of live animals, which makes conducting transactions wholly remotely, i.e. via the internet, challenging. We suggest that a likely prerequisite of trading transactions involving reptiles, legal or illegal, is F2F contact at least at point of handover of a purchased animal. If one considers the alternatives, such as employing DEFRA-licensed couriers for reptiles purchased over the internet, then the specifics of documentation involved with this system would, we suggest, make its use for transactions involving reptiles of questionable legal origin analogous to a F2F transaction. The only exception is where animals are sent illegally through the post; for example see: Zhou, N. 2017. Australian customs intercepts parcel of live snakes, tarantulas and scorpions. The Guardian Online. https://www.theguardian.com/australia-news/2017/apr/04/australian-customs-intercepts-parcel-of-live-snakes-tarantulas-and-scorpions.

In the case of past and future transactions, the fact that our data indicated a greater prevalence of past year F2F transactions versus anticipated transactions “next year” may reference the unpredictability of reptiles of questionable legal origin becoming available for sale. Such animals are likely to be rare, so their appearance for sale will probably occur sporadically and be difficult to anticipate. Purchasing prevalence may therefore be equally difficult for an individual to predict due to uncertainties around reptile availability. Factors such as an individual’s financial position, personal responsibilities and competing leisure interests may also affect likelihood of purchase. Refining survey questions to reflect such subtleties may make them more meaningful to respondents and increase engagement, as well as supporting more nuanced understanding of purchasing behaviours.

In terms of model performance, UCT and PM produced estimates that were significantly different from and greater than the DQ estimate for past year F2F purchases. This suggests that the question: “In the past year, have you purchased a reptile of questionable legal origin from a seller face to face?” is actually sensitive to respondents, perhaps because such purchases might be illegal. In addition, UCT produced an estimate that was significantly different from and greater than the DQ estimate for next year F2F purchases which similarly suggests that the question: “In the next year are you likely to purchase a reptile of questionable legal origin F2F?” is sensitive, perhaps due to potential illegality. These indications of question sensitivity may be a reaction to Interpol’s “Operation RAMP” (Interpol, 2010), an enforcement initiative which targeted the illegal reptile trade in 51 countries, including the U.K. We contrast this outcome with results from a study by Hinsley et al. (2017) which researched rule breaking in the orchid growing community. Here, DQ estimates were not significantly different from those for UCT in any of the sensitive questions posed which was suggested to be because of a lack of enforcement for this specific trade.

For remaining sensitive questions per purchase route option (F2F or online) and timeframe (±1 year) there were no other instances where a statistically significant difference was evident between estimates and DQ.

Some respondents were prepared to answer the multiple response option questions directly, indicating purchase of reptiles of questionable legal origin. Taking into account responses to this question, and purchasing prevalence estimates from DQ relative to the sensitive question models, it appears that some respondents were quite comfortable indicating that they had purchased reptiles of questionable legal origin, and from where. This apparent lack of sensitivity towards the subject may reflect perceptions of low enforcement of wildlife trade legislation by some respondents (Hinsley et al., 2017) since knowledge and understanding of legal requirements through CITES was fairly high overall in this group (i.e. 49.4% agreed and 42.9% strongly agreed that they had relevant CITES knowledge and understanding). Respondents' personalities and inclinations may also have been a factor, for example predisposition towards rule-breaking (Eysenck, 1964; Eysenck and Eysenck, 1971; Eysenck and Gudjonsson ,1989) or, if hobbyist reptile keepers, their motives and drivers for collecting (Charalampos and Angelidou, 2018).

Our results, representative of UK-based individuals in the main, indicate that some trade in reptiles of legally questionable origin takes place post INTERPOL led efforts to counter this trade through Operation RAMP (INTERPOL, 2010).

5.6. Conclusions

In this study we applied an online survey to research prevalence of F2F versus online purchasing behaviours for reptiles of questionable legal origin, and applied different sensitive question methodologies together with direct questions and a multiple response option question to do this. Paradoxically, our use of an online survey may, through online disinhibition, have increased the likelihood of securing "honest" answers or might equally have permitted confounding behaviours, including deliberately withholding or distorting the truth. Despite internal control groups within the online survey it is difficult to distinguish behaviours that may be linked to the online situation without a suitable F2F "comparator" group. The use of online surveys is fairly well established in psychological research (for example, see Rieps and Lengler "The Web Experiment list" (2005)) and differences between online and "laboratory" outcomes are reviewed in Birnbaum (2004) where one

conclusion is that outcome differences may be linked to the different people (personalities) involved in the studies.

