CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA
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RESPONSE BY TRAFFIC AND THE MIKE-ETIS TECHNICAL ADVISORY GROUP (TAG)
TO SINGAPORE'S COMMENTS ON ETIS METHODOLOGY

This information document has been submitted by the Secretariat on behalf of TRAFFIC and the MIKE-ETIS Technical Advisory Group (TAG), in relation to agenda item 29.3 on *National ivory action plans process: Report of the Secretariat.*[*]

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[*] *The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CITES Secretariat (or the United Nations Environment Programme) concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.*

**Comments from TRAFFIC and the MIKE-ETIS Technical Advisory Group (TAG)
on SC69 Doc. 29.3 Annex 5 submitted by the Government of Singapore on**

Issues Relating to the ETIS Analysis Submitted to CoP17

Background

At the 17th meeting of the CITES Conference of the Parties (CoP17), TRAFFIC presented the analyses of the Elephant Trade Information System (ETIS) in CoP17 Doc. 57.6 (Rev. 1) and its Addendum, which identified Singapore as 'country of concern' in the illegal trade in elephant ivory. The Government of Singapore has, in SC69 Doc. 29.3 Annex 5, subsequently outlined a series of concerns about the ETIS analysis to CoP17, as well as the operation and methods which support the monitoring system tracking illegal trade in ivory in general.

This document constitutes both a management and technical response to the comments about ETIS contained in SC69 Doc. 29.3 Annex 5 from TRAFFIC and the MIKE-ETIS Technical Advisory Group (TAG). The management response was guided by input from TRAFFIC and the technical response was steered by input from the two statisticians who analysed the ETIS data for the CoP17 ETIS report. This document is structured with an introductory statement from TRAFFIC, a series of management and technical responses concerning specific issues raised by the Government of Singapore in the subsection entitled *Singapore's Concerns with the ETIS Report* in SC69 Doc. 29.3 Annex 5 (on pages 14-16), and brief concluding remarks. Further, a detailed response from the ETIS statisticians to a technical review of the ETIS methods offered by two academics in Singapore is presented as Annex 1 of this document. Annex 1 directly addresses the issues raised in "*Review on 'Dissecting the Illegal Ivory Trade: An Analysis of Ivory Seizure Data' and 'The Elephant Trade Information System (ETIS) and the Illicit Trade in ivory: A Report to the 17th Meeting of the Conference of the Parties to CITES*'" in SC69 Doc. 29.3 Annex 5 (see pages 38-46).

Introduction

It is important to acknowledge that some degree of uncertainty characterizes the evidence underpinning decision making for the conservation of African and Asian Elephants under the Convention, particularly as elephant poaching and ivory trade crime primarily unfolds as an unobservable series of illegal events with only some elephant carcasses and some ivory seizures becoming known in any given year. The *precautionary principle* drives TRAFFIC's commitment to produce the best possible analysis of illegal ivory trade for the CITES Parties to consider because failure to do so could result in inaction and cause serious irreversible harm to two of the world's most iconic species which are currently facing serious decline from trafficking in elephant ivory. The 1997 mandate in Resolution Conf. 10.10 (Rev. CoP17) that underpins the development of two monitoring systems -- the Elephant Trade Information System (ETIS) and Monitoring of Illegal Killing of Elephants (MIKE) -- was a deliberate and commendable example of the CITES Parties embracing the precautionary principle to support the Convention's policy interventions for elephant conservation. Understanding the dimensions of elephant poaching and illegal ivory trade with evidence generated through sustained commitment to two long-term monitoring programmes has been an enduring cornerstone of CITES engagement to support elephant conservation over the past two decades.

In assessing illegal trade in elephant ivory, the Parties, in Resolution Conf. 10.10 (Rev. CoP17), have expressly mandated ETIS to deliver comprehensive analyses that address three key objectives:

> *i) measuring and recording levels and trends, and changes in levels and trends, of illegal elephant killing and trade in ivory and other elephant specimens in elephant range States, ivory consumer States and ivory transit States;*
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> *ii) assessing whether and to what extent observed trends are related to measures concerning elephants and trade in elephant specimens taken under the auspices of CITES; changes in the listing of elephant populations in the CITES Appendices; or the conduct of legal international trade in ivory; and*
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> *iii) establishing an information base to support the making of decisions on appropriate management, protection and enforcement needs.*

The mandate in this Resolution gives TRAFFIC the responsibility of implementing ETIS on behalf of the CITES Parties.

To meet the technical requirements ascribed in these three objectives, TRAFFIC's work on ETIS has been supported through a longstanding collaboration with two statisticians – Mr. Robert W. Burn and Dr. Fiona M. Underwood – both formerly of the University of Reading in the United Kingdom, now independent consultants. They have assisted in the design and operation of ETIS, and have been instrumental in developing the methodology used to deliver the information requested by the CITES Parties for their decision-making. Accordingly, the services of the ETIS statistical team are retained on a consultancy basis under contract using funding resources available to TRAFFIC. Part of the strength of ETIS lies in the continuity that has been engendered by having the same individuals engaged with its development and operation since its inception in 1998.

ETIS also benefits from an ongoing collaboration with a range of experts who comprise the TAG nominated by the CITES Secretariat and approved by the MIKE-ETIS Subgroup of the Standing Committee. Whilst it is recognized that CITES documents are not, strictly speaking, subjected to peer review in the same sense as published academic papers, the ETIS results are nonetheless reviewed by the TAG prior to their submission into CITES fora. Further, the methods used to produce the ETIS analyses have been published in a peer-reviewed scientific journal (Underwood *et al.*, 2013) to promote transparency and allow for independent validation of ETIS results by promoting a forum for technical discussion with other statisticians who review and critique the work. Whilst neither TRAFFIC (for ETIS) nor the CITES Secretariat (for MIKE) currently make the codes that are used to perform the analyses publicly available in CITES documents, there is a move to address this issue in the future in the broader interest of openness.

It is also worth remembering that what happens in terms of translating the ETIS results into policy or subsequent actions is solely the prerogative of the CITES Parties through their deliberations, not those who generate or present the information in successive reports from the ETIS and MIKE programmes. The clear separation between these informative technical contributions and the subsequent decision-making of the CITES Parties is an important circumscription defining the specific roles of the two long-term monitoring programmes for elephants under the Convention.

