Monitoring the Illegal Killing of Elephants (MIKE) Report: PIKE trend analysis – Methodology and Results

September 2020

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1. This report was prepared by the CITES Secretariat.

Background

2. The CITES programme for Monitoring the Illegal Killing of Elephants, commonly known as MIKE, was established by the Conference of the Parties (CoP) to CITES at its 10th Meeting (Harare, 1997), and is conducted in accordance with the provisions in Resolution Conf. 10.10 (Rev. CoP18) on *Trade in elephant specimens*. The CITES MIKE Programme is managed by the CITES Secretariat under the supervision of the CITES Standing Committee. Since implementation began in 2001, the operation of the CITES MIKE Programme in Africa has been possible thanks to the support from range States implementing the CITES MIKE Programme and submitting data on an annual basis as well as the generous financial support of the European Union (EU) and other donors.

3. MIKE aims to inform and improve decision-making on elephants by measuring trends in levels of illegal killing of elephants, identifying factors associated with those trends, and building capacity for elephant management in range States. MIKE operates in a large sample of sites spread across African and Asian elephant range in 32 countries in Africa and 13 countries in Asia. In 2020, Zimbabwe nominated an additional voluntary MIKE site, i.e. Hwange National Park. The nomination for the site was considered by the MIKE-ETIS Technical Advisory Group (TAG) for inclusion in the MIKE network and supported, bringing the total number of MIKE sites in Africa to 69. The 69 MIKE sites are estimated to hold more than 50% of the African elephant population on the continent. There are 29 sites in Asia.

4. MIKE data is collected by law enforcement and ranger patrols in the field, and through other means in designated MIKE sites. When an elephant carcass is found, site personnel try to establish the cause of death and other details, such as the sex and the age of the animal, the status of ivory and the stage of decomposition of the carcass. This minimum set of standardized information relating to each carcass detected at MIKE sites is then submitted to the CITES MIKE Programme.

5. The CITES MIKE Programme, in collaboration with UNEP's Science Division and with funding provided by the EU, developed a web-based (online) database management and reporting system. The new MIKE Online Database contains more than 23,000 records submitted by participating range States. The data visualization features allow range States to map the carcass locations and produce graphs on the frequency of carcass related attributes (i.e. carcass decay stage, age and sex of elephant that died, as well as type and cause of death).

PIKE as an index of poaching pressure

6. The CITES MIKE Programme evaluates relative poaching levels based on the Proportion of Illegally Killed Elephants (PIKE), which is calculated as the number of illegally killed elephants found, divided by the total number of elephant carcasses encountered by patrols or other means, aggregated by year for each site.

7. PIKE is an index of poaching pressure and provides trends relating to the levels of poaching, but it may be affected by several potential biases related to data quality, the fact that MIKE sites are not randomly selected, the reporting rate, the carcass detection probabilities, and the variation in natural mortality rates across MIKE sites, including increases in natural mortality caused by drought and other factors (Burn et al. 2011; document CoP18 Doc 69.2 and its Addendum). Converting the value of PIKE into a measure of actual poaching mortality (i.e. proportion of the elephant population poached) is complicated due to all the aforementioned biases; however PIKE remains a reliable indicator to monitor and study changes in poaching pressure over time.

8. At its 15th meeting, the MIKE-ETIS TAG (September 2019, Nairobi) discussed the biases affecting PIKE, and whether an alternative measure/index should be considered. The MIKE-ETIS TAG recommended however that PIKE should remain the index of poaching pressure, and encouraged the CITES Secretariat, through the CITES MIKE Programme, to continue to work on addressing, where feasible, the biases that affect PIKE, in collaboration with the TAG.

9. In this regard, the CITES Secretariat is in the process of documenting the following biases that affect PIKE:

   a. Management-related deaths and deaths categorised as "Unknown"
   b. Natural mortality
   c. Detection probability

The Secretariat will continue to update the Standing Committee and CITES Parties on progress made in the assessment of these biases.

PIKE trend analysis: Methodology

10. In 2018, the CITES Secretariat, in collaboration with the MIKE-ETIS TAG statisticians and an independent statistician, initiated a process to review the MIKE analytical methodology to determine whether it could be refined, or its scientific robustness improved, and to further enhance the analytical basis for MIKE. The approach included a review of the current methodology, consideration of new statistical developments, and alternative methods or models for PIKE trend analysis, while taking into consideration the imbalances and inconsistencies inherent in the data.

11. In its MIKE report to the 18th meeting of the Conference of Parties (CoP18; Geneva, 2019; document CoP18 Doc. 69.2), the CITES Secretariat informed Parties that a process to refine and improve the statistical analysis to determine the PIKE trend had been initiated.

12. The PIKE trend presented in the MIKE report to CoP18 was calculated using estimated marginal means (LSmeans) of a linear model weighted by the total number of carcasses (R-script for analysis of MIKE data). The continental PIKE trend was estimated based on a model with subregion and year as factors, while the subregional trends were estimated from a model using country and year as factors.

13. This methodology was also used for the PIKE trend analysis in the reports to the three previous meetings of the Conference of the Parties (CoP16, Bangkok, 2013 in document CoP16 Doc. 53.1; CoP17, Johannesburg, 2016, in document CoP17 Doc. 57.5; and CoP18, Geneva, 2019 in document CoP18 Doc 69.2 and its addendum), and to meetings of the Standing Committee (SC62, Geneva, July 2012, in document SC62 Doc. 46.1 (Rev. 1); SC65, Geneva, July 2014, in document SC65 Doc. 42.1; SC66, Geneva, January 2016, in document SC66 Doc. 47.1; SC69, Geneva, November 2017, in document SC69 Doc. 51.1; and SC70, Sochi, October 2018, in document SC70 Doc. 49.1.

14. The analysis of MIKE data that was published in the peer-reviewed scientific literature (Burn et al., 2011) used a Bayesian hierarchical model based on a generalised linear mixed model. This model was therefore different from the one used to produce the reports referred to in paragraph 13 above. The review of the MIKE analytical methodology initiated by the CITES Secretariat in collaboration with the MIKE-ETIS TAG considered various methodologies / models: LSmeans and linear regression; generalized linear model (GLM) / generalized additive model (GAM); generalised linear mixed models (GLMM) / generalised additive mixed models (GAMM); spatial binomial GLM or GAM; and spatial-temporal binomial GLM /GAM.

15. The review and assessment of the application of the various models referred to in paragraph 14 were concluded by the CITES Secretariat in collaboration with the MIKE-ETIS TAG. At its 15th meeting (September 2019, Nairobi), the MIKE-ETIS TAG evaluated the report on the review, which presented the advantages and disadvantages of various statistical modelling approaches for analysing MIKE data. It recommended the use of a Bayesian generalised linear mixed model (GLMM) approach, with model results weighted and unweighted by local elephant population estimates to replace the modelling approach [estimated marginal means (LSmeans)] that had been used in the reports cited in paragraph 13 above. The approach recommended is closer in form to the model used in the MIKE analysis that was published by Burn et al., 2011.