Our survey data have enabled a comparative methodological assessment to be made between three sensitive question models and direct questions applied to estimate the prevalence of engagement in the illegal wildlife trade through F2F versus online transactions. Our results indicate a greater prevalence of F2F compared to online transactions for survey participants, and during the past year (UCT and PM) rather than the next (UCT). Despite the groundswell towards online purchases for many items of commerce, legal and illegal, our results suggest that the illegal wildlife trade presents a very particular case where characteristics of the "commodities" (in this case, live reptiles) being traded can exert a strong influence over the prevalence of F2F versus online trading routes.

The unpredictable availability of legally questionable reptiles, and uncertainties about individuals' future circumstances, may affect response choice and underlie the prevalence estimates described for UCT and PM vs. DQ.

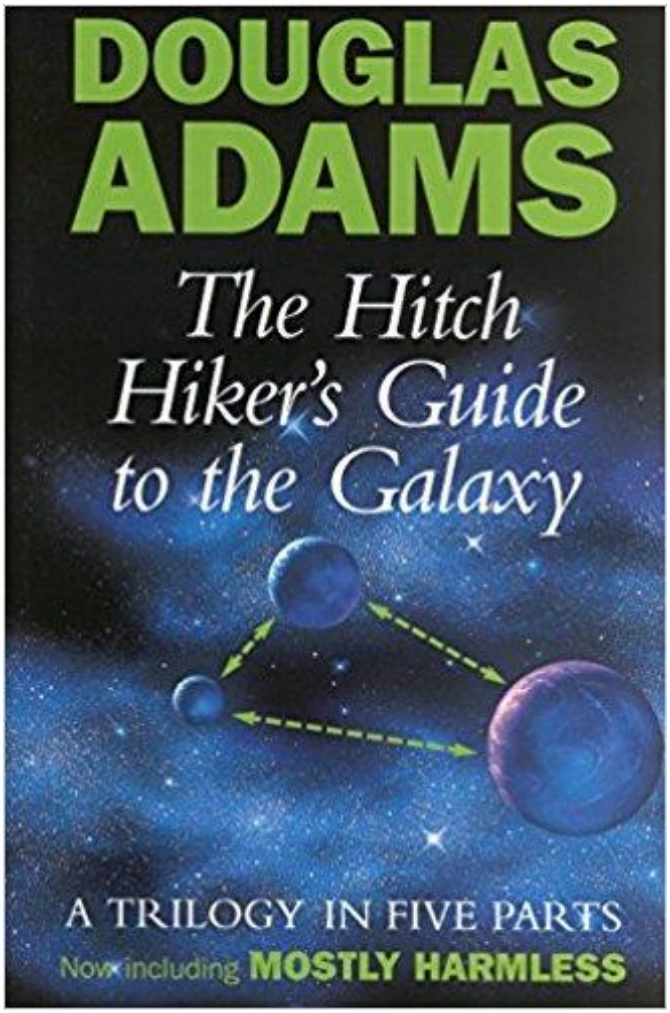
In terms of purchase route, an observation is that differing F2F versus online prevalence may occur where wildlife trade commodities are more suited to online purchase, and to relatively anonymous delivery. Elephant ivory items may offer an example of this type of commodity (Yeo et al., 2017; IFAW, 2018).

As highlighted earlier in this paper psychological acceptance by respondents of "sensitive question" models is important, i.e. not simply focusing on statistical power when planning studies (Ulrich et al., 2012). Other research (Robinson, 2015; Hinsley et al., 2017) and this study indicate the complexities of sensitive question models and potential utility of DQ compared to them. Aspects such as question model choice, respondent receptivity to models, and the actual (versus presumed) sensitivity of questions to respondents should be evaluated as part of study design, perhaps via a pilot study. In addition, the potential for multivariate analysis, to explore population characteristics in more depth, should be considered for studies of appropriate sample size. Refinements to questions which make

them more meaningful to respondents may both enhance engagement and produce more insightful results.

This study indicates that opportunities exist for further research into the utility of sensitive question models to improve understanding of attitudes towards illegal wildlife trade, as well as prevalence of this trade and trends in purchasing routes. The novel “Parallel Model” performed comparably to the more established UCT model, producing statistically significantly different estimates for purchasing prevalence for the past year F2F compared to DQ, although with wider confidence intervals (± 95%).

It would be of value to extend this study, incorporating the method refinements described, to evaluate a range of hobbyist and commercial groups. Drivers for illicit behaviour may differ depending on whether individuals’ interest stems primarily from collecting (if a compelling interest) or financial gain (if a commercial enterprise). Better understanding of the problem statement, including the drivers for and extent of illegal wildlife trade, should provide a cohesive target for actions designed to address it.



