Seasonal Births in Sub-Saharan Africa

Abstract:

Despite our ability to breed continuously, human populations often exhibit seasonal variation in reproduction. Seasonality of births has been extensively studied in North America, Europe, and East Asia but less so in African settings. Using the Demographic and Health Surveys, we document, test, and compare birth seasonality in Sub-Saharan Africa. For certain countries (with large sample sizes), we also look at within country variation by ethnicity, religion, and region. We also look at whether or not birth seasonality has declined within the past three decades. We also validate the DHS results with birth data obtained from other sources such as censuses. Thus far we find a wide range of seasonal patterns and different amplitudes, with the largest seasonal birth amplitudes concentrated in West Africa.

Introduction:

Despite our ability to breed continuously, human populations often exhibit seasonal variation in reproduction. As a result, the study of birth "seasonality or amplitude, *i.e.* the numerical difference between the percentage deviations of the maximum and minimum number of births from the annual mean for any given year" has a long history (Cowgill, 1966 page 233). But the geographic scope of these studies has been mostly limited to North America, Europe, and East Asia (Cowgill, 1966; Roenneberg and Aschoff, 1990; Arcury *et al.*, 1990; Lam and Miron, 1991; Becker, 1991; Manfredini, 2009). Study of birth seasonality in sub-Saharan Africa has been hampered by the lack of vital registration data (Bantje 1987; table 1). Furthermore, research was focused in regions that exhibited great seasonal variation in temperatures (Ferguson, 1987). The research we present in this paper will help close the gap and provide contemporary documentation of the seasonal pattern of births in sub-Saharan Africa.

Interest in birth seasonality is in part generated by the plethora of articles looking at the relationship between birth month and later life outcomes such as infant mortality, life expectancy, female fecundity, educational attainment, and wages (Dobhammer and Vaupel, 2001; Moore *et al.*, 1997; ADD MORE CITATIONS). Many of these studies assume that month or quarter of birth is randomly distributed across the population, but at conception these children may already be different if there are differences in seasonal fertility patterns across women (Buckles and Hungerman, 2010). As Buckles and Hungerman point out "seasonality in outcomes might reflect inherent differences in personal attributes or family background" (Buckles and Hungerman, 2010, page 1). For instance, Moore *et al.* (1997) found that children born during the hungry season in rural Gambia had excess mortality in young adulthood compared to those born during the harvest season. The authors concluded that early life exposures correlated with birth season may be driving this effect, however, since these authors did not first look to see if season of birth differed across women or add controls for maternal characteristics, we don't know if it is the neonatal exposures or the maternal characteristics that's driving their findings. To address this issue, our research also looks at birth seasonality across different maternal characteristics, thereby highlighting the instances where lack of controls for maternal characteristics may lead to biases in the study of birth month and later life outcomes in SSA.

Finally, the seasonal pattern of births and its amplitude have important implications for infectious disease dynamics; specifically it induces seasonal variations in the proportions of susceptibles and can be one of the mechanisms responsible for observed seasonal epidemic patterns of many childhood infectious diseases.

Objective:

This paper is primarily descriptive, aiming to document birth seasonality in SSA in more detail than previously. We first present a review of the literature on birth seasonality in Sub-Saharan Africa (SSA); next we use birth data from the Demographic and Health Surveys (DHS), to systematically document, test, and compare birth seasonality in SSA. Where possible, we disaggregate the data by socioeconomic status, region, ethnicity, and religion to see if birth month is correlated with aspects of family background. Declining birth seasonality has been documented in many countries; therefore we also look at whether or not SSA birth seasonality has declined within the past three decades. The findings will help shape our hypotheses on drivers of birth seasonality presented in a subsequent paper (Dorelien, 2011). We also compare the DHS results with other more traditional sources of birth data such as those from census data where available. The DHS has not been used to document birth seasonality per se, but Pitt and Sigle (1997) and Artadi (2005) in unpublished manuscripts both use DHS birth data to model whether labor demand and consumption and labor demand and child survival could help explain seasonal fertility patterns, respectively.

Research Questions:

1. Are births periodic in SSA?
2. What are the amplitudes and phases of birth seasonality in SSA?
    a. Country analysis versus ecological zones
3. Has birth amplitude declined over time in SSA?
4. Does birth seasonality vary across SES, ethnicity, and religion?