16. Prof Carl Schwarz, one of the statisticians on the MIKE-ETIS TAG, prepared two technical reports, one on a MIKE Analysis for Africa and the second on a MIKE Analysis for Asia. The reports include an explanation of the technical details relating to the existing estimated marginal means (LSmeans) model and the new Bayesian GLMM, and provide background information in support of adopting the Bayesian GLMM going forward, with an assessment of the new model, a sensitivity analysis, and considerations for further work required to incorporate temporal and spatial-temporal correlation to strengthen the analysis in future. These reports were shared and discussed with the range States at the MIKE regional meeting for Africa that took place in November 2019 in Nairobi, and with Asian elephant range States during the subregional meetings that took place in 2019 [3 October 2019, Thimphu (Bhutan) and 29-30 October 2019, Bangkok (Thailand)]. The technical reports can be accessed through the following link: Technical Report – Africa; Technical Report – Asia. Paragraphs 17 to 19 below summarize information extracted from the technical reports that is most relevant for the changes in the model and the results reported in this report.

17. The main reasons why changing to the Bayesian GLMM was recommended, and the advantages associated with the model, are the following:

a) The Bayesian GLMM fully accounts for the binomial structure at the site-year level, i.e. of *n* carcasses observed, *x* are illegally killed. The previous estimated marginal means (LSmeans) model did not, leading to predicted PIKE values that could be less than 0 or greater than 1 on some occasions.

b) The Bayesian GLMM incorporates the hierarchical structure inherent in the way the MIKE data is collected. In other words, observations are grouped into clusters such that data from MIKE sites is nested in countries, countries in regions, and regions within a continent. It is well accepted (and recommended) in the statistical literature to apply mixed effects models on nested data (Zuur et al., 2009). The GLMM models explicitly allows for nested dependencies and also deal with the pseudo-replication problem that arises when taking observations from the same MIKE site from one year to the next. This is an improvement over the estimated marginal means (LSmeans) model, which could not cope with such nested-level dependencies.

c) Due to the explicit binomial distribution assumption for the observed frequency of poached elephants, the Bayesian GLMM fully accounts for different sample sizes, i.e. a PIKE based on observing 1 illegally killed elephants out of 2 elephant carcasses is given a different weight than a PIKE based on observing 20 illegally killed elephants out of 40 elephant carcasses.

d) Multiple sources of variation are automatically included in the PIKE estimates, e.g. changes in PIKE over time at a particular MIKE site; variation between MIKE sites; and unbalanced reporting across countries and subregions.

e) Each MIKE site is given equal weight when computing the continental or subregional PIKE. Consequently, countries with more MIKE sites will automatically be given more weight in the aggregate PIKE estimates.

f) The Bayesian GLMM implicitly accounts for spatial autocorrelation in the PIKE among MIKE sites that are in close geographic proximity to one another. In addition, other weightings can be applied, e.g. by including the local elephant population estimates at each MIKE site when computing an aggregate PIKE.

g) Finally, in future, it will be possible to extend the new model to account explicitly for spatial-temporal autocorrelation.

18. As mentioned above, the new model allows for the application of weightings, e.g. the use of local population estimates to compute a population-weighted PIKE. For comparative purposes, the results for the PIKE analysis are presented in **Annex 1** of this report using: (i) the model that has been used for previous reporting (estimated marginal means (LSmeans) model) and (ii) the new recommended analytical model (Bayesian implementations of generalized linear mixed model (GLMM), with results unweighted (MM.p.uw) and weighted (MM.p.w) by local elephant population estimate).

19. The unweighted marginal mean PIKE (the MM.p.uw approach) gives equal weight to each site, regardless of the underlying elephant population estimate in each MIKE site. The weighted marginal mean PIKE (the MM.p.w approach) weights each site's yearly PIKE value by the underlying estimated local elephant population estimate. Population data has been extracted from the 2016 African Elephant Status Report (Thouless et al., 2016) for African elephants; and population estimates provided by MIKE national focal points at subregional meetings were used for the Asian elephant populations at MIKE sites[1]. Weighting by elephant population estimate requires population estimates for each site and year. To fill in or "impute" missing survey values, a "last value carried forward" approach was adopted (Gelman and Hill, 2006). Thus, for each site, the last population survey estimate reported in the 2016 AESR is carried forward until the next survey estimate. For years prior to the earliest available survey, a reverse strategy is used - the earliest survey estimate is carried backward. It should be noted that the PIKE weighting by population estimate has been done on an experimental basis and requires further work that will be undertaken by the CITES Secretariat in collaboration with the MIKE-ETIS TAG. Future work may include looking at the impact of different imputation or interpolation methods, and uncertainty in the population estimates, for example.

20. To facilitate the transition to the new model, the PIKE trend analysis was calculated using the previous analytical approach [i.e. estimated marginal means (LSMeans) model], as well as the new approach using

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[1] Only one estimate for each MIKE sites in Asia was used for the weighted PIKE analysis for Asia.

Bayesian GLMM (unweighted and weighted by local elephant population estimate) and the results for all three approaches are provided in **Annex 1** of this report. The MIKE-ETIS TAG has recommended the use of the unweighted Bayesian GLMM to interpret PIKE trends over time until further work on weighted Bayesian GLMM has been finalized and assessed. In this report, the results of the estimated marginal means (LSMeans) model (previous approach) and the unweighted Bayesian GLMM (**MM.p.uw** – unweighted by elephant population estimate) (new approach) are shown in the same plot to facilitate the transition to the new analysis and to provide a visual comparison of the results (Figures 2, 3 and 5).

PIKE trend analysis for 2019: Africa

21. This section provides an update since CoP18, as well as the results of the new analysis. The report to CoP18 (CoP18 Doc. 69.2 and its Addendum) provided a trend analysis based on MIKE data that had been received up to the end of December 2018.

22. The data set used for this PIKE trend analysis for Africa consists of 20,712 records of elephant carcasses found between 2003 and the end of 2019 at 63 MIKE sites in 30 range States in Africa, representing a total of 711 site-years.

23. Compared to the analyses produced for CoP18, the PIKE trend analysis presented in this document considers an additional 1,294 records of elephant carcasses encountered in the course of 2019, that were submitted by 58 MIKE sites in Africa. The number of reporting MIKE sites has remained the same as in 2018 (58 sites submitted reports in 2018 and 2019) (see Figure 1A).