"Earthman, the planet you lived on was commissioned, paid for, and run by mice. It was destroyed five minutes before the completion of the purpose for which it was built, and we've got to build another one…

Mice are not, as is commonly assumed on Earth, small white squeaking animals who spend a lot of time being experimented on.

In fact, they are the protrusions into our dimension of hyper-intelligent pan-dimensional beings. These beings are in fact responsible for the creation of the Earth.

The whole business with the cheese and the squeaking is just a front."

Excerpt: The Hitchhiker's Guide to the Galaxy, by Douglas Adams

Chapter 6: General Discussion

6.1 Drivers for research

The illegal, international trade in wildlife poses serious and pressing threats at a number of levels. Traded species are increasingly threatened with extinction and these harms extend to compromised biodiversity and ecosystem instability. Associated threats include biosecurity issues, such as disease (and zoonose) introduction and the introduction of alien species. There is acute awareness of the critical need for enhanced understanding of the extent and nature of the illegal wildlife trade to address its challenges. This is amplified for the online trading environment which is growing rapidly, attractive to illegal trade and complex to monitor and regulate. Mirroring adoption by general trade (legal and illegal) the online environment is increasingly being used as a means to conduct illegal wildlife trade. Its attractiveness is illustrated by recent experience where, in response to ivory trade bans, trade shifted from physical trading outlets to online media.

6.2 Meeting the challenge of wildlife cybercrime

Cybercrime, including wildlife crime, is acknowledged to present significant detection and regulatory challenges. As a relatively new operating environment the internet is still being evaluated to understand how it is being used by criminals and how this might evolve over time (Wall, 2007; Miller, 2018 a, b). Barriers to criminal activity online remain low whilst potential rewards, including from illegal wildlife trade, are high. Detection challenges mean that the risks of operating online, including via the surface web, continue to be small compared to the financial rewards on offer so trade continues (outcomes from Chapters 2 and 3 illustrate this. See also Hernandez-Castro and Roberts, 2016). Tactics such as use of linguistic camouflage to signal elephant ivory are used to conceal illicit trade on the surface web, and the relatively small volume of wildlife trade (legal and illegal) compared to the larger volume of generalist trade provides additional cover (Yeo et al., 2017).

The illegal online wildlife trade is not just a conservation issue; it is inherently multi-faceted in terms of traded commodities, trading actors and motivations, global extent and potential impacts. The diverse and expanding range of online media further complicates the picture, ranging from the surface web, through social media platforms to the dark web. The disunited regulatory framework that applies to illegal wildlife trade at varying country and regional levels makes it challenging to study. There is no single accepted definition of what constitutes “trade” and what constitutes “wildlife”. Instead, definitions vary greatly between countries and across types of traded commodity. Definitions of legal and illegal trade also vary; for example, the word “wildlife” has a legal definition in some countries but only applies to animals. In addition, some illegalities are identifiable, so detectable through online trade whereas others, while they exist, cannot necessarily be identified through an online post. Instead, these “deeper” online illegalities require other detection methods to be applied.

Illegal trade may take place on the surface web, social media (including closed groups) or via the dark web. It is possible that combinations of online routes may be used to conduct illegal trade; for example, posting an item briefly on the surface web has been identified as a means by which some illegal trade is flagged to potential buyers so that the transaction may continue offline. This occurs in China where individuals obtain a phone number then go to “WeChat” (similar to WhatsApp) to continue the transaction more privately (Roberts, 2018). It may be anticipated that shifts in preference between online trading media will occur, and that their use in isolation or combination may vary (including with offline routes as a “hybrid” market (Lavorgna, 2014)). Exact usage patterns may differ according to the commodity being traded, and which actors are involved i.e. whether organised or smaller scale criminals or accidental transgressors, unaware of or confused by the legal requirements of trade. Further, opportunities to shift rapidly between online trading options can be exploited in order to continue trading and evade detection. Complexities such as these demand an appropriately informed interdisciplinary approach to enhance understanding the illegal online trade in wildlife (St John et al., 2010; Pooley et al., 2013; Bennet et al., 2017).

6.3 Biodiversity loss as a global risk

The risks of biodiversity loss and ecosystem collapse are classified as having above average likelihood and impact by the World Economic Form in their 2018 assessment of global risks (WEF 2018 WEF Global risks landscape 2018). The connections between these "Environmental" risks and others, including failure of climate change mitigation and extreme weather events, are mapped (WEF 2018 WEF global risk interconnections map 2018). Environmental risks feature increasingly in the top 5 WEF risks (impact and likelihood) from 2008-2018. In 2011 biodiversity loss, specifically, was ranked as the 4th most likely global risk (WEF 2018 WEF global risks evolution 2008 to 2018).

