PIKE TREND ANALYSIS USING THE LEAST-SQUARES MEANS APPROACH

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Implementation in R

The R code for LS means approach for analyzing the Monitoring of the Illegal Killing of Elephants (MIKE) carcass data to derive continental and subregional proportion of illegal killing of elephants (PIKE) follows.

Preprocessing steps

Load the required libraries.

```
library(gplots) # for barplot2
library(doBy)   # for LSMEANS
library(dplyr)  # for data manipulation
library(knitr)
```

To simplify the coding, a function *PIKE.LSmeans* is defined. This user-defined function calculates LS means estimates, the 90% confidence interval, and trims the estimates so that they fall between 0-1.

```
#### Define function PIKE.LSmeans  #####

# ----------- Define SAS-type LS MEANS  -----------
PIKE.LSmeans <- function(lm.obj) {
  # Purpose: Define SAS-type LS MEANS
  # Purpose: Calculate  marginal means & ci for the effect year ("yr")
  # usage: lm.obj <- lm(pike~subregionid+yr,data=carcdat,weights=totcarc) or
  # usage: lm.obj <- lm(pike~ccode+yr, data = ....) for regional estimates
  # usage: To call function: PIKE.LSmeans(lm.obj)

  require(doBy) # load LSmeans() funtion

  # calcluate lsmeans estimates by year ("yr")
  lsmns <- LSmeans(lm.obj, c("yr"))

  # calculate the ci using 90% CI with infinite df
  upper.ci <- lsmns$coef[,1] + qnorm(.05,lower.tail=F)*lsmns$coef[,2]
  lower.ci <- lsmns$coef[,1] - qnorm(.05,lower.tail=F)*lsmns$coef[,2]


  # bound the upper & lower ci between 0-1
  upper.ci <- ifelse(upper.ci > 1, 1, upper.ci)
  upper.ci <- ifelse(upper.ci < 0, 0, upper.ci)

  lower.ci <- ifelse(lower.ci > 1, 1, lower.ci)
  lower.ci <- ifelse(lower.ci < 0, 0, lower.ci)

  # bound pike estimate to be positive
```

```
  lsmns$coef$estimate <-ifelse(lsmns$coef$estimate < 0, 0, lsmns$coef$estimate)

  # append ci to model results
  lsmns$coef <- cbind(lsmns$coef,lower.ci, upper.ci)
  lsmns
}
### end of functions
```

Import and prepare the data

For the analysis a single data file is required. It contains aggregated total number of carcasses and the total number that were illegally killed per year for a specific site. This data is publicly available from the following site: https://cites.org/eng/prog/mike/data_and_reports#MIKE%20Data%20Analysis

The data is read in using the *read.csv*() function and stored in a data frame (*carcdat*):

```
# set file name
file.name <- file.path("data/190307_PikeStatsUpTo2018FusionTableFormat.csv")
EC.df <- read.csv(file.name) # aggregated counts
```

As part of preparing the data the variable names are shorten and rows where the total number of carcasses equals zero are excluded. Data from 2003 and onwards is used in the analysis. The MIKE KSG and any sites that have reported only once, and the new MIKE site are not part of the analysis. $PIKE$ is calculated applying the following equation:

$$PIKE = \frac{\text{Number of carcasses killed illegally}}{\text{Total number of carcasses}}$$

and a new column *yr* (year) is assigned as a categorical variable. Finally, MIKE sites from Africa are selected.

```
carcdat <- rename(EC.df,
            siteid =  MIKEsiteID,
            illegal = NumberOfIllegalCarcasses,
            totcarc = TotalNumberOfCarcasses,
            subregionid = SubregionID,
            un_region = UNRegion,
            ccode = CountryCode)

# remove any rows where the total number of carcasses  reported is zero
carcdat <- filter(carcdat, totcarc>0)

# Select sites with  year > 2002
carcdat <- filter(carcdat, year > 2002)
# Select sites that have reported more than once (count > 1)
carcdat <- group_by(carcdat, siteid) %>% mutate(count=n()) %>%
           filter (count>1) %>%
           ungroup()
# JB: KSG infl. point removed
carcdat <- filter(carcdat, siteid != "KSG")

#new MIKE sites added in 2018: KFE, LGL, LZN, MAN, MJT, NLW and SMN
newMIKESites <- c("KFE","LGL","LZN","MAN", "MJT", "NLW", "SMN")
# exclude  newMIKEsites data for this analysis
carcdat <- filter(carcdat, !(siteid %in% newMIKESites))
```

```
# prepare data -  convert year to factor and calculate PIKE index
carcdat$yr   <- as.factor(carcdat$year)
carcdat$pike <- carcdat$illegal/carcdat$totcarc # PIKE index

#copy the data to  data frame carcdat.all
carcdat.all <- carcdat

# Select MIKE sites in Africa
carcdat  <- carcdat[carcdat$un_region=='Africa',]
carcdat  <- droplevels(carcdat)
```