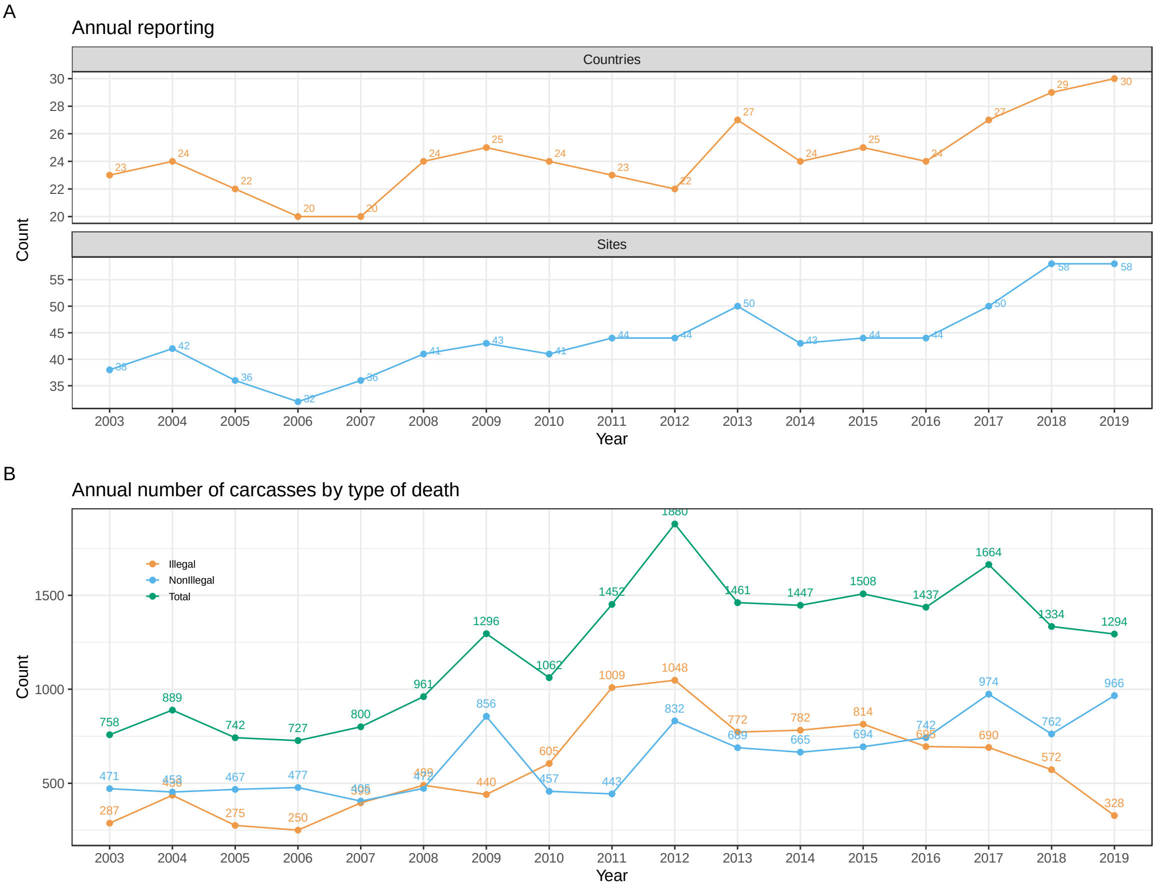

Figure 1: *A. Number of countries and MIKE sites that submitted reports (2003 – 2019). In 2019, the number of sites that reported from Central, Eastern, Southern and West Africa were 10, 15, 17 and 16 respectively. B. The total number of carcasses reported irrespective of cause of death (green), the number of carcasses of elephants illegally killed (orange) and the number not illegally killed (blue) (natural deaths, management related deaths and unknown type of death) reported by year.*

24. All MIKE sites in eastern and southern Africa submitted reports, while 10 sites in central Africa (63% of the sites in Central Africa), and 16 sites in west Africa (89% of the sites in West Africa) submitted reports for 2019. Of the sites that reported, three sites in central Africa and seven sites in west Africa reported zero carcasses found in 2019. Compared to 2018, 40 fewer elephant carcass records were submitted in 2019 (see Figure 1B). Three hundred and twenty-eight (328) of the 1,294 carcasses reported in 2019 were

recorded as illegally killed; while 572 of the 1,334 carcasses reported in 2018 were recorded as illegally killed.

25. As indicated in paragraph 20, the results of the estimated marginal means (LSMeans) model (previous approach) and the unweighted Bayesian GLMM (**MM.p.uw** – unweighted by elephant population estimate), are shown in the same plot to facilitate the transition to the new analysis and a visual comparison of the results (Figures 2 and 3).

Continental PIKE trend (Africa)

26. Figure 2 shows the continental PIKE estimate across years based on the estimated marginal means (LSMeans) (previous approach) and the unweighted Bayesian GLMM (**MM.p.uw**) (new approach). The error bar or the confidence/credible interval shows the level of uncertainty in the annual PIKE estimates. In Bayesian analysis, a 95 percent credible interval (CI) is an interval within which a PIKE estimate falls with a 95% probability.

27. The annual mean PIKE estimates based on the previous (LSMeans) and new approach (Bayesian GLMM) broadly follow the same pattern: PIKE generally increased from 2003 to 2010, peaked in 2011, and decreased from 2011 to 2019. The trendline for the unweighted Bayesian GLMM PIKE estimates (MM.P.uw) shows that there is sufficient evidence to confirm an upward trend (increase in PIKE) from 2003 to 2011, and a downward trend (decrease in PIKE) from 2011 to 2019 (see **Annex 2** for the table with details relating to the statistical support for the downward trend). Over the last five years (2015 to 2019), the unweighted continental PIKE estimate shows a downward trend with a level of certainty over 95%.

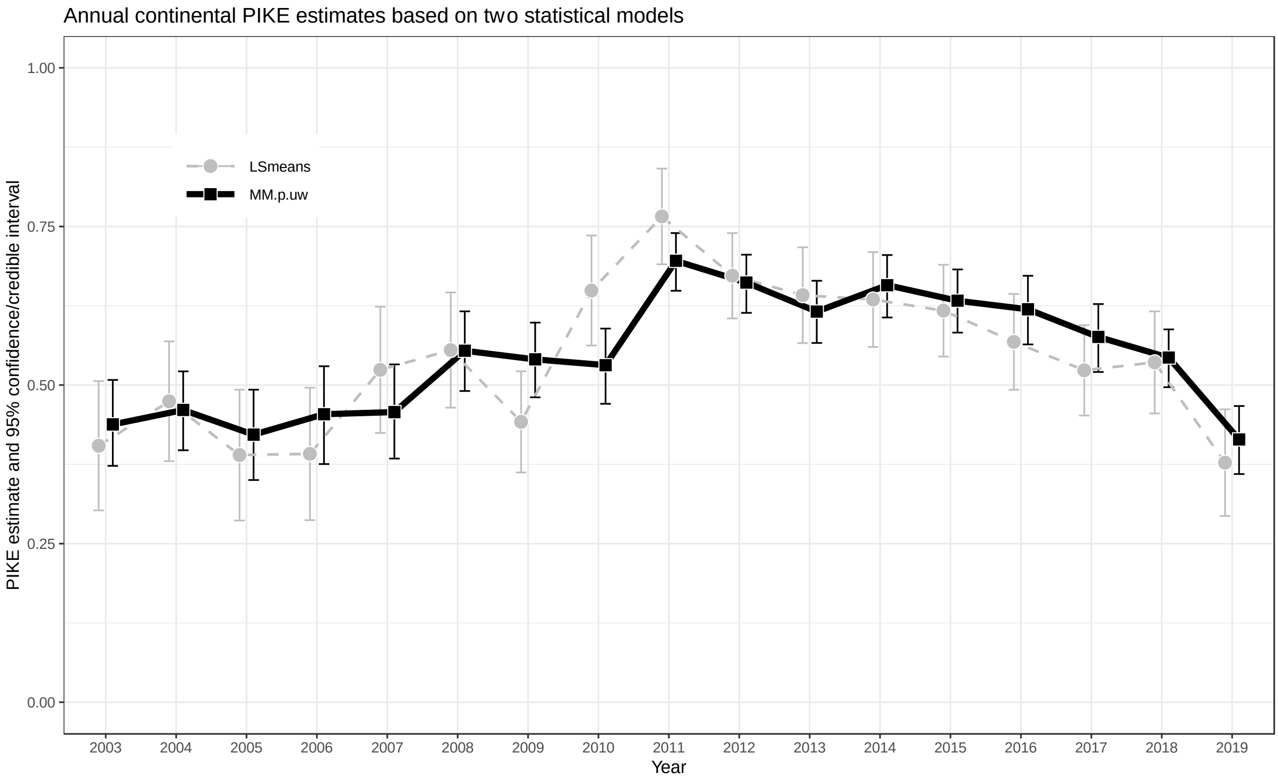

Figure 2: *Continental PIKE estimates based on the previous model (grey dashed line) (**LSMeans**) and the new Bayesian GLMM approach with results unweighted (**MM.p.uw**) by elephant population estimate (black solid line). The error bar or the confidence / credible interval shows the level of uncertainty in the annual PIKE estimates.*

Subregional PIKE trends (Africa)

28. While the continental PIKE trend has been decreasing since 2011, this is not the same for all four African subregions. Only for eastern and southern Africa, there is sufficient evidence to confirm a downward trend in PIKE. This however is not the case for central and west Africa, as discussed below. The downward trends in eastern and southern Africa were similar in magnitude and range, and it is highly probable that these two subregions contribute disproportionately to the continental downward trend and essentially driving the observed trend for the whole of Africa.