For the financing of ETIS, Resolution Conf. 10.10 (Rev. CoP17) Annex 1, paragraph 7 states that "*a funding mechanism will be established to ensure that ETIS is fully operational*." In fact, a stable funding mechanism for ETIS or MIKE has never been established under the Convention. The operation and management of ETIS is not part of the Secretariat's budget, although the Secretariat has made some resources available to ETIS on occasions in the past and, more recently, joint proposals have been developed in collaboration with the CITES MIKE Programme to secure part of the ETIS funding needs under cooperative arrangements. Otherwise, TRAFFIC has independently fundraised to support the bulk of the ETIS operation over the last two decades. In this regard, TRAFFIC would like to acknowledge with gratitude the support from the Governments of the United Kingdom (Department of Environment, Food and Rural Affairs – DEFRA and the Darwin Initiative) and the United States (the Department of State, and the Fish and Wildlife Service's African Elephant Conservation Fund), the European Union through support to the MIKES Project, and WWF, all of which have helped to financially support the ETIS programme over the years.

The issue of *ad hoc* funding arrangements is important to mention because it is relevant to TRAFFIC's ability to effectively service requests from the CITES Parties, in this case the Government of Singapore's desire to obtain the code and algorithm behind the ETIS analysis to CoP17. In preparing the code for transmission to a third party, TRAFFIC will face cost implications for which a budgetary provision has not been made. TRAFFIC is certainly willing to engage the Government of Singapore in this regard provided that resources are available to make it happen. This constraint was communicated to the Government of Singapore the same day TRAFFIC was first contacted about this issue on 11 August 2017. TRAFFIC has since provided a specific costing for carrying out this activity, but there has been a lack of engagement. TRAFFIC also approached the CITES Secretariat and requested funding support to action the request of the Government of Singapore, but the Secretariat has also not been able to make the necessary funding available.

Overall, and moving back to the big picture of assessing illegal ivory trade, TRAFFIC remains heartened by the fact that ETIS is generally recognized globally as one of the best examples of trade monitoring through the pioneering usage of elephant ivory seizure data to elicit defensible, unbiased, objective patterns of illegal trade. It is nonetheless acknowledged that, given the degree of complexity in the ETIS data, no analysis will ever be perfect, but TRAFFIC is committed to pursuing "best practice" methods to derive the best possible results for presentation to the CITES Parties. TRAFFIC welcomes the constructive input from the Government of Singapore and their academic reviewers to improve, through further development, the methods behind the ETIS analyses in a positive and collaborative spirit.

1. Comments on ETIS Methods

This section constitutes a technical response to the comments about the ETIS analysis presented in SC69 Doc. 29.3 Annex 5 under the subheading *Singapore's Concerns with the ETIS Report*. The text of the statements made in the Singapore document are presented in italics. Some of the concerns relate to the management of the ETIS operation which is handled by TRAFFIC, whilst others address methodological issues associated with the ETIS analysis, thus the responses are noted as management or technical-related comments, as appropriate, which express the views of TRAFFIC and the TAG.

1.1 <u>Paragraph 23, page 14</u>: *Singapore articulated why we did not agree with the methodology, findings and conclusions of the ETIS report at COP17 (CoP17 Com. II Rec.2 (Rev.2)). In particular, there was no consultation with us by the authors of the Report despite the fact that consultation was mandated by the CoP. There was a lack of clarity in the methodology. The data used in the analysis was not verified with us. The report also did not take into account the robust domestic framework within Singapore, including Singapore's strong and effective enforcement efforts*.

<u>Management comment</u>: Prior to CoP17, the Government of Singapore contacted TRAFFIC on 18 August 2016 with a series of questions concerning the ETIS analysis to CoP17. The same day TRAFFIC responded in a comprehensive manner, providing: a detailed memo to answer a series of specific questions about Singapore's role in the illegal trade in ivory and the CoP17 ETIS analysis; the scientific paper which describes the analytical framework for ETIS (i.e. Underwood *et al.*, 2013); the most recent version of Singapore's ETIS Country Report in a tabular Excel spreadsheet format which included all of the data that Singapore had provided, plus all records from other countries that made ivory seizures noting Singapore as the country of origin, export, re-export, transit or destination; and a graphic summary of the ETIS data for Singapore. At the time, this response was acknowledged by both the Government of Singapore and the CITES Secretariat. TRAFFIC further offered to visit Singapore using its own resources to discuss the ETIS analysis prior to CoP17, which led to a four-hour meeting with Agri-Food and Veterinary Authority (AVA) officials on 30 August 2016. Following that meeting, the Government of Singapore wrote: "*It was our pleasure to meet with you on 30 August 2016 to discuss the ETIS report.*" TRAFFIC believes that, in fact, considerable time, effort and finance was expended in extensive consultations with the Government of Singapore over the ETIS analysis. (NB: Other comments on the ETIS methodology and the ETIS data are dealt with more specifically below).

1.2 <u>Paragraph 24, page 15</u>: *To better understand how the ETIS analysis resulted in Singapore's identification as a country of primary concern, we engaged a statistician from the National University of Singapore and an economist from the Singapore Management University to undertake a preliminary analysis of the ETIS report's methodology (Annex E). Their analysis raised several questions about the methodology and conclusions of the ETIS report.*

<u>Management comment</u>: Singapore's efforts in this regard led to the paper presented on pages 38-46 in SC69 Doc. 29.3 Annex 5. The primary concerns relate to: (1) a model of reported seizures from which the Transactions Index and Weights Index are derived; and (2) the cluster analysis which identifies countries with similar characteristics with respect to their role in the illegal ivory trade and serves as the basis to determine countries of 'primary' and 'secondary concern'. A detailed response to this paper has been prepared by the ETIS statisticians and is presented on pages 10-16 of this document. Other specific technical points are addressed below as they appear in the context of other statements made by the Government of Singapore.

<u>Technical comment</u>: It should be noted that the two technical reviewers in Singapore's submission (one named, the other anonymous) do not express any fundamental disagreement with the basic foundation upon which the ETIS analysis rests. This is encouraging because the underlying premise of the ETIS analysis is that patterns in raw reported seizure data cannot be directly interpreted to describe the illegal ivory trade. Conceptually, the ETIS model is based on the assumption that the number of reported ivory seizure cases will change over time for three very separate reasons: changes in levels of illegal ivory trade; changes in levels of law enforcement effort to make seizures; or changes in levels of reporting seizures to ETIS; or, collectively and more likely, in some combination of these three factors. Unless the rates of seizures and rates of reporting are accounted for, it is not possible to understand whether there are real changes in the illegal trade in ivory. To the best of our knowledge, the ETIS methodology represents the only analytical framework that specifically addresses inherent bias in seizure data owing to the fact that individual countries differ widely in their abilities, firstly, to make and, secondly, to report seizures to ETIS. This bias adjustment is a step in the right direction towards mitigating the fundamental challenge of interpreting seizure data and results in a far better understanding of illegal trade in elephant ivory. As more research is done to identify drivers and relevant measures of the seizure and reporting rate, we expect that the ETIS methods and results can be further improved.