Continental PIKE Estimate for Africa

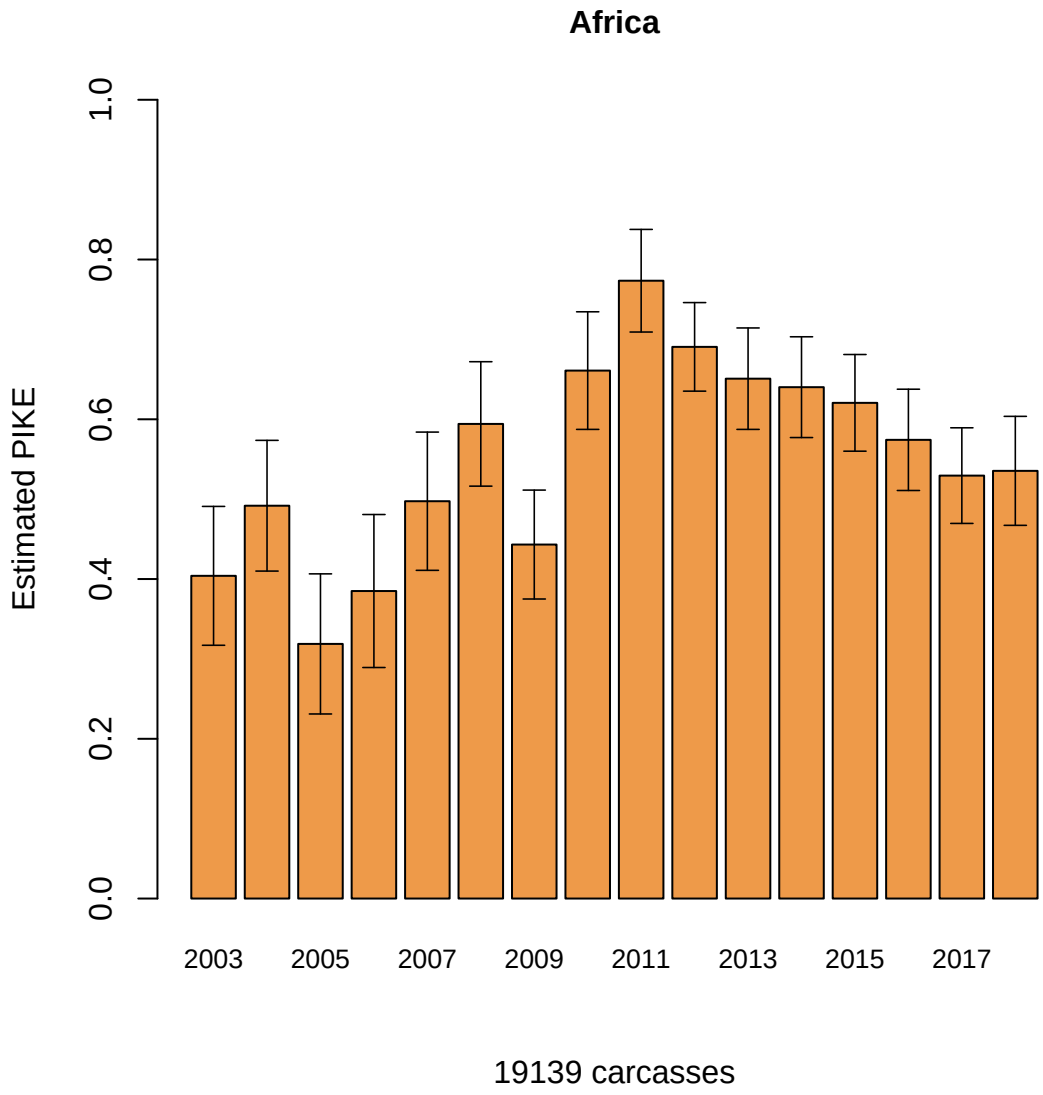
Apply the LS means to the weighted linear regression model, where PIKE is the response variable and year (yr) and sub-region (subregionid) are factors. The weights in the linear model are the total number of carcasses (totcars). The LS means $PIKE$ estimates are saved in file "output/af_lsmns_90CL.csv".

```
#  weighted linear regression model with covariates subregion and year,
#  weighted by total number of carcasses
af.lm <- lm(pike ~ subregionid + yr, data=carcdat, weights=totcarc)

# call PIKE.LSmeans function, see above
af_lsmns <- PIKE.LSmeans(af.lm)

# write LS means coefs to disk
res <- data.frame(region="Africa", af_lsmns$coef,  af_lsmns$grid)
write.table(res,"output/af_lsmns_90CL.csv", sep=',', row.names=F)
```