29. Figure 3 shows the subregional PIKE estimate across years based on the estimated marginal means (**LSMeans**) (previous approach) and the unweighted Bayesian GLMM (**MM.p.uw**)(new approach). The error bar or the confidence/credible interval shows the level of uncertainty in the annual PIKE estimates. In general, the annual mean PIKE estimates for the different subregions based on the previous (LSMeans) and new approach (Bayesian GLMM) broadly follow the same pattern. The estimated marginal means (LSMeans) (grey dashed line) for eastern Africa is however lower than the unweighted Bayesian GLMM and the reason for this relates to how PIKE from the MIKE sites are aggregated to estimate PIKE at the subregional level. The estimated marginal means (LSMeans) (previous approach) effectively totals the carcasses detected and the number of illegally killed elephants to the country level and then each country is given equal weight in estimating the subregional PIKE, while the Bayesian GLMM gives each site equal weight when estimating the subregional PIKE. Countries with more than one MIKE site were therefore given the same weight as countries with only one MIKE site in the previous approach (LSMeans) resulting in a lower trend. As indicated in paragraph 20 above, the MIKE-ETIS TAG recommended the use of the unweighted Bayesian GLMM (**MM.p.uw**) to interpret PIKE trends over time.

Central Africa

30. The PIKE estimates for central Africa are shown in Figure 3.A. Based on the unweighted Bayesian GLMM approach, there is strong evidence that the PIKE trend increased from 2003 to 2011 and remained at high PIKE levels up to 2019. The unweighted Bayesian GLMM for the last five years, shows neither an upward nor downward trend. The unweighted PIKE estimate in Central Africa remains high, with an average PIKE estimate of 0.74 (range: 0.67 - 0.80) over the last five years (Figure 3.A). Site specific PIKE trends in the subregion varies, with PIKE trend estimates over the last five years not showing strong evidence of either a downward or upward trend in PIKE at 11 of 14 sites that submitted data over the five years (78% of the MIKE sites that submitted data).

Eastern Africa

31. The PIKE estimates for eastern Africa are shown in Figure 3.B. Between 2003 and 2019, the highest PIKE estimate for the subregion was in 2011. Based on the unweighted Bayesian GLMM approach there is strong evidence of a downward trend in PIKE between 2011 and 2019. The trend shows that PIKE remained relatively unchanged from 2012 to 2015, followed by a 2-year downward trend until 2017. In the document submitted to CoP18 (Doc. 69.2 and its Addendum), it was reported that the subregional PIKE estimate for eastern Africa declined in 2017 largely due to a high number of natural mortalities in MIKE sites in Kenya caused by a major drought. Although PIKE could be biased downwards if the total carcass count is high because of adverse environmental conditions, such as drought (Burn et al., 2011), the 2019 unweighted Bayesian GLMM PIKE estimate (PIKE = 0.28, 95% CI [0.22,0.35]) is the lowest value since 2011 and based on the data is not attributed to increased natural mortalities from external factors such as droughts.

Southern Africa

32. The PIKE estimates for southern Africa are shown in Figure 3.C. Based on the unweighted Bayesian GLMM approach PIKE likely increased between 2003 and 2011 and subsequently decreased (between 2011 and 2019). Between 2015 and 2017 the PIKE estimate remained relatively unchanged, and a downward trend started in 2018 and continued in 2019. In the subregion, while some MIKE sites showed a downward trend in PIKE, others showed an upward trend in the last five years. Overall the trend in the last five years is downward due to a decrease in PIKE estimates in the last two years (2018 and 2019).

West Africa

33. The PIKE estimates for west Africa are shown in Figure 3.D. Low carcass counts for the subregion with the smallest African elephant population increases the high level of uncertainty of the PIKE estimates (i.e. the width of the credible intervals). Inferring a subregional trend is difficult, especially considering the high contribution to the total number of carcasses for the subregion from a single site, Pendjari Biosphere Reserve. Based on the unweighted Bayesian GLMM approach there is marginal evidence of a downward trend over the last five years. This however needs to be interpreted with caution. In 2019, a single site, Pendjari Biosphere Reserve (Benin), reported 48% of all the carcasses in the region. If the regional five-year trend is calculated from 2014 to 2018 (excluding the year 2019), then there is no indication of a downward trend in PIKE. Over the last five years, some west African MIKE sites showed a downward trend in PIKE, and others an upward trend.

34. Compared to the three other subregions, west Africa has the smallest elephant populations. It also reported the lowest total number of carcasses: 899 carcasses reported over 17 years (Figure 3. D).