1.3 Paragraph 25, page 15: *First, the ETIS report's methodology is subjective and open to interpretation because assumptions are used to determine a projected rate of seizure and reporting, as opposed to what was factually observed. Various proxy variables are used to determine the seizure and reporting rates of various countries assessed in the ETIS reports. The report's use of Deviance Information Criteria to select the proxy variables for the estimation of latent variables like seizure rates has been critiqued by several academics. These proxy indicators included variables like Corruption Perceptions Index (CPI), control of corruption, government effectiveness, political stability, rule of law, regulatory quality, voice & accountability, Gini coefficient, GDP, Human Development Index (HDI), Legislation score, Data collection score, CITES reporting score, and a Law Enforcement (LE) ratio. But these proxies are unlikely to reflect the actual underlying seizure and reporting rates. Hence, these proxies may introduce errors in the analysis.*

Technical comment: The first sentence appears to be an inaccurate statement. The ETIS methodology is neither subjective, nor can the seizure and reporting rates for each country be "*factually observed*" in each year. The only observable data about the illegal ivory trade are the reported seizures that comprise the ETIS data and, for the reasons noted in 1.2, these data are incomplete representations of the true number of seizures made in each country in every year and cannot be directly interpreted to describe the illegal ivory trade.

The key difficulty with modelling reported seizure data is that the seizure and reporting rates are unknown for each country in each year. The ETIS model does not attempt to model the *actual* rates of these factors because there is insufficient information for doing so. Accordingly, the aim of the ETIS model is to provide *relative* rates to describe why countries differ in their ability to make and report seizures, and how this changes in a *relative* manner over time. It is acknowledged that finding variables and corresponding data that describe the differing situations in each country and in every single year is challenging. Therefore, it is useful to have a large list of candidate proxy variables for testing what may describe aspects of these differences. Moreover, ETIS is constantly searching to broaden the list of candidate variables for testing. Thus, as noted above, a range of proxy measures compiled by the United Nations, the World Bank and others institutions are assessed in the ETIS model. Some of these variables describe the socio-economic environment within which law enforcement bodies (who make seizures) and CITES Management Authorities (who report seizures) function. Others variables are more directly related to the performance of law enforcement agencies (i.e. law enforcement ratio or LE ratio) or CITES Management Authorities (i.e. the CITES reporting score), or the manner in which individual seizure cases were reported to ETIS (i.e. the data collection score). When conducting an ETIS analysis, these variables are tested in the model to see if they describe variability between countries or over time. The majority of variables tested are not used because their utility in describing why countries differ in their ability to make and report seizures appears limited. However, the proxy variables that that are employed to describe variation are not, as suggested by Singapore, always weakly related. For example, the data collection score and the LE ratio appear to account for significant variability in seizure and reporting rates.

The Singapore statement above also notes issues with the use of Deviance Information Criterion (DIC) which is fully addressed in the response of the ETIS statisticians in 2.5.3 on page 15-16 below.

1.4 Paragraph 26, page 15: *Second, the methodology used also underestimates uncertainties in the seizure and reporting rates. These uncertainties are also passed on to the smoothed expected transactions. The smoothing methodology may also introduce some new sources of bias due to the way irrelevant variations in proxy variables are propagated through into the seizure and reporting rates. It can be expected that different countries would have different relationships between proxies and the true underlying rates. In short, the modelling assumptions made are subjective, hard to justify, and raise doubts about the report's findings.*

Technical comment: Directly modelling the uncertainties in the seizure and reporting rate, as suggested in the Singapore technical review, is an issue worth exploring, although further modification of the ETIS model may be required to accommodate this approach. Even if the current model were to underestimate uncertainty in the seizure and reporting rates, this does not imply that the variability in the Transactions Index (the ETIS output that tracks global illegal ivory trade activity) is also underestimated. If that were the case then it should be observed in the model checking that is subsequently carried out. In fact, extensive model checking suggests that, if anything, the current model overestimates -- rather than underestimates -- variability and uncertainty in the Transactions Index. This finding seems logical given that residual variation is captured in the part of the model that describes transactions, rather than the part of the model that concerns seizure and reporting rates. In sum, statistical modelling of complex data inevitably involves making choices concerning which variables to include, the mathematical structure of the model, statistical assumptions and a host of other factors. There is rarely, if ever, a single set of choices that serve to define a "correct" model in any absolute sense. The ETIS model is complex, but the results that are presented to CITES are easily understandable, and seem to be the best that can be achieved with the information available to define the relative state of the illegal ivory trade in each year.

1.5 Paragraph 27, page 15: *Third, the use of the Law Enforcement Ratio (LE Ratio) as a proxy variable to determine seizure rates across countries is questionable. The LE Ratio of a country is defined as the number of seizures made within a country divided by total number of seizures a country is involved in. It is more likely for a source country at the start of the trade chain to have a lower LE Ratio compared to a destination country at the end of the chain. This is because a source country has more opportunity to be implicated in other countries' seizures down the chain, thereby increasing its total number of seizures. In short, the LE Ratio is likely to be biased against countries at the start of the trade chain. This is a fundamental issue since the CoP17 ETIS report relies only on the LE Ratio to approximate seizures.*

Technical comment: Firstly, there is an inherent misunderstanding in the statement above. The LE ratio is a proxy variable used to describe why countries differ in their ability to make seizures -- it is not used to approximate the number of seizures.

Ideally, to explain why countries differ in their ability to make seizures, information about law enforcement effort and effectiveness should be used, for example, data on the resources (staff, budget and equipment) allocated for law enforcement, and the proportion of shipments that end up being inspected in each year. However, such data are simply not available for all countries in all years, and even for countries where such data are produced it is usually not directly comparable to what is being produced in other countries. This state of affairs prompts the ongoing search for proxy variables. In the absence of other data, ETIS derives the LE ratio from ETIS seizure records itself. The LE ratio represents the proportion of reported seizures that a country makes out of all reported seizures that could have been made by the country in question. In document CoP17 Inf. 67, point 1.1 describes the current definition of this ratio. This revised definition sought to resolve a bias against countries towards the end of the trade chain, and ensures that countries are not implicated in seizures for which they had no opportunity to take law enforcement action themselves.