In terms of biodiversity management, the Convention on Biodiversity is concentrating efforts to address biodiversity loss by applying business management concepts including transformational change to deliver "A new deal for nature" (See Waughray, 2018 Transforming the global biodiversity agenda in a changing global context; Loorbach 2018 Mainstreaming or Transformation? Biodiversity in Transition; Loorbach 2018 Exploring elements for a transformative biodiversity agenda post-2020). The need to better communicate biodiversity importance and foster public and political support is described and compared to climate change, which attracts more attention (Legagneux et al., 2018).

Under CITES, a group focusing specifically on wildlife cybercrime was recently constituted. This may provide a focal point for alignment of research activities and communication of outcomes to partner groups, policy makers and the wider public.

Overall, the picture of increasing prominence of biodiversity loss as an issue of global concern and the groundswell of initiatives aimed at stemming it suggest an environment receptive to initiatives that support delivery of this aim.

6.4 Research Focus

The research focus of this thesis is to contribute towards addressing a key area of unmet need which underpins illegal wildlife trade counter-measures. Specifically, bridging an informational "gap" which the UNODC, as a key commentator on this vulnerability,

identified as essential to addressing wildlife trafficking. I translated this informational (knowledge and understanding) gap to the online environment for illegal wildlife trade as a compelling area of unmet need.

I applied two approaches to researching illegal online wildlife trade and the behaviours associated with it. These were: a) “Measurement” (modelling) of online trade postings by application of two different mark recapture (MRC) models to encounter history data for the online ivory trade (Chapters 2 and 3) and b) “Asking” people who may be involved with illegal (online) wildlife trade to share information on usage of the internet for the trade through an online survey incorporating sensitive question models (Chapter 4).

6.5 Contributions to knowledge

I evaluate research outcomes in the context of thesis aims. I then identify conclusions and recommendations based on this assessment.

Chapter 2: Method validation.

As a foundation to subsequent studies, I evaluated the suitability of MRC as a method to assess (illegal) online wildlife trade by conducting a sensitivity study and two modelling studies, respectively in the presence and absence of heterogeneity in parameter probability. I assessed MRC model performance across a range of parameter values representative of those associated with the online trade in ivory using representative encounter history data as the basis for simulations. Outcomes supported use of MRC as a suitable method to research the (illegal) online wildlife trade.

Chapter 3: To apply MRC to assess and elucidate key population parameters associated with the illegal online wildlife trade.

In my initial MRC study, I built on prior research into online trade in CITES-listed species (Yeo, 2011) to assess population parameters associated with (illegal) online trade in elephant ivory conducted in the UK. Online media operate “24/7” and, currently, suitable technology to permit continuous monitoring and interrogation does not exist. MRC offers a

resource-efficient means to monitor trade since it can be applied to elucidate diverse trading population parameters based on incomplete observation.

Our results indicate that a trade continues to take place via eBay UK, despite its policy prohibiting this, and that two distinct trading populations exist characterised by the pattern of their ivory sales. These may represent a large number of occasional (or non-commercial) sellers and a smaller number of dedicated (or commercial) sellers. Directing resource towards reducing the volume of occasional sales, such as through education, would allow focus on characterising the extent and value of the illegal, “commercial” online ivory trade. MRC demonstrates potential for application to better characterise the illegal, online trade in ivory (and other wildlife commodities) thus expanding the knowledge base.

Chapter 4: To assess the suitability of multi-state open robust design (MSORD) mark recapture to evaluate time-separated online trade encounter histories to elucidate trading population parameters.

I developed my exploration of MRC application by applying the complex, multi-parameter multi-state open robust design (MSORD) model to time-separated sets of encounter histories of online “ivory” trade items (UK trade). My intent was to examine the suitability of MSORD for modelling data from snap-shot online wildlife trade monitoring studies to derive maximum information and resource benefit from them. In this way, to build knowledge and understanding of the illegal online trade in ivory (and potentially other wildlife trade commodities).

MSORD suitability was indicated and statistically significant estimates produced for key population parameters. MSORD exhibits potential for application to assess the illegal, online wildlife trade in particular given its facility for estimating state transition probabilities which can infer illegal trade. Future research should focus on evaluating MSORD effectiveness compared to simpler MRC models in delivering desired outcomes for online illegal wildlife trade monitoring. As a next step, a structured feasibility study would consider relative time, cost and model complexity as part of this assessment.

Chapter 5: To undertake a methodological comparison applying sensitive question models (including a novel model) to evaluate buying prevalence and trends associated with items of illegal wildlife trade.