Plot continental trend

Plot of the continental wide PIKE estimate and its 90% confidence interval across years.

```
par(mfrow=c(1,1))
# include the total number of carcases in the subtitle
subtitle <- paste(sum(carcdat$totcarc), 'carcasses', sep=' ')

barplot2(af_lsmns$coef[,1], names.arg=af_lsmns$grid[,1],
         plot.ci=TRUE,
         ci.l=af_lsmns$coef[,6],
         ci.u=af_lsmns$coef[,7],
         main="Africa",
         sub=subtitle,
         ylim=c(0,1), cex.main=1, cex.names=0.8,
         cex.axis=1.0, ci.lwd=.8,
         ylab='Estimated PIKE', col="tan2")
```



Subregional PIKE estimates

The PIKE estimate of a subregion model includes year and country, where country refers to the location of the MIKE site and the weights are the total number of carcasses. For each subregion, the LM means predictions, across countries, give the annual PIKE estimate and its confidence bands. The PIKE estimates are saved in the file "output/sr_lsmsn.csv".

The four subregions in Africa are coded as: FC - Central, FE - Eastern, FS - Southern, FW - West

```
##### Subregional LS means weighted by sample size #####
fc.data  <- carcdat[carcdat$subregionid=='FC',] #subset data
fc.lm    <- lm(pike~ccode+yr, data=fc.data, weights=totcarc)
fc_lsmns <- PIKE.LSmeans(fc.lm)

fe.data  <- carcdat[carcdat$subregionid=='FE',]#subset data
fe.lm    <- lm(pike~ccode+yr, data=fe.data, weights=totcarc)
fe_lsmns <- PIKE.LSmeans(fe.lm)

fs.data  <- carcdat[carcdat$subregionid=='FS',]#subset data
```