The issue with the revised definition of the LE ratio is acknowledged. However, countries can play multiple roles in the trade, for example, acting as a source, transit or destination point for certain ivory shipments. Whilst elephant range states clearly act as source countries on occasion, they can also appear at other points along the trade chain. In general, given the nature of seizures data, the LE ratio does capture broad differences in law enforcement over time and between countries. For example, it is worth noting that the LE ratio of some elephant range state countries is, in fact, higher than countries that typically are characterised as transit or destination countries further along the trade chain. This indicates that law enforcement is better for certain mainly source countries than certain destination or transit countries. Further refinement of the LE ratio is needed, but the record of steady improvement over the previous definition of the LE ratio is incontestable.

Finally, in the absence of more directly observable data on law enforcement, the LE ratio is recognised as a reasonable proxy for capturing some of the differences in the ability of countries to make seizures and how this changes over time. We are aware of difficulties with the measure and the ETIS team and statisticians are always seeking ways to improve measurement of LE effort using seizures data, and looking for alternative measures and variables that can be employed to improve bias adjustment.

1.6 Paragraph 28, page 15: *Fourth, the report does not adequately explain the inconsistency between the trends in illegal trade (expressed by relative number of estimated transactions) and the actual seizure data. For example, although the relative number of transactions actually went up significantly in 2012 compared to 2011, there were fewer actual seizures in 2012 compared to 2011. This is counter-intuitive. While it could be due to the application of different bias adjustments to the data over the years, the report does not even attempt to address the mismatch or explain the changes in bias adjustments.*

Technical comment: As stated, the premise of the ETIS methodology is that countries differ in their ability to make and report seizures, and this varies between and within countries over time. The analysis seeks proxy variables that may account for these differences to provide relative seizure and reporting rates. The values of the proxy variables that describe why countries differ in their ability to make and report seizures vary over time and between countries. Thus, relative seizure and reporting rates for each country will change over time depending on the proxy variables for each country and year. Bias adjustment essentially scales the number of seizures by the relative seizure and reporting rate, and the degree of bias adjustment differs for each country and in each year. For example, a large number of seizures may be reported in one year by a country with high relative seizure and reporting rates, which would suggest that the relative number of transactions is actually very similar to the reported number of seizure cases. In the same year, a very low number of seizures may be reported by another country with far lower relative seizure and reporting rates, suggesting that the relative number of transactions is much higher than the number of seizures that were actually reported. These differences will be captured as a relative measure in the Transactions Index for these two countries and serve to explain why there may be differences between the number of reported seizures in a given year and the relative number of estimated transactions. In other words, if the relative seizure and reporting rates are much lower in a year in which fewer seizures have been

reported, it is conceivable that, through the bias adjustment process, the relative number of transactions may be estimated to show greater illegal ivory trade activity than in a year in which many more ivory seizures were reported. (In Underwood *et al.* (2013) http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0076539, an illustrative example of this point can be found in Figure 2).

With respect to the example of the years 2011 and 2012 used in the Singapore statement, it is also important to draw attention to the overlapping confidence intervals for the Transactions Index in these years suggesting a degree of uncertainty about how much greater ivory trade activity took place in 2012 over 2011. It is worth noting, that in subsequent iterations of the Transaction Index (most recently the assessment in SC69 Doc. 51.1 Annex in Figure x2 covering the period 2007 through 2016), the mean estimate for 2012 has continued to remain slightly greater than 2011 in the Transaction Index.

1.7 <u>Paragraph 29, page 16</u>: *Fifth, there are issues with the clustering analysis. Broadly speaking, it is not clear why clustering, which is a descriptive technique, is suitable for decision making or inference about individual countries in the way described in the ETIS reports. More specifically, the clustering seems to have been derived from the inputs which are computed based on the smoothed expected transaction numbers previously discussed. Although these are only estimates, they are assumed to be totally accurate. There does not seem to be any attempt to investigate the effects of uncertainty in the smoothing and transaction indices or on the stability of the clustering. This is likely to have serious implications on the results of the analysis, particularly if the uncertainties are correlated with each other. Furthermore, other choices made in the clustering algorithm, such as the distance and linkage criteria as well as the scaling of variables, would affect the stability of the clustering. However, these choices do not appear to have been investigated either.*

<u>Technical comment</u>: It is agreed that the cluster analysis methods used in the CoP17 analysis do not lend themselves to further statistical inferential analysis so that measures of uncertainty (such as confidence intervals) are not available. This does not, however, invalidate this method, which is a widely applied technique in the social sciences, psychology, market research and other disciplines for making sense of complex data so that meaningful priorities can be established. However, careful attention is needed in the selection of appropriate variables to include in the analysis, the choice of appropriate modelling methods, and the interpretation of results. For the CoP16 ETIS report, extensive exploratory analysis characterised the selection of variables appropriate for cluster analysis using bias-adjusted data. A range of variables were considered for inclusion and the results were validated through investigation of how the dendrogram changed when specific variables were removed or added to the analysis. In addition, the results were triangulated with other methods, in particular using 'Principal Components Analysis'. In the CoP17 analysis, the decision was taken to use the same variables as in the previous analysis primarily because the Parties, at CoP16, had actioned the cluster analysis results to instigate the National Ivory Action Plan (NIAP) process. It was reasoned that a high degree of consistency and rigour needed to be maintained between the CoP16 and the CoP17 reports because the method and results had been duly accepted by the Parties at CoP16.

1.8 <u>Paragraph 30, page 16</u>: *Moreover, it remains unclear how the clusters are formed. It is not clear what the basis is for clustering countries into the 13 groups in 2016 ETIS report. There is no explanation as to whether the clustering is based on previous years' reports or particular statistical criterion. In addition, the dendrogram in the ETIS report which plots the clustering of the assessed countries lacks consistency. The cut-off point in the dendrogram, which essentially determines the number of clusters, has changed from report to report. In 2009, the cut-off height was well under 5 on the y axis. In 2013, it was above 5. In 2016, it was under 5.*

<u>Technical comment</u>: Details of the cluster methods used in ETIS are described in Burn and Underwood, 2013. In the CoP17 ETIS report, the cluster analysis produces the dendrogram presented on pages 11-12 of CoP17 Doc. 57.6 (Rev. 1). Two of the nine variables used to form the clusters were the 'total number of seizures over one tonne' and the 'total weight of seizures over one tonne' in the period 2012-2014 (the most three recent years of data available at the time). Countries which were implicated in such large seizures, including Singapore, end up being grouped together (and in this case on the right-hand side of the dendrogram). The cut-off is determined post-hoc once the dendrogram has been produced. The cut-off is a relative measure and the value chosen is primarily based on what is considered to be useful for interpreting the results. Determination of the cut-off point is not a technical statistical decision and nor is it necessarily based on previous analyses, but all ETIS reports have described between 12 and 14 clusters with the CoP17 analysis based on 13 clusters. Importantly, neither the cut-off point nor the number of clusters affects the structure of the dendrogram or the position of any country in it. The cut-off simply determines the number of clusters which is the means for describing the ivory trade characteristics of the countries that end up falling together. The dendrogram is purposely included in the report so that Parties can see for themselves the similarities and differences between countries and assess how changing the cut-off would alter the number of groups.