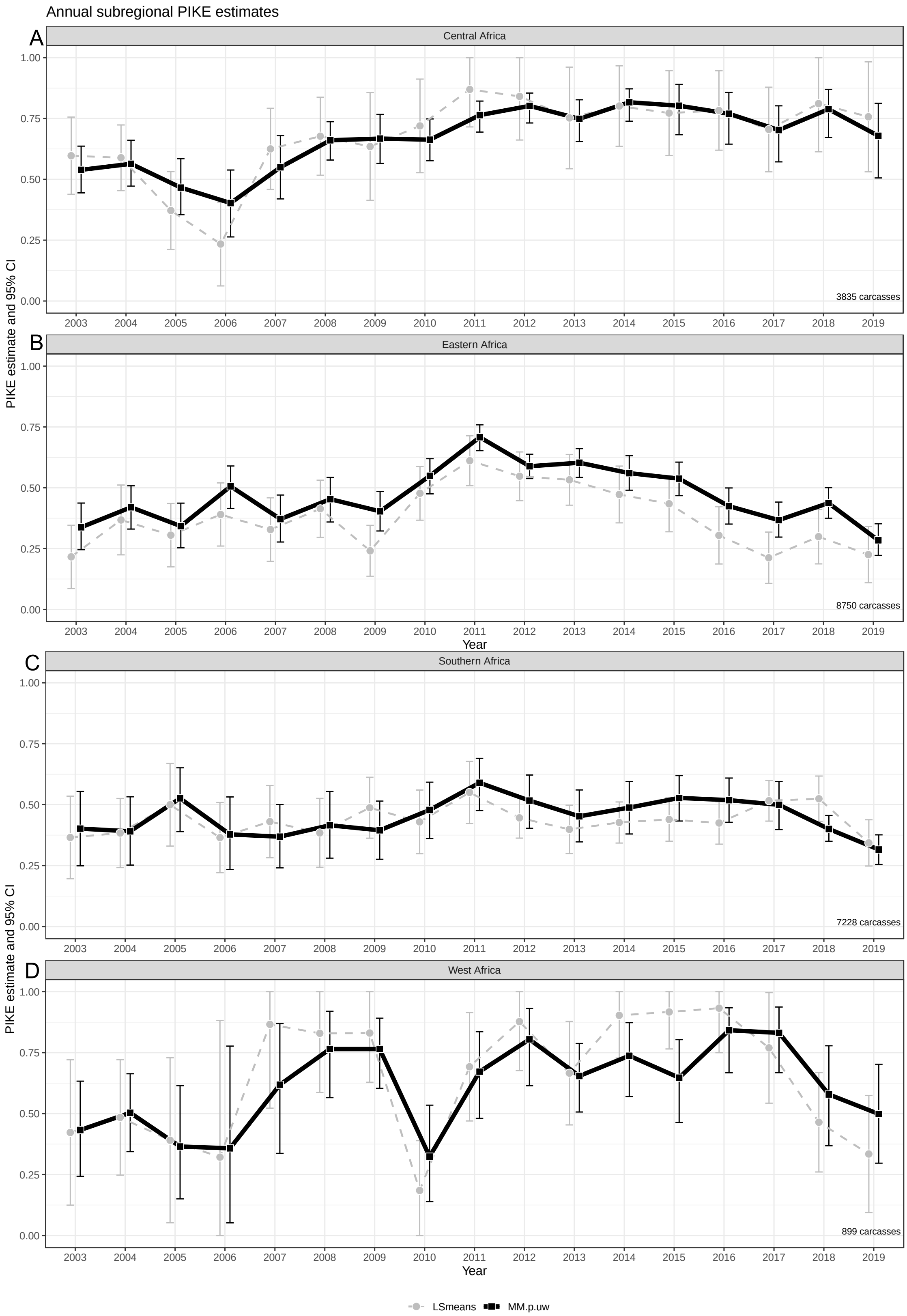

Figure 3: *Subregional PIKE estimates across years based on estimated marginal means (**LSMeans**) (previous approach – grey dashed line) and Bayesian GLMM (new approach – black solid line) for unweighted (**MM.p.uw**) by local elephant population estimates. The error bar shows the level of uncertainty in the annual PIKE estimates and represent 95% credible intervals. The total number of carcasses (from 2003-2019) for each subregion are shown at the bottom right corner of each graph. A – Central Africa; B – Eastern Africa; C – Southern Africa and D – West Africa.*

PIKE trend analysis: Asia

35. The CITES Secretariat reported on the levels and trends in illegal killing in Asia at CoP18 in document CoP18 Doc. 69.2. The MIKE sites in south east Asia submitted reports up to 2019 but unfortunately, carcass data for 2018 and 2019 for the MIKE sites in south Asia have not been submitted and therefore the most current trend analysis for Asia is from 2003-2017, using the most recent updated data in the MIKE online database.

36. It should be noted that the CITES MIKE Programme implemented a data reconciliation process when carcass data were transferred to the new MIKE Online Database, and that the analysis for this report is based on verified carcass records included in the database. The data set used for this analysis consists of 3,252 records of elephant carcasses found between 2003 and the end of 2017 at 29 MIKE sites in 13 range States in Asia, representing a total of 210 site-years (Figure 4 A).

37. Approximately 95% of the carcasses are from MIKE sites in south Asia, and the remaining 5% from MIKE sites in south east Asia. It should be noted that more than 70% of Asian elephants occur in south Asia. In 2016, 11 MIKE sites reported zero elephant carcasses detected and in 2017, 12 MIKE sites reported zero carcasses detected.

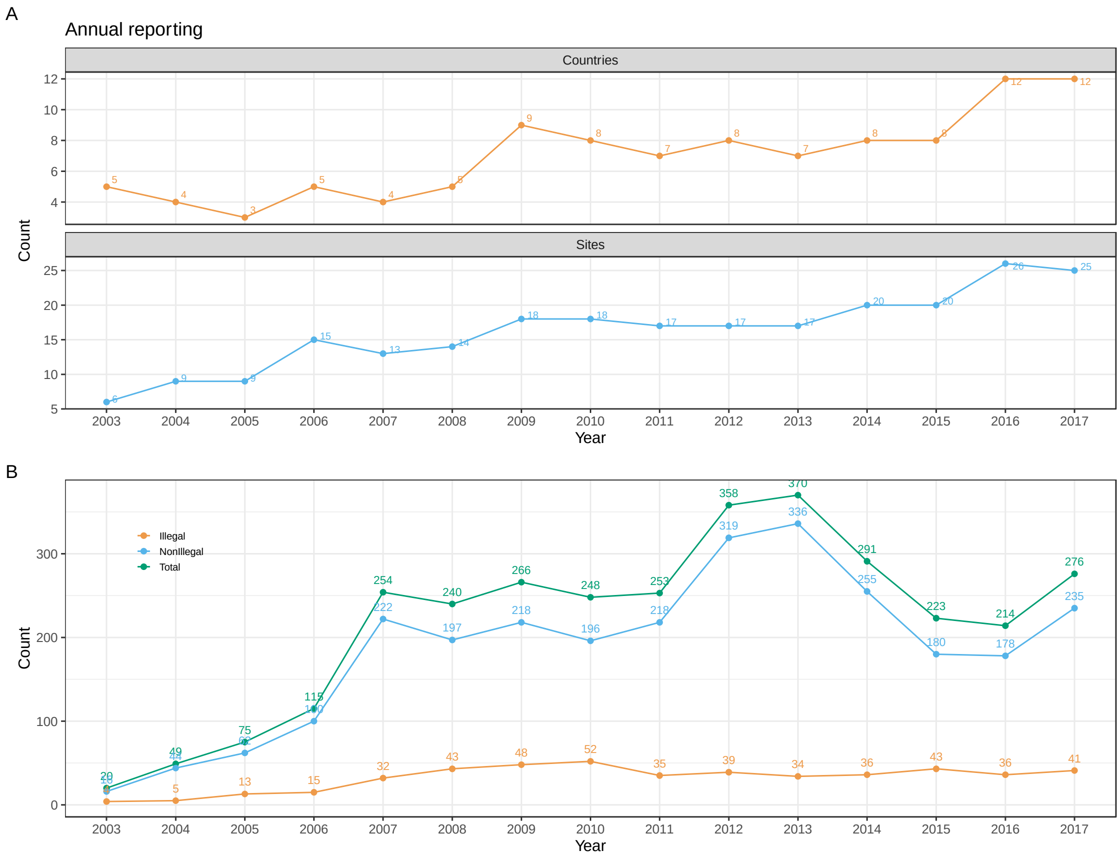

Figure 4: *(A) Total number of countries and sites that submitted reports by year. (B) The total number of carcasses reported irrespective of cause of death (green), the number of carcasses of elephants illegally killed (orange) and the number not illegally killed (blue) (natural deaths, management related deaths, unknown type of death) reported by year.*

38. Figure 5 shows the continental PIKE estimate across years based on the estimated marginal means (LSMeans) (previous approach); and the unweighted Bayesian GLMM (**MM.p.uw** - unweighted by elephant population size)(new approach). The error bars or the confidence/credible intervals shows the level of uncertainty in the annual PIKE estimates. In Bayesian analysis, a 95 percent credible interval (CI) is an interval which contains the true value with a 95% probability. The unweighted Bayesian GLMM (MM.p.uw) annual PIKE estimates tracks the estimated marginal means (LSMeans). The PIKE trend based on the unweighted Bayesian GLM in the last five years has remained relatively flat, with a PIKE value of 0.22 (95% CI [0.053, 0.488]).