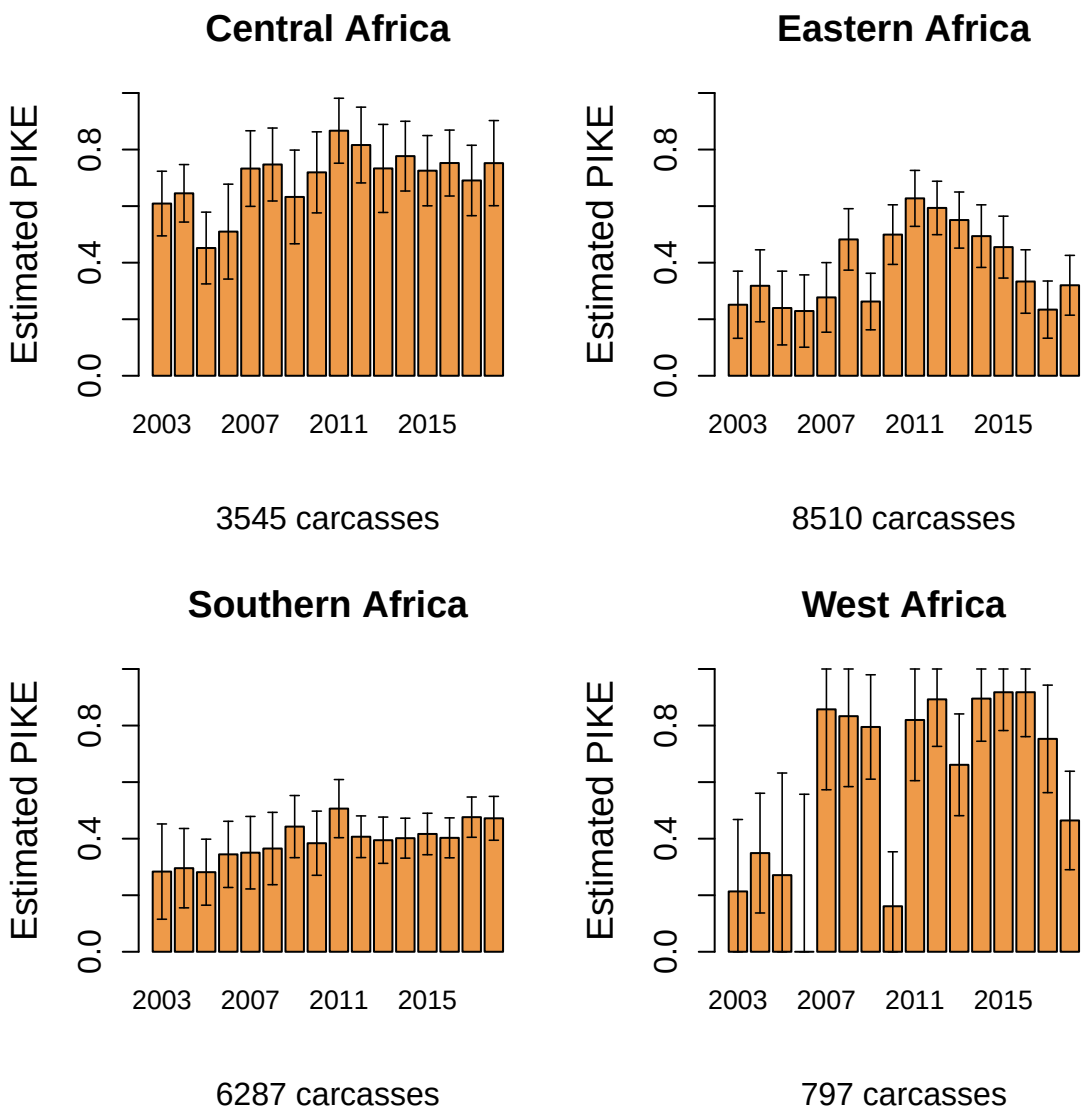
```
fs.lm    <- lm(pike~ccode+yr, data=fs.data, weights=totcarc)
fs_lsmns <- PIKE.LSmeans(fs.lm)

fw.data  <- carcdat[carcdat$subregionid=='FW',]#subset data
fw.lm    <- lm(pike~ccode+yr,data=fw.data, weights=totcarc)
fw_lsmns <- PIKE.LSmeans(fw.lm)

#create subregional ids: fc, fe, fs & fw
fc_id <- rep("fc",times=length(fc_lsmns$grid$yr))
fe_id <- rep("fe",times=length(fe_lsmns$grid$yr))
fs_id <- rep("fs",times=length(fs_lsmns$grid$yr))
fw_id <- rep("fw",times=length(fw_lsmns$grid$yr))

#save the lsmeans coefs for fc,fe,fs & fw regions. Note, fc_lsmns$grid
#contains the years
sr_lsmns <- rbind(
  cbind(subreg=fc_id, as.data.frame(fc_lsmns$coef), fc_lsmns$grid),
  cbind(subreg=fe_id, as.data.frame(fe_lsmns$coef), fe_lsmns$grid),
  cbind(subreg=fs_id, as.data.frame(fs_lsmns$coef), fs_lsmns$grid),
  cbind(subreg=fw_id, as.data.frame(fw_lsmns$coef), fw_lsmns$grid)
  )

# write subregional lsmeans coefs to a file
write.table(sr_lsmns,"output/sr_lsmsn_90CL.csv",sep=',',row.names=F)
```