1.9 **Paragraph 31, page 16**: *To better understand the findings of ETIS report, Singapore obtained the raw data used by TRAFFIC and attempted to verify this data. While we managed to confirm some of the raw data, our checks on four seizures made by Australia which passed through Singapore revealed that one seizure was pre-Convention ivory while the other three cases were not investigated to confirm if the seizures were, in fact, of elephant ivory. The four Australian cases indicate that unverified data was used in the analysis by TRAFFIC. We are currently seeking information on the remaining unverified cases, but while contact has been made with the relevant authorities, responses have not been forthcoming.*

Management comment: TRAFFIC is pleased that the Government of Singapore has taken steps to validate the seizure data provided in its ETIS Country Report, which is one of the purpose of keeping Parties apprised of the data that concerns them. Concerning apparent discrepancies with ETIS records provided by the Government of Australia, TRAFFIC does not believe that unverified data was used in the ETIS analysis, but rather that the status of previously validated seizures was changed at the instigation of the Government of Australia subsequent to CoP17. Between 1996 and 2017, the Government of Australia has duly reported 145 seizure cases to ETIS involving ivory products for which Singapore was identified as country of origin, export, transit or destination. Two seizure cases in this dataset which entailed two worked ivory pieces with an estimated total weight of 1.4 kg, (together with 33 other seizure cases involving other nations), were retracted by the Government of Australia in correspondence dated 26 June 2017. All of these cases had previously been reported to ETIS between 2013 and 2015 by the Government of Australia but, owing to various decisions, including legal actions taken that resulted in the release of the seized elephant products in question, these cases no longer constituted seizure cases for inclusion in ETIS. TRAFFIC has duly followed these instructions and none of these records are now eligible for inclusion in any future ETIS analyses (including the one before SC69). Concerning the other two cases noted by Singapore above, neither the Governments of Singapore nor Australia have yet brought these cases to the attention of TRAFFIC, or requested that they be investigated or retracted. TRAFFIC awaits information that could potentially change the status of another two cases that relate to Singapore. Finally, because these cases involve very small weight values and fall in the worked ivory small weight class, it is not likely that the results of the ETIS analysis to CoP17 would have been altered in any measurable way had these cases been removed prior to analysis.

1.10 **Paragraph 32, page 16**: *Overall, the ETIS analysis is opaque and makes several debatable and subjective claims. For instance, the report insinuates that Singapore's law enforcement efforts have been ineffective, without providing any evidence to back up these claims. Singapore is a country governed by strong rule of law. As indicated above, we were ranked first globally in "Regulatory Enforcement" in the World Justice Project's 2016 Rule of Law Index, an indicator used in the World Bank Worldwide Governance Indicators. The report also refers to Singapore as a country that did not report on its ivory stockpile. But the Singapore government does not maintain any ivory stockpile to begin with. The ETIS analysis is intended to provide the basis for identifying parties for participation in the NIAP process. To be credible, there is a critical need for transparency, objectivity and clarity in the process and approach. Parties, particularly those which have been identified, need more understanding of the methodology that is employed, the data that is used, the relative weightage of the proxy indicators and the broad assumptions underpinning the analysis. Unfortunately, the current analysis does not hold up to such basic standards.*

Management comment: Concerning the Government of Singapore's suggestion that the ETIS analysis is opaque and lacks transparency in terms of its methods, process and approach, TRAFFIC draws attention to its record of engagement with Singapore outlined in 1.1 above. With the ETIS methods published in the peer-review scientific literature, other methodological detail provided in the reports submitted to CITES CoPs and Standing Committees, active engagement with the TAG on a range of methodological issues and with the CITES Parties on data issues through the periodic generation of ETIS Country Reports, and a 15-year record of making analytical submissions into CITES proceedings without serious technical challenge, we believe that every effort has been made (within available resources) to ensure that the ETIS analysis is transparent, objective and accurate to the best of our ability.

Concerning the Government of Singapore's comments about the characterisation of its law enforcement in the CoP17 ETIS analysis, like all countries, Singapore's relative seizure rate is measured through the LE ratio (as described in 1.5 above). In this regard, Singapore's LE ratio is quite low owing to the fact that ivory seizures are rarely made and reported to ETIS, a fact mentioned in the CoP17 ETIS analysis; for example, over the last ten years from 2007-2016, Singapore has reported seven seizures, involving an estimated 8,225 kg of ivory, all of which occurred in the period 2013-2015, with no seizures reported in any of other seven years, whilst over the same period 53 other seizure cases, involving an estimated 8,969 kg of ivory, were reported by other countries that implicated Singapore in the trade chain. With respect to governance, the CoP17 ETIS report stated that Singapore had the fourth best score of any country in the analysis.

Concerning the statement about Singapore not declaring any ivory stockpiles, at CoP16 in March 2013, the Parties amended Resolution Conf. 10.10 (Rev. CoP17) to require government-held stocks of ivory to be declared to the CITES Secretariat by the 28 February of each year. Such data are transmitted to the MIKE and ETIS programmes and reported on in the ETIS analysis to the CoP. At the time the CoP17 ETIS report was submitted to the CITES Secretariat on 27 May 2016, the Secretariat had not informed TRAFFIC that Singapore had ever submitted an ivory stock declaration. It was subsequently reported that the Government of Singapore destroyed 7.9 tons of confiscated illegal ivory on 13 June 2016. It is assumed that confiscated ivory becomes "government-held stocks" and, if so, Singapore would have had three opportunities in 2014, 2015 and 2016 to report government-held ivory stocks to the CITES Secretariat pursuant to Resolution Conf.10.10 (Rev. CoP17).