39. A large discrepancy between the weighted and unweighted Bayesian GLMM annual PIKE estimates was found. The annual PIKE estimate from the unweighted Bayesian GLMM is consistently higher than the weighted Bayesian GLMM. This may be due to the fact there is only one elephant population estimate

currently used for the MIKE sites in Asia across all years. Consequently, the population estimates (imputed values) are constant from 2003-2017. This and other factors, including the large Asian elephant populations in MIKE sites in India that in general have low PIKE estimates, may contribute to why the weighted and unweighted Bayesian GLMM PIKE estimate differ, with the weighted Bayesian GLMM PIKE estimate lower than the unweighted estimate. As mentioned in paragraph 20 above, the PIKE weighting by population size has been done on an experimental basis and requires further work that will be undertaken by the CITES Secretariat in collaboration with the MIKE-ETIS TAG. Future work will include engaging range States to obtain more information relating to population estimates across years at each MIKE site.

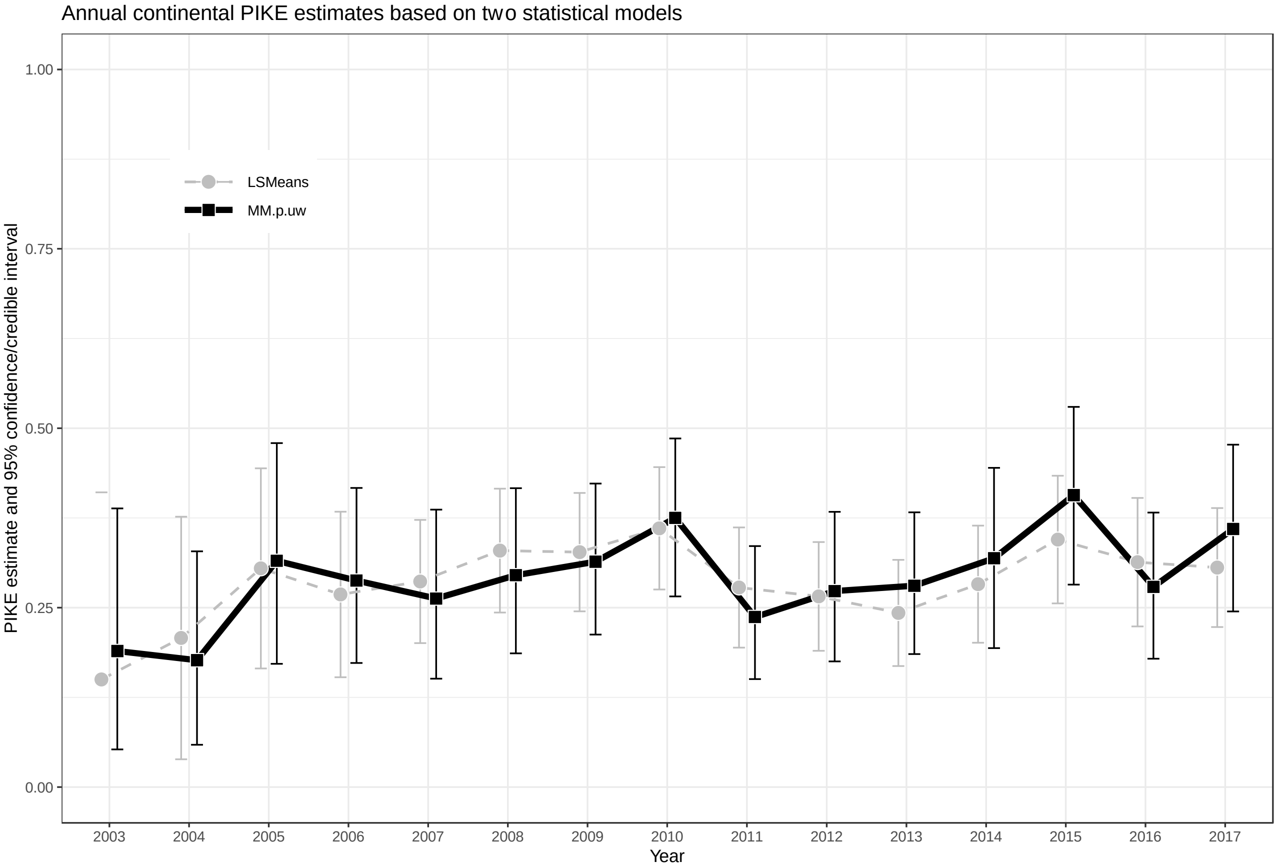

Figure 5: *Continental PIKE estimates based the previous model (**LSMeans**) and the new Bayesian approach (**MM.p.uw**).*

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Annex 1

RESULTS FOR PIKE TREND ANALYSIS USING LSMEANS AND BAYESIAN GLMM UNWEIGHTED AND WEIGHTED BY ELEPHANT POPULATION ESTIMATE

The figures in this Annex, shows the results for the PIKE analysis using the following three approaches:

i. estimated marginal means (LSmeans) (the model that has been used for previous reporting);
ii. Bayesian implementations of generalized linear mixed model (GLMM), with results unweighted by local elephant estimate (MM.p.uw); and
iii. Bayesian GLMM weighted (MM.p.w) with results weighted by loca elephant population estimate.

Figure A1-1 shows the continental PIKE estimate across years for Africa based on the estimated marginal means (LSMeans) (previous approach – orange graph) and the unweighted (**MM.p.uw**)(blue graph) and weighted (**MM.p.w**)(green graph) by local elephant population estimate Bayesian GLMM. The error bar or the confidence/credible interval shows the level of uncertainty in the annual PIKE estimates. In Bayesian analysis, a 95 percent credible interval (CI) is an interval within which a PIKE estimate falls with a 95% probability. The MIKE-ETIS TAG has recommended the use of the unweighted Bayesian GLMM to interpret PIKE trends over time until further work on weighted Bayesian GLMM has been finalized and assessed.