I shifted focus to engage with people more directly to understand their involvement in illegal wildlife trade, preferred transaction routes, i.e. face to face or online, and how this balance may be changing. I applied sensitive question models (including the novel Parallel Model) and direct questioning to investigate potentially sensitive purchasing behaviours in a reptile keeper community, principally drawn from the UK.

My results indicated a statistically significant prevalence of F2F transactions for survey participants, and during the past year (using the unmatched count technique and the novel parallel model). The nature of the traded "commodity" (in this case, live reptiles) may drive F2F transactions; the past year rather than next year timeframe may reference the unpredictability of a reptile of interest becoming available for sale. It could also suggest uncertainties over respondents' future personal or financial readiness to purchase reptiles, i.e. competing priorities.

Further research into the utility of sensitive question models to improve understanding of the illegal online wildlife trade is warranted. The complexities of sensitive question models and the importance of considering aspects such as respondent receptivity and relative utility of DQ should be considered as part of study design.

6.6 Conclusions and Recommendations

Considered as a whole, the outcomes from this thesis have potential for application to increase knowledge and understanding of the illegal online trade in wildlife. The MRC approaches I applied may offer resource-sparing means to monitor online trade and better understand trading population parameters. Currently, monitoring reports tend to include simple, descriptive statistics whereas I suggest a deeper understanding of illegal online trade would be of more value; appropriate MRC application could support this. Enhanced understanding of the qualitative as well as quantitative aspects of trade could provide a

more accurate basis for informed policy development and coordinated interventions ranging from educational, to law enforcement. For example, my study applying MRC (the Jolly Seber model) to the online ivory trade suggested two distinct trading populations of relatively few, persistent higher-volume sellers and relatively numerous, occasional lower-volume sellers. Should the many, sporadic single item sales be associated with occasional sellers then this might indicate a lack of understanding of trading requirements, rather than deliberate transgression. Education to raise awareness might then be appropriate. If this resulted in a reduction in the volume of sporadic, online trade then detection and enforcement resources could be directed towards addressing persistent, higher volume sellers.

Application of MSORD demonstrated that this complex model was suitable for assessment of demographic parameters of interest for illegal online wildlife trade. Similar to the JS model, MSORD offers a means to gain deeper understanding of trading population parameters of interest from snap-shot online illegal trade monitoring studies. Novel research into enabling direct, rather than derived, estimation of population size (N) using MSORD (Worthington et al., 2018) presents a highly useful extra dimension to future research. Due to MSORD model complexity, a structured feasibility study is suggested to compare MSORD performance and time and resource costs to those of other, simpler MRC models relative to delivering required objectives. A potential anomaly was noted for downloaded data which suggested that slightly less than 100% available data may have been “scraped” using our original method. An investigation to better understand the origins of this feature was recommended. The viability of using newly developed, non-3rd party scrapers, whose architecture is fully known and which may be adaptable, should be assessed as part of this exercise (see Hernandez-Castro and Roberts, 2015).

I applied sensitive question models via an online survey to assess buying prevalence for illegal wildlife trade items face to face or online and how this balance might be changing. The characteristics of illegal wildlife trade face to face versus online may differ, linked to

structural differences between these two environments and the behaviours that may predominate. As well as offering more readily available global scope for trade, the online environment has been associated with “disinhibited” behaviour, which may result in individuals buying illegal items of wildlife trade online where they may not have done face to face. Equally, it is feasible that disinhibition may affect sellers similarly (not researched in this thesis but recommended for future research, i.e. “Dealers” in wildlife trade items). If trade is shifting online, then it is necessary to have knowledge of key differences between as well as similarities in trade characteristics to aid the development of appropriate interventions. For example, how might demand reduction approaches and impact, in terms of behavioural response, differ online versus face to face? In China, a “Millennial” hyper-socially connected demographic is buying elephant ivory post-ban, so how might intervention approaches need to be tailored to address this group’s drivers for engaging in trade? Informed by outcomes from my sensitive question model study, a survey including sensitive questions could be used to better understand the drivers for the ivory purchasing evident in this group. I recommend engaging pre-survey to test that assumptions, for example regarding presumed sensitivity of certain topics, as well as question design are meaningful to the proposed respondent group.

The online environment embodies a duality in that it can be used to act against illegal wildlife trade, as well as providing a medium for it. The reach of online media could be used to positive effect, for example to communicate with purchasers of illegal wildlife trade items in pursuit of demand reduction. As with any targeted communication, prior understanding of the intended audience would be key and surveys incorporating sensitive question models could be applied to develop this. Wider, targeted communication to foster public support for counter-illegal wildlife trade initiatives and biodiversity conservation could be delivered using online media.