Concluding Remarks

In conclusion, there is no question that all monitoring systems can be improved, including ETIS, and that TRAFFIC is committed to pursuing "best practice" in terms of the management, operation and technical outputs that define ETIS. The ETIS model has charted a highly innovative approach towards understanding illegal trade in ivory globally and the ETIS methods hold significance for the monitoring and understanding of wildlife trade and, more broadly, crime generally. Whilst ETIS is credibly filling a void in terms of producing annual trends in illegal trade in elephant ivory, it would benefit from further methodological development and exploratory analysis. To pursue such a path, however, will require resources. If the CITES Parties, including the Government of Singapore, are committed to pursuing scientific excellence and ensuring that the ETIS results always represent the highest possible standard in terms of understanding levels of illegal ivory trade and underlying trade dynamics, then resources should be made available to engage the TAG and other external technical experts in further development of the ETIS model for the long-term benefit of elephant conservation. TRAFFIC is open and willing to engage in constructive collaborations with any Party to CITES wishing to improve the science behind ETIS.

Response to
Review on "Dissecting the Illegal Ivory Trade: An Analysis of Ivory Seizure Data" and "The Elephant Trade Information System (ETIS) and the Illicit Trade in ivory: A Report to the 17th Meeting of the Conference of the Parties to CITES" issued by the Government of Singapore in SC69 Doc. 29.3 Annex 5

by Fiona M Underwood & Robert W Burn
31 October 2017

2.1 Introduction

As the two statisticians responsible for developing the ETIS methodology, we wish to thank the reviewers in Singapore for their comments and for engaging with our work. We are always happy to look for partners to help us improve and further develop the methodology. Their comments have helped us clarify our ideas on the methodology and indicated an area in which we could further develop, and hopefully improve, the model.

We note firstly that neither reviewer expresses any disagreement with the basic premise that one cannot directly interpret reported seizures to learn about the illegal ivory trade. Thus, an approach is needed to attempt to deal with some of the biases in reported seizures data – namely that countries differ in their ability to make and report seizures. Our methodology is the only one that we are aware of that attempts to deal with these biases and we feel this is an important step in the right direction in the absence of any usable alternatives. Indeed, we are gratified that the reviewers do not appear to find fault with the main features of our approach to bias adjustment and modelling the trend, namely, a multivariate negative binomial count process modelled in a Bayesian framework as a hierarchical model with latent variables representing seizure and reporting rates.

With such complex data, no analysis is ever going to be perfect, but we have done the best that we can with available information. Statistical modelling of complex data usually involves making choices – which variables to include, the mathematical structure of the model, statistical assumptions, etc. Outside of the academic world these choices are never made in an operational void because there is a pressing need to make sense of the incomplete and imperfect data available to decision-makers. There is rarely, if ever, one, and only one, set of choices that amount to a single 'correct' model. While the reviewers have made some valid criticisms, some of their remarks basically suggest that they would not have made the same choices that we made.

The criticisms presented by the two reviewers relate to the analysis presented in the CoP17 report in Milliken *et al*. (2016) and the methodology that is described in Underwood *et al*. (2013) and Burn and Underwood (2013). In places the criticisms relate to a lack of detail, mainly in the CoP17 report. It is worth noting that documents that constitute agenda items in the proceedings of a CITES Conference of the Parties are not the same as technical documents in peer-review science or the academic world. Thus, methods are described in a general manner and briefly, as the CITES Parties are far more interested in the results. The aim of the peer-reviewed paper, Underwood *et al*. (2013,) and the technical report, Burn and Underwood (2013), was to provide detailed references on the ETIS methodology, although we accept that there may still be places where more detail is necessary. As ETIS continues to move towards even greater transparency, in future analyses these issues may be resolved.

The reviewers' criticisms relate to: (1) a model of reported seizures from which the Transactions Index and Weights Index are derived; and (2) a cluster analysis which identifies countries with similar characteristics with respect to their role in the ivory trade. Both of these are based on the ivory seizures data held by the Elephant Trade Information System (ETIS). Before providing detailed responses to each reviewer, we first summarise the main points regarding each of these two sets of criticisms.

2.2 Model of reported seizures

The main criticism here comes from David J. Nott (Reviewer 2) who suggests that we have been underestimating the uncertainty in our estimates of the Transactions Index because we have not directly accounted for all potential variability in the seizure and reporting rates. In fact, Reviewer 2 states that this makes our modelling unacceptable. Whilst directly modelling the residual variation is something that we agree could be useful to explore, we do not agree that we are underestimating the uncertainty or that our model is unacceptable for use. This is because of detailed model checking. Our model checking suggests that, if anything, we are overestimating the variability in the Transactions Index. It is possible that by accounting for the residual variation in the seizure and reporting rate (as suggested by the reviewer), the variability in the Transactions Index decreases. In the meantime, model checking suggests that we are capturing the main features in our data.

2.3 Cluster analysis – general comments

There are a number of points that have been made by the two reviewers about the cluster analysis. We respond in detail to these comments later, but we first wish to provide some background on the cluster analysis and describe the process by which it is carried out and how the countries of 'primary' and 'secondary concern' are identified.

The cluster analysis has been a part of the report to the Conference of the Parties since 2002. One of the objectives in the mandate issued by the CITES Parties for the establishment of ETIS specifically calls for "*establishing an information base to support the making of decisions on appropriate management, protection and enforcement needs*" (see Resolution Conf. 10.10 [Rev. CoP17]). The cluster analysis came about because the ETIS team wished to identify countries with similar characteristics with respect to their role and importance in the illegal ivory trade as one of the means for addressing this objective and to inform the management actions required. Cluster analysis seemed to be a useful tool for achieving this requirement, especially as descriptions of the clusters provided an opportunity for other data and published material on ivory trade in specific countries to be presented. Because of its utility, a cluster analysis has been included in every ETIS report to each CoP. More recently, at CITES CoP16 and at CoP17, the Parties made decisions to use the results of the cluster analysis to guide the choice of countries that should be considered under the National Ivory Action Plan (NIAP) process to address a range of issues that serve to undermine implementation of the Convention for the conservation of elephants.

We agree with the reviewers that cluster analysis is often used as an exploratory tool. It is nevertheless widely used to inform decision making, for example in social sciences, psychology, market research and criminology, etc. The methods we have used do not lend themselves to further statistical inferential analysis so that measures of uncertainty such as significance levels, confidence intervals, etc. are not available. In our view, this does not invalidate the methods. The methods provide a way to help make sense of a complex set of data. We agree with the reviewers that care is needed in selecting appropriate variables to include in the analysis, choosing appropriate modelling methods and in interpretation of the data.

In the previous CoP16 report we, with the ETIS team at TRAFFIC International, spent a considerable time exploring which variables would be appropriate for the cluster analysis given the development of our new bias adjustment method for the ETIS data. A number of variables were considered for inclusion and we validated our methods by investigating how the results changed when variables were removed or added to the analysis. In addition, we triangulated the results with other methods, in particular using Principal Components Analysis. In this most recent CoP17 analysis, we took the decision to use the same variables as in the previous analysis. This was to ensure a level of consistency and rigour between the two reports – and also because the method and results had been accepted by the Parties at CoP16 when they instigated the National Ivory Action Plan process.