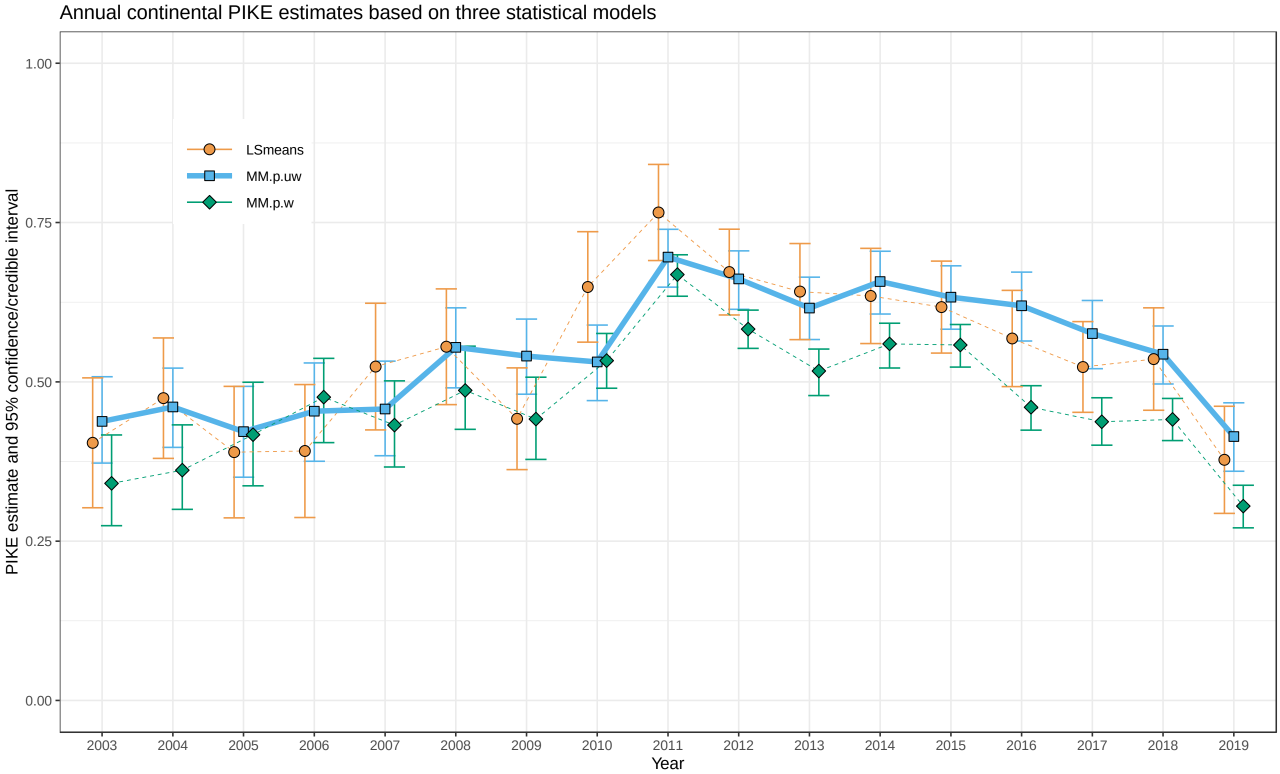

Figure A1-1: *Africa – Continental PIKE estimates based the previous model (orange) (**LSMeans**) and the new Bayesian GLMM approach with results unweighted (blue) (**MM.p.uw**) and weighted by elephant population estimate (green) (**MM.p.w**). The error bar or the confidence / credible interval shows the level of uncertainty in the annual PIKE estimates.*

Figure A1-2 shows the PIKE estimate across years for the subregions in Africa based on the estimated marginal means (**LSMeans**) (previous approach) and the unweighted (**MM.p.uw**), and weighted (**MM.p.w**) by local elephant population estimate Bayesian GLMM (new approach). The error bar or the confidence/credible interval shows the level of uncertainty in the annual PIKE estimates. In general, the annual mean PIKE estimates for the different subregions based on the previous (LSMeans) and new approach (Bayesian GLMM) broadly follow the same pattern. The estimated marginal means (LSMeans) (orange line) for eastern Africa is however lower than the unweighted and weighted Bayesian GLMM and the reason for this relates to how PIKE from the MIKE sites are aggregated to estimate PIKE at the subregional level. The estimate marginal means (LSMeans) (previous approach) effectively totals the carcasses detected and the number of illegally killed elephants to the country level and then each country is given equal weight in estimating the subregional PIKE, while the Bayesian GLMM gives each site equal weight when estimating the subregional PIKE. Countries with more than one MIKE site were therefore given the same weight as countries with only one MIKE site in the previous approach (LSMeans) resulting in a lower trend. As indicated in the report, the MIKE-ETIS TAG recommended the use of the unweighted Bayesian GLMM (**MM.p.uw**) to interpret PIKE trends over time.

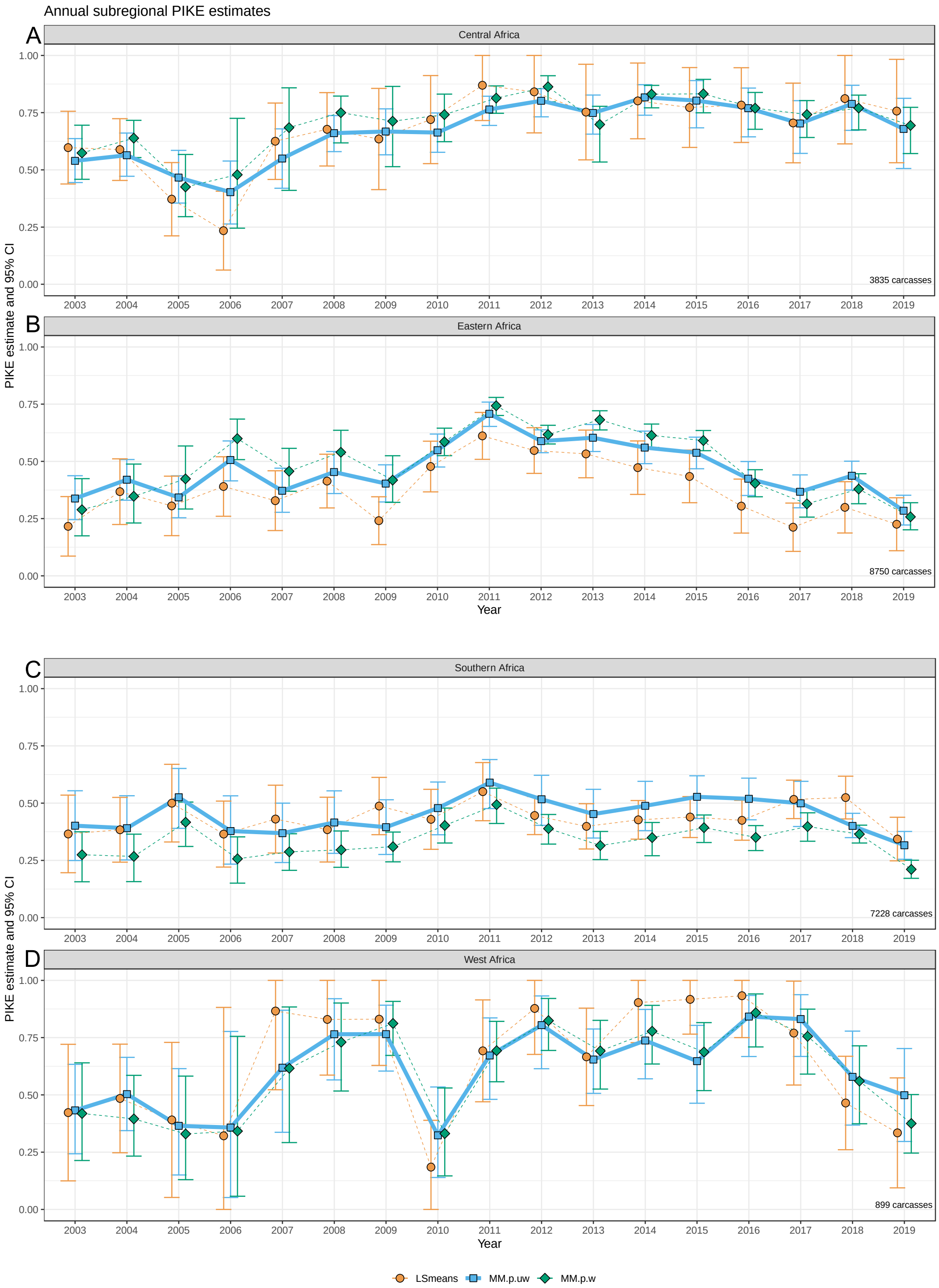

Figure A1-2: *Africa – Subregional PIKE estimates across years based on estimated marginal means (**LSMeans**) (previous approach-orange dashed line) and Bayesian GLMM for unweighted (**MM.p.uw**) (blue solid line), and weighted (**MM.p.w**) by local elephant population estimate (green dashed line). The error bar shows the level of uncertainty in the annual PIKE estimates and represent 95% credible intervals. The total number of carcasses (from 2003-2019) for each subregion are shown at the bottom right corner of each graph. A – Central Africa; B – Eastern Africa; C – Southern Africa and D – West Africa*

Figure A1-3 shows the continental PIKE estimate across years for Asia based on the estimated marginal means (LSMeans) (previous approach); and (ii) the unweighted (**MM.p.uw**), and weighted (**MM.p.w**) by local elephant population estimate for the Bayesian GLMM (new approach). The error bars or the confidence/credible intervals shows the level of uncertainty in the annual PIKE estimates. In Bayesian analysis, a 95 percent credible interval (CI) is an interval which contains the true value with a 95% probability. The unweighted Bayesian GLMM (MM.p.uw) annual PIKE estimates tracks the estimated marginal means (LSMeans). The PIKE trend based on the unweighted Bayesian GLM in the last five years has remained relatively flat, with a PIKE value of 0.22 (95% CI [0.053, 0.488]).