Plot subregional trends

Plot trends for Central, Eastern, Southern and West Africa.

```
#plot the subregional results using the function barplot2() from the gplots package.
par(mfrow=c(2,2))

barplot2(c(fc_lsmns$coef[,1]), names.arg=fc_lsmns$grid[,1],
         plot.ci=TRUE,
         ci.l=c(fc_lsmns$coef[,6]),
         ci.u=c(fc_lsmns$coef[,7]),
         main="Central Africa",
         sub=paste(sum(fc.data$totcarc),'carcasses',sep=' '),
         ylim=c(0,1),
         cex.main=1.4, cex.names=1.0, cex.axis=1.2,
         ci.lwd=.8, cex.lab=1.4, cex.sub=1.2,
         ylab='Estimated PIKE', col="tan2")


barplot2(fe_lsmns$coef[,1], names.arg=fe_lsmns$grid[,1],
         plot.ci=TRUE,
         ci.l=fe_lsmns$coef[,6],
         ci.u=fe_lsmns$coef[,7],
         main='Eastern Africa',
         sub=paste(sum(fe.data$totcarc),'carcasses',sep=' '),
         ylim=c(0,1),cex.main=1.4,cex.names=1.0, cex.axis=1.2,
         ci.lwd=.8, cex.lab=1.4, cex.sub=1.2,
         ylab='Estimated PIKE',col="tan2")
```

```
barplot2(fs_lsmns$coef[,1], names.arg=fs_lsmns$grid[,1],
         plot.ci=TRUE,
         ci.l=fs_lsmns$coef[,6],
         ci.u=fs_lsmns$coef[,7],
         main='Southern Africa',
         sub=paste(sum(fs.data$totcarc),'carcasses',sep=' '),
         ylim=c(0,1),cex.main=1.4,cex.names=1.0, cex.axis=1.2,
         ci.lwd=.8, cex.lab=1.4, cex.sub=1.2,
         ylab='Estimated PIKE', col="tan2")


barplot2(fw_lsmns$coef[,1], names.arg=fw_lsmns$grid[,1],
         plot.ci=TRUE,
         ci.l=fw_lsmns$coef[,6],
         ci.u=fw_lsmns$coef[,7],
         main='West Africa',
         sub=paste(sum(fw.data$totcarc),'carcasses',sep=' '),
         ylim=c(0,1),cex.main=1.4,cex.names=1.0, cex.axis=1.2,
         ci.lwd=.8, cex.lab=1.4, cex.sub=1.2,
         ylab='Estimated PIKE',col="tan2")
```



Continental PIKE Estimate for Asia

Select data for MIKE sites in Asia and follow the same LS means procedure for Africa.

```
# Select data for MIKE sites in Asia

carcdat  <- carcdat.all[carcdat.all$un_region=='Asia',]
carcdat  <- droplevels(carcdat)

# Asia lm model
as.lm    <- lm(pike~subregionid+yr, data=carcdat, weights=totcarc)

# see PIKE.LSmeans function above
as_lsmns <- PIKE.LSmeans(as.lm)

# write LS means coefs to disk
res <- data.frame(region="Asia", as_lsmns$coef, as_lsmns$grid)
write.table(res,"output/as_lsmns_90CL.csv", sep=',', row.names=F)
```

Plot PIKE trend for Asia.

```
par(mfrow=c(1,1))

subtitle <- paste(sum(carcdat$totcarc), 'carcasses', sep=' ')

barplot2(as_lsmns$coef[,1], names.arg=as_lsmns$grid[,1],
         plot.ci=TRUE,
         ci.l=as_lsmns$coef[,6],
         ci.u=as_lsmns$coef[,7],
         main="Asia",
         sub=subtitle,
         ylim=c(0,1),
         cex.main=1, cex.names=0.8, cex.axis=0.8, ci.lwd=.8,
         ylab='Estimated PIKE', col="tan2")
```