This research indicates that illegal, online wildlife trade is ongoing in the UK trading populations I have assessed, despite initiatives and enforcement actions designed to counter it. This leads me to consider the effectiveness of such initiatives, and factors that

may impact this. Ensuring clear understanding of the extent and nature of trade being conducted, including the behavioural drivers that underpin it, is fundamental to effective intervention. Methods applied in this thesis demonstrate potential as a means to enhance clarity by enabling a deeper and more nuanced understanding of trade. My research into the reptile keepers' group illustrates that face to face trade is still "preferred" in some quarters, perhaps linked to the nature of the wildlife being traded. This finding suggests trade dynamics to be case and context dependent which further underlines the importance of testing assumption validity relative to the specific area of trade being researched. It also illustrates the importance of not ignoring face to face or "physical" wildlife trade outlets in the compulsion to address the threats posed by online trade.

Future, coordinated research is indicated by outcomes from this thesis. I suggest this should form part of an integrated initiative to secure enhanced understanding of illegal (online) wildlife trade. The recently constituted CITES Working Group on Wildlife Cybercrime (which succeeded the CITES e-Commerce group) may provide a forum to align research activities and coordinate and communicate key outcomes. In this way, enhanced understanding, including a contribution from this research, could be translated into impactful measures to counter the illegal online trade in wildlife and support biodiversity management.

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Appendix 1: Reptile keeping survey; SurveyGizmo, January 2018

Welcome to my survey - thank you for taking part

My name is Lydia Yeo and I am a PhD student at the University of Kent, researching the online wildlife trade. I am keen to understand how people use the internet compared to traditional methods, such as face-to-face transactions, for wildlife trade. This is the main focus of my survey.

The vast majority of wildlife trade is perfectly legal, with a minority being illegal. I appreciate that questions exploring illegal aspects of wildlife trade may be sensitive. Therefore, within my survey, I am exploring the perception of methods that enhance anonymity. Because of the way the questions have to be presented as part of the methodology they may appear strange and possibly repetitive. I would, however, ask you to please bear with me on this and complete the whole survey.

The survey itself should take around 10 minutes of your time to complete.

Please note that -

1. Collated (anonymous) survey outcomes may be submitted for publication in peer-reviewed scientific journals.

2. Once started, you have the option to withdraw from completing the survey at any time by closing the survey page.

The time and thought you invest into completing this survey is much appreciated - thank you

Next steps

Please select the YES option to confirm -

You have read and understood why this survey is being conducted

You understand that data from it may be published

You understand that you may withdraw from survey completion at any time (by closing the survey page)

You are actively involved in reptile keeping

You are aged 18 years or over

You consent to complete this survey

Alternatively, please select the NO option should you NOT wish to complete the survey:

Should you wish to discuss the survey before deciding whether or not to consent to complete it please contact Lydia Yeo at lmy4@kent.ac.uk. Doing so will not compromise your anonymity, should you subsequently decide to complete the survey, since individual respondents are not identifiable from survey returns.

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

1. Please tick YES or NO to indicate whether or not you are willing to take part in the survey

*This question is required.

☐ YES - I consent to undertake this survey on the basis of the information provided to me

☐ NO - I do not wish to complete this survey

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

2. To which gender do you assign yourself? *This question is required.

☐ Female

☐ Male

☐ Other

3. Which age range do you belong to? *This question is required.

-- Please Select --

4. What is your country of residence? *This question is required.

-- Please Select --

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

5. How many years have you been keeping reptiles for? *This question is required.

☐ 0 - 5 years

- [ ] 6 - 10 years
- [ ] 11 - 20 years
- [ ] Over 20 years

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

6. Which of the following best describes the type of reptile keeper you are? *This question is required.

- [ ] A hobbyist (i.e. non - commercial) reptile keeper
- [ ] A commercial (i.e. for profit) reptile keeper

7. Please read the following 5 statements and select the answer that best represents your view *This question is required.	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. I have a knowledge of the Convention on International Trade in Endangered Species (CITES)	○	○	○	○	○
2. I have an understanding of CITES Regulations	○	○	○	○	○
3. I believe that, in general, CITES is important for sustainable wildlife trade	○	○	○	○	○
4. I believe that CITES is relevant to reptile keeping	○	○	○	○	○
5. I believe that CITES is important for reptile conservation	○	○	○	○	○

This question has answer validation

Min = 0
Max = 5
Must be numeric
Whole numbers only
Positive numbers only

8. How many of the following statements do you agree with?

During the last year I attended in person at least one specialist meeting (e.g. hobbyist meeting, trade fair or conference) connected to reptile keeping

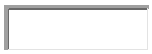
I have a local shop nearby where I purchase items connected to reptile keeping

During the last year I have purchased in person (face to face) a reptile of questionable legal origin

I prefer to buy items connected to reptile keeping through online stores

I am a member of only one reptile keeping group

Please insert a number between 0 and 5 in the box below *This question is required.