For all ETIS analyses, given the variables to be used in the cluster analysis, we carry out the cluster analysis (using the same algorithm which is Ward's clustering with squared Euclidean metric) and produce a dendrogram which represents the similarities between countries. This dendrogram is then presented to the ETIS team and is also provided in the report so that all Parties can assess the similarities and differences between countries for themselves.

Using the dendrogram, the results from the Principal Components Analysis, other relevant variables that are summarised in the CoP reports (see for example Table 3 in CoP17 Doc. 57.6 [Rev. 1]), and expert judgement, the ETIS team: (1) decide the cut-off to determine how many clusters will be described; and (2) identify 'countries of primary' and 'secondary concern'.

We feel that this is a robust approach to the analysis but we also note that given the role that the cluster analysis now plays in determining policy under the Convention, we would welcome opportunities for more extensive review of the sensitivities of the method and how different selections of variables might affect the clustering. We don't, however, think that this negates the outcomes of previous analyses.

2.4 Concluding overview remarks

In conclusion, although there is always scope for improving models, there is a pressing need to make sense of the incomplete and imperfect data available to decision-makers. We have spent a long time developing methods to provide an evidence base, which we feel is defensible, neutral and unbiased. As statisticians our contributions are strictly within the bounds of our professional competence and we adhere to the Royal Statistical Society's Code of Conduct. We hope that the Parties accept the methodology and results, even though they may be uncomfortable with the outcomes for any particular country.

2.5 Response to reviewer 1

2.5.1 LE ratio

The Law Enforcement (LE) Ratio is a proxy variable that is used to help describe how countries differ in their ability to make seizures and how this changes over time. Ideally, to explain these differences, direct measures of law enforcement effort and effectiveness would be available for all CITES Parties. For example, data on the resources (such as numbers of staff, budgetary allocations and equipment) that are invested in law enforcement, and the number and proportion of the total number of shipments that are inspected. Unfortunately, such data are not available for all countries and all years, and even for countries where some of this information is available, it is not always directly comparable. Hence the search for proxy variables. In the absence of other data, we derive a proxy measure from the ETIS seizure records. The LE ratio represents the proportion of reported seizures that a country actually made out of all reported seizures that they could have made. The justification for the current definition is explained in the document CoP17 inf. 67 (point 1.1 on page 2) and now avoids including seizures in which a country is implicated in the trade chain but had no opportunity to take law enforcement action itself.

We acknowledge the issue that the reviewer has raised with the current definition of the LE ratio, although it is a definite improvement on the previous definition and it better captures differences in countries ability to make seizures. Classification of countries into particular roles in the trade chain, for calculation of the LE ratio, as suggested by the reviewer, is not necessarily straightforward. In many cases, countries can play multiple roles in the trade, acting as source, transit and destination points for different shipments. Furthermore, not all seizures concern shipments moving along a trade chain but are seized *in situ*, for example in market places, warehouses, ivory processing plants or national parks where there is no trade route to describe.

We recognise that more work is needed to further refine the LE ratio and address the above issue. However, given the biases in reported seizures data, the lack of data available to measure law enforcement effort and effectiveness directly, and the absence of alternative proxies, our view is that the LE ratio remains a reasonable proxy to help describe how countries differ in their ability to make seizures. We are always seeking to improve existing measures and develop new candidate proxy variables and are open to suggestions for additional or alternative measures.

2.5.2 Counterintuitive effect of bias adjustment

Our understanding of this point is that the reviewer thinks that, because there were more reported seizures in 2011 than 2012, the Transactions Index should also be higher in 2011 than 2012. The reviewer's underlying assumption seems to be that the bias adjustment depends on the number of seizures made in the previous year.

The main difficulty with this interpretation is that the reviewer is assuming that everything other than the number of reported seizures remains constant over time "… *holding other things constant"*. This is not the case – the bias adjustment depends not only on the seizure rate but also the reporting rate, which is a function of the data collection score and CITES reporting score. As can be seen in Figure 1 of Burn and Underwood (2013), these all vary over time and between countries. Thus ETIS may contain more reported seizures for 2011 rather than 2012 because countries have higher levels of reporting and not because there is more trade.

Second, the seizure rate depends on the LE ratio which is a function of Seizures In[1] and Seizures Out,[2] not just the number of Seizures In. The reviewer is certainly right to question their own assumption that '*the splits between Seizure In and Seizure Out*' are constant across all countries. In fact, if they were, this would suggest that the LE ratio was not a very useful measure to use to adjust for differences in seizure rates between countries or over time.

Finally, we note that there are large credible intervals for the Transactions Index suggesting a degree of uncertainty about how much larger 2012 is over 2011.

2.5.3 Use of DIC and credible intervals for variable selection

'… a combination of DIC and inspection of credible intervals was used although the detail was not explained …'

This is a fair point. In fact our use of DIC (the Deviance Information Criterion) was largely restricted to helping decide broad features of the model structure, while the main tool used for deciding the inclusion of individual covariates was posterior credible intervals. We are aware of the potential difficulties with DIC, as described in Spiegelhalter *et al.* (2002, 2014), and we always regard it with some scepticism. We accept that this was not made clear in Underwood *et al.* (2013) or Burn and Underwood (2013). The confidence that we have in our models,

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[1] seizures made by the country in question

[2] seizures made by other countries that implicate the country in question as part of the trade route

however, derives mainly from an extensive examination of posterior predictive graphical checks. These checks were not included in the CITES CoP17 report, mainly because they necessitate a large volume of graphical output.

We are not convinced that the point about the use of data augmentation in BUGS, which invalidates the use of DIC, is relevant to our model, although we thank the reviewer for making us aware of this work. There are two different types of latent variable models and it may be that we have been somewhat careless in our definition. The type of latent variable model that we are using is an example of Structural Equation Modelling (Skrondal and Rabe-Hesketh, 2004). In fact, it is possible to algebraically eliminate the three latent variables – the Transactions Index, seizure rate and reporting rate – and write the model as a function of covariates only. The reviewer's point seems to be relevant to models with latent variable models that are an essential part of the model, for example latent class analysis for mixture models where the latent variables inextricably remain an inherent part of the models.

2.5.4 No account taken of measurement error in cluster variables

Cluster analysis was used here as an informal descriptive technique for summarising data in a way that might suggest some classification of countries. There was no intention to produce a statistical model for the purposes of prediction or inference. Admittedly other analyses may be possible here. The possibility of 'positively correlated' errors (Comment 4, page 41 of SC69 Doc. 29.3 Annex 5) does not invalidate the use of clustering.