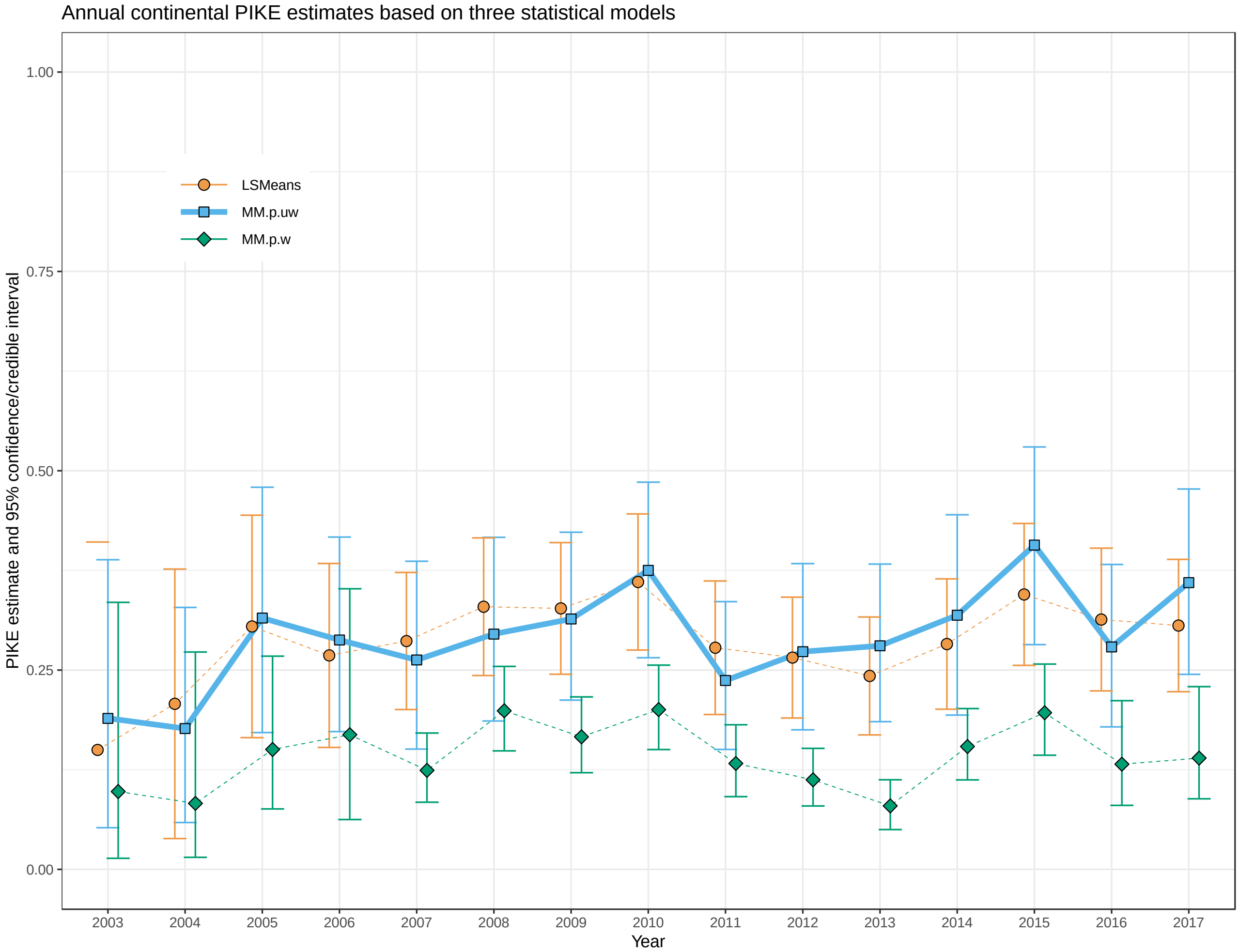

Figure A1-3: *Asia – Continental PIKE estimates based the previous model (orange) (**LSMeans**) and the new Bayesian GLMM approach with results unweighted (blue) (**MM.p.uw**) and weighted by local elephant population estimate (green) (**MM.p.w**). The error bar or the confidence / credible interval shows the level of uncertainty in the annual PIKE estimates.*

Annex 2

ESTIMATED TRENDS IN PIKE FROM UNWEIGHTED BAYESIAN GLMM BY REGION AND TIME PERIOD AND STATISTICAL SUPPORT FOR A DOWNWARD TREND

Region	Time period Years	Estimated slope (annual estimate of PIKE change) ($year^{-1}$)	95% Credible interval	Probability that trend is negative	Level of certainty associated with the reported trend (i.e. slope)
Africa	2003-2011	0.033	[0.027, 0.040]	0.0%	highly certain upward
	2011-2019	-0.016	[-0.023, -0.011]	99.9%	highly certain downward
	2015-2019	-0.051	[-0.068, -0.035]	99.9%	highly certain downward
Central Africa	2003-2011	0.038	[0.028, 0.049]	0.0%%	highly certain upward
	2011-2019	0.000	[-0.013, 0.012]	50.7%	uncertain of a trend
	2015-2019	-0.023	[-0.063, 0.015]	88.0%	uncertain of a trend
Eastern Africa	2003-2011	0.038	[0.029, 0.046]	0.0%	highly certain upward
	2011-2019	-0.034	[-0.041, -0.027]	99.9%	highly certain downward
	2015-2019	-0.049	[-0.069, -0.029]	99.9%	highly certain downward
Southern Africa	2003-2011	0.017	[0.004, 0.030]	0.005%	likely upward
	2011-2019	-0.013	[-0.023, -0.002]	99.0%	highly certain downward
	2015-2019	-0.054	[-0.079, -0.029]	99.9%	highly certain downward
Western Africa	2003-2011	0.038	[0.016, 0.059]	0.0%	highly certain upward
	2011-2019	-0.006	[-0.027, 0.014]	71.7%	uncertain of a trend
	2015-2019	-0.056	[-0.113, 0.002]	97.0%	likely downward
	2014-2018	-0.012	[-0.068, 0.043]	68.0%	uncertain of a trend

The slope estimate tells how much PIKE changes on average over a single year in a given time period. A negative value of the slope means that the trend is downward and positive value that the trend is upward. The credible interval gives the range of values the slope can possibility take with 95% certainty. The probability that the trend is downwards is based on a linear regression model of the posterior PIKE estimate over a specified time period. Probability of downward trend is highly certain when the probability value is greater than 99.9% (or 0% if the slope is positive), value of 97% is likely existing, and value of less than 95% is uncertain.