This question has answer validation

Min = 0
Max = 4
Must be numeric
Whole numbers only
Positive numbers only

9. How many of the following statements do you agree with?

During the last year I attended in person at least one specialist meeting (e.g. hobbyist meeting, trade fair or conference) connected to reptile keeping

I have a local shop nearby where I purchase items connected to reptile keeping

I prefer to buy items connected to reptile keeping through online stores

I am a member of only one reptile keeping group

Please insert a number between 0 and 4 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 5
Must be numeric
Whole numbers only
Positive numbers only

10. How many of the following statements do you agree with?

During the last year I attended in person at least one specialist meeting (e.g. hobbyist meeting, trade fair or conference) connected to reptile keeping

I have a local shop nearby where I purchase items connected to reptile keeping

During the last year I have purchased in person (face to face) a reptile of questionable legal origin

I prefer to buy items connected to reptile keeping through online stores

I am a member of only one reptile keeping group

Please insert a number between 0 and 5 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 4
Must be numeric
Whole numbers only
Positive numbers only

11. How many of the following statements do you agree with?

During the last year I attended in person at least one specialist meeting (e.g. hobbyist meeting, trade fair or conference) connected to reptile keeping

I have a local shop nearby where I purchase items connected to reptile keeping

I prefer to buy items connected to reptile keeping through online stores

I am a member of only one reptile keeping group

Please insert a number between 0 and 4 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 5
Must be numeric
Whole numbers only
Positive numbers only

12. How many of the following statements do you agree with?

Social media (e.g. Facebook &/or Twitter) is the main method I use to keep in contact with other reptile keepers

During the last year I joined a new online forum that specifically discusses reptile keeping

The main reptile keeping group I am a member of has an online sales area

During the last year I have purchased over the internet a reptile of questionable legal origin

The main reptile keeping group I am a member of uses social media (e.g. Facebook &/or Twitter) to communicate with members

Please insert a number between 0 and 5 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 4
Must be numeric
Whole numbers only
Positive numbers only

13. How many of the following statements do you agree with?

Social media (e.g. Facebook &/or Twitter) is the main method I use to keep in contact with other reptile keepers

During the last year I joined a new online forum that specifically discusses reptile keeping

The main reptile keeping group I am a member of has an online sales area

The main reptile keeping group I am a member of uses social media (e.g. Facebook &/or Twitter) to communicate with members

Please insert a number between 0 and 4 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 5
Must be numeric
Whole numbers only
Positive numbers only

14. How many of the following statements do you agree with?

The main reptile keeping group I am a member of has a written, voluntary Code of Conduct that relates to the sale and purchase of reptiles

I contribute articles to magazines or newsletters on reptile keeping

The main reptile keeping group I am a member of maintains a members only electronic discussion forum

In the next year I am likely to purchase in person (face to face) a reptile of questionable legal origin

I plan to add to my reptile collection in the next month

Please insert a number between 0 and 5 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 4
Must be numeric
Whole numbers only
Positive numbers only

15. How many of the following statements do you agree with?

The main reptile keeping group I am a member of has a written, voluntary Code of Conduct that relates to the sale and purchase of reptiles

I contribute articles to magazines or newsletters on reptile keeping

The main reptile keeping group I am a member of maintains a members only electronic discussion forum

I plan to add to my reptile collection in the next month

Please insert a number between 0 and 4 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 5
Must be numeric
Whole numbers only
Positive numbers only

16. How many of the following statements do you agree with?

In the last year I visited a reptile show outside my country of residence

I prefer to buy reptiles in person (face to face)

In the next year I am likely to purchase over the internet a reptile of questionable legal origin

In the next year I plan to visit more than one zoo to specifically see their reptile collection

I believe that the sale of reptiles is moving online

Please insert a number between 0 and 5 in the box below *This question is required.

This question has answer validation

Min = 0
Max = 4
Must be numeric
Whole numbers only
Positive numbers only

17. How many of the following statements do you agree with?

In the last year I visited a reptile show outside my country of residence

I prefer to buy reptiles in person (face to face)

In the next year I plan to visit more than one zoo to specifically see their reptile collection

I believe that the sale of reptiles is moving online

Please insert a number between 0 and 4 in the box below *This question is required.

18. Please read Statements A and B then answer EITHER Question 1 OR Question 2 based on your response

Statement A: My birthday is between 1st January and 30th June

If YES please answer Question 1: Is the final digit of your mobile phone an even number?

Statement B: My birthday is between 1st July and 31st December

If YES please answer Question 2: In the past year, have you purchased a reptile of questionable legal origin from a seller face to face?