2.5.5 Why were 13 clusters chosen?

The clustering algorithm we use is such that the number of clusters is selected post-hoc. That is, it does not determine the outcome of the clustering mechanism. We purposely include the dendrogram from which the clusters are identified in the CoP17 report so that it is possible to see what would happen if a higher or lower cut-off was selected leading to fewer or more clusters, respectively. As noted in the introduction, the number of clusters is determined by the ETIS team to assist with interpretation of the results and in no way affects the structure of the dendrogram.

2.6 Reviewer 2 – David J. Nott

2.6.1 Overconfident inferences about the λ_{ikt}

Our understanding of the reviewer's main criticisms here is that we have not accounted for any residual component of variation in the seizure and reporting rates. Because the reviewer thinks that the seizure and reporting rates are only weakly related to the proxy variables, they state that this is an unacceptably strong assumption and will lead to overconfident inferences, in particular of the λ_{ikt}s that are used to obtain the Transactions Index.

We thank the reviewer for suggesting that we model residual variation for the seizure and reporting rate. We will need to investigate how or whether this would work; we suspect that with the current formulation there may be identifiability issues, but other strategies, such as a simplified model that combines seizure and reporting rates, may make this possible.

However, it is not our experience that all of the proxy variables are weakly related to the rates. In particular, the LE score and the data collection score appear to be quite strongly related to differences in the seizure and reporting rates between countries, respectively, so the residual variation may turn out to be relatively small.

Furthermore, we are not convinced that the current model is overconfident in its inferences. If that were the case, we would expect it to emerge in our model checking. Specifically, the main component of our model checking is to calculate posterior predictive distributions of the data – the $\tilde{y}_{ikt}$s as described by Gelman and Hill (2007). We compare summaries of these distributions with seizure records for individual years by ivory class and country, with summaries such as $\sum_i y_{ikt}$ the total number of seizures in each ivory class for each year, and $\sum_i \sum_k y_{ikt}$ the total number of seizures in each year. If we were overconfident in our inferences then we would expect our 90% (or other percentage) credible intervals for the posterior predictive distributions to contain less than 90% (or other relevant percentage) of the data. In fact, our experience is that our credible intervals are too wide, rather than too narrow, and contain more than 90% of the data. Given the current model formulation this would suggest that our estimates of λ_{ikt} are also not overconfident.

So, although we acknowledge that modelling residual variation in the seizure and reporting rates may be informative, we do not think that our model is underestimating uncertainty in the Transactions Index, or that our model is unacceptable as the reviewer suggests.

2.6.2 Scaled seizure and reporting rates between zero and one

We are not clear why the reviewer has an issue with the seizure and reporting rates being between zero and one. Our model aims to relate observed data – that is reported seizures – with transactions (our variable of

interest) by adjusting for the fact that only a proportion of transactions are seized and only a proportion of these seizures are reported. Thus, these are proportions and as such need to be constrained between zero and one.

However, we do not believe that we have sufficient information to estimate the *actual* seizure and reporting rates and so we aim at getting *relative* rates. Or, in other words, in our modelling, we aim to remove some of the bias in the reported seizures data by finding variables that might describe some reasons for differences in a country's ability to make and report seizures. Although the rates are constrained to lie between zero and one, it is still possible for the seizure or reporting rate of any one country to be many times more or less than the reporting or seizure rate of another country. For example, in the most recent analysis the largest mean reporting rate of 0.952 is more than 14 times greater than the smallest mean reporting rate of 0.066.

2.6.3 Cluster analysis

We accept that the ETIS analysis to CoP17 contains few details of the statistical methodology, and of the clustering method in particular, as is typical for a report to a CITES CoP. Again, the clustering method was Ward's method with a squared Euclidean metric (as described in Burn and Underwood, 2013). Although not included in the CoP17 report, a Principal Component Analysis (PCA) of the same variables was also carried out. The biplot of the PCA broadly supported the main findings of the cluster analysis.

As noted in the CoP17 report, it is the case that a different set of variables could lead to different groupings but for consistency we used the same variables as the CoP16 report. It is true that cluster analysis is often used as an exploratory technique, but in the ETIS analysis it was used to provide preliminary indications of possible groupings. The ultimate account of the groups that emerge was a synthesis of the cluster indications with a great deal of detailed expert knowledge in arriving at conclusions. Admittedly, there are informal elements to this process, which may benefit from methodological refinements. That said we again reiterate that we believe the results that are derived from the cluster analysis have merit.

2.6.4 Other comments

2.6.4.1 No random effects for higher order terms

We do not allow the higher order orthogonal polynomial terms to be country specific because in many cases there is insufficient information to estimate the parameters, and it can cause difficulties in convergence. This means that we are describing average trends at this level rather than individual country level trends.

2.6.4.2 Model checking

We have provided some more detail in section 2.2 regarding model checking.

2.7 References

Burn, R.W., Underwood, F.M. (2012). A new statistical modelling framework to interpret ivory seizures data: A technical report describing the new modelling framework for analysing seizures data from the Elephant Trade Information System. Mathematics Report series (1/2013), Department of Mathematics and Statistics, University of Reading, UK.

Gelman, A., Hill, J. (2007). Data analysis using regression and multilevel/hierarchical models. Cambridge University Press, UK.

Milliken, T., Underwood, F.M., Burn, R.W., Sangalakula, L. (2016). The Elephant Trade Information System (ETIS) and the Illicit Trade in Ivory: A report to the 17th meeting of the Conference of the Parties to CITES. CoP17 Doc. 57.6 (Rev. 1), CITES Secretariat, Geneva, Switzerland.

Skrondal, A., Rabe-Hesketh, S. (2004). Generalised latent variable modelling: Multilevel, longitudinal and structural equation models. Chapman & Hall/CRC.

Spiegelhalter, D.J., Best, N.G., Carlin, B.P., Van der Linde, A. (2002). Bayesian measures of model complexity and fit. Journal of the Royal Statistical Society. Series B: Statistical Methodology, 64 583 – 639.

Spiegelhalter, D.J., Best, N.G., Carlin, B.P., Van der Linde, A. (2014). The deviance information criterion: 12 years on. Journal of the Royal Statistical Society. Series B: Statistical Methodology, 76 485 – 493.

Underwood, F.M., Burn, R.W., Milliken, T. (2013). Dissecting the illegal ivory trade: an analysis of ivory seizures data. PLoS One 8(10): e76539.