*This question is required.

- YES
- NO

19. Please read Statements A and B then answer EITHER Question 1 OR Question 2 based on your response

Statement A: My birthday is between 1st March and 31st August

If YES please answer Question 1: Is the final digit of your mobile phone an odd number?

Statement B: My birthday is between 1st September and 29th February

If YES please answer Question 2: In the past year, have you purchased a reptile of questionable legal origin over the internet?

*This question is required.

- YES
- NO

20. Please read Statements A and B then answer either Question 1 or Question 2 based on your response

Statement A: My birthday is between 1st May and 31st October

If YES please answer Question 1: Is the final digit of your mobile phone an even number?

Statement B: My birthday is between 1st November and 30th April

If YES please answer Question 2: In the next year, are you likely to purchase a reptile of questionable legal origin from a seller face to face?

*This question is required.

- YES
- NO

21. Please read Statements A and B then answer EITHER Question 1 OR Question 2 based on your response

Statement A: My birthday is between 1st July and 31st December

If YES please answer Question 1: Is the final digit of your mobile phone an odd number?

Statement B: My birthday is between 1st January and 30th June

If YES please answer Question 2: In the next year, are you likely to purchase a reptile of questionable legal origin from a seller over the internet?

*This question is required.

- YES
- NO

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

22. Please read the following, two questions:-

Q1: Is your birthday in February, October or December?

Q2: In the past year, have you purchased a reptile of questionable legal from a seller origin face-to-face?

Now, select your response:-
*This question is required.

- My response is NO to both questions, OR YES to both questions
- My response is YES to one question AND NO to the other

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

23. Please read the following, two questions:-

Q1: Is your birthday in March, May or October?

Q2: In the past year, have you purchased a reptile of questionable legal origin from a seller over the internet?

Now, select your response:-
*This question is required.

- [ ] My response is NO to both questions, OR YES to both questions

- [ ] My response is YES to one question AND NO to the other

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

24. Please read the following, two questions:-

Q1: Is your birthday in April, July or November?

Q2: In the next year, are you likely to purchase a reptile of questionable legal origin from a seller face-to-face?

Now, select your response:-
*This question is required.

- [ ] My response is NO to both questions, OR YES to both questions

- [ ] My response is YES to one question AND NO to the other

This question has answer validation

Min . answers = 1 (if answered)
Max . answers = 1 (if answered)

25. Please read the following, two questions:-

Q1: Is your birthday in June, August or November?

Q2: In the next year, are you likely to purchase a reptile of questionable legal origin from a seller over the internet?

Now, select your response:-
*This question is required.

- [ ] My response is NO to both questions, OR YES to both questions

☐ My response is YES to one question AND NO to the other

26. Please answer either YES or No to the following, four questions *This question is required.	YES	NO
In the past year, have you purchased a reptile of questionable legal origin from a seller face-to-face?	○	○
In the next year, are you likely to purchase a reptile of questionable legal origin from a seller face-to-face?	○	○
In the past year, have you purchased a reptile of questionable legal origin from a seller over the internet?	○	○
In the next year, are you likely to purchase a reptile of questionable legal origin from a seller over the internet?	○	○

This question has answer validation

Min . answers = 1 (if answered)
Min . answers per row = 1 (if answered)

27. Please EITHER tick to show where you have bought any reptiles of questionable legal origin (tick all that apply) OR tick to indicate that you have never bought any reptiles of questionable legal origin *This question is required.	Tick to select
Face to face transactions from a private individual/ residence	☐
Face to face transactions from non-online shops or businesses	☐
Online shops or businesses	☐
Shows or exhibitions	☐
Online auction sites (e.g. eBay)	☐
Online classified advertisements (e.g. Gumtree)	☐
General social media (e.g. Facebook)	☐
Specific social media (e.g. reptile keepers' online forum)	☐
Twitter	☐
Instagram	☐
WhatsApp	☐

27. Please EITHER tick to show where you have bought any reptiles of questionable legal origin (tick all that apply) OR tick to indicate that you have never bought any reptiles of questionable legal origin *This question is required.

Tick to select

Dark web ☐

I have never bought any reptiles of questionable legal origin ☐

The survey is now complete

Thank you for completing this survey. Your feedback is essential to our research and your contribution is valued.

Should you have any QUESTIONS on this survey, please contact Lydia Yeo at the University of Kent, United Kingdom lmy4@kent.ac.uk

Other thoughts or suggestions you may have on any aspect of this survey are welcomed – please include these in the comments box, below. Thank you.

28. My comments on this survey are as follows -

Thank you for taking our survey. Your response is very important to us.