Literature Review:

Seasonal patterns of birth vary by regions. Throughout the 20th century the United States had a bimodal distribution of birth. The first peak in births occurred from

February-March and the second larger peak occurred from August-September. This pattern persisted despite increasing urbanization and contraceptive use. It isn't until the past 20 years that the February-March peak and April trough have disappeared (Meade and Earickson, 2000). [1] Historically the European pattern consisted of a global peak in the spring (usually around April) and a secondary local peak in September. However, in the most recent decades, the seasonality of births in many European countries has begun to follow the American pattern with one main peak in September (Manfredini, 2009).

A general African birth pattern has not yet been identified; therefore we summarize the limited number of papers describing birth seasonality in a sub-Saharan African setting (SSA).

South Africa- Lam and Miron (1991) described birth seasonality in South Africa from 1950 to 1984. The data was disaggregated into white and black births. Blacks births peaked in September and had a trough in May. The birth amplitude was approximately 10 percent. Birth seasonality for white South Africans was much less pronounced, the amplitude was less than five percent, but they also exhibited a September peak. Cowgill (1966), using South African birth data from 1935 to 1958, described the same pattern.

Kenya- Using birth data from January 1979 to June 1982, Ferguson was able to identify a national pattern consisting of a strong peak in September and a secondary peak from April-May. The September amplitude ranged fro 11 to 21 percent above monthly average. This study may suffer from significant selection bias—Ferguson's data came from district birth registers, but in many districts only a small fraction of births were registered during that time period. In contrast to the national pattern, a very high degree of birth seasonality for births occurring between 1958 and 1983 was found for the

[1] The April trough is still present in the Black American population.

Ngisonyoka Turkana in Northwest Kenya (Leslie and Fry, 1989). More than half of the births in the Ngisonyoka Turkana occurred between March and June and the peaks were generally observed in April and May (amplitude ~56 percent). It is important to note that for the Leslie and Fry data, the sample size was 495 births, and the Turkana did not have any written birth records so the information was collected from interviews to create reproductive histories.

Tanzania- Bantje (1987) compiled birth data from nine rural hospitals throughout Tanzania. Depending on the location, the births occurred between the 1940s and 1985. Only four locations exhibited clear seasonal patterns. In these regions, which happened to all be holoendemic[2], the peaks occurred between September and November with an amplitude of approximately 26 percent.

Zaire- (Bailey *et al*., 1992).

These studies indicate that seasonal patterns do exist in SSA, and that the amplitude can vary from 5 to 56 percent depending on the population. The highest birth amplitudes were observed in pastoral setting, and in areas of high malaria transmission. However it is difficult to determine if a consistent "African" pattern emerges.

Demographic and Health Surveys Data:

The birth data used in this study come from the Demographic and Health Surveys (DHS). The DHS are nationally representative surveys of women of childbearing age carried out in developing countries. We have two samples in our study, one sample includes every available SSA survey in our study (81 surveys, 31 countries), and another that only includes surveys with geographic coordinates (47 surveys, 25 countries) (see

[2] Holoendemic – transmission occurs year-long.

appendix for list of countries). We are able to use the DHS, because every women aged 15-49, was asked the month and year of birth of every child they have ever had (complete reproductive history). Therefore, even though the majority of the surveys were taken starting in the 1990s, we are able to have birth information on children born in the eighties and even earlier. In addition to the month and year of birth data we also extract the following variables from the DHS- birth order number, region, rural/urban classification, ethnicity, religion, sex, whether or not the child is alive, and age at death of deceased children. Furthermore the geocoded surveys allow us to merge the DHS data with other spatial datasets in order to attain additional covariates.

Sampling Weights

Due to design and happenstance, the probability of cases being selected and interviewed to be included in the DHS are not equal (DHS website). Therefore sampling weights are available to adjust for these differences, and should be used when tabulating cases. The primary sampling unit of the DHS is the cluster. We use the DHS sampling weights in our analysis.

DHS Data Quality

Survey data can be prone to incomplete and inconsistent observations. Therefore, in addition to including many probes in the survey questionnaire, the DHS uses multiple imputations to deal with incomplete observations. According to the DHS imputation strategy, the birth date (birth month and birth year) of the observations with missing data are first constrained to a certain logical range, then based on additional constraints (information about breast feeding and etc.) the range is further constrained to a minimum interval of seven months. Finally, a random imputation method is used to assign the imputed date within the constrained ranged (Croft, 1990).

Observations with imputed birth month and or birth year are dropped from our sample. The numbers of imputed observations ranged from less than a percent to 60 percent in some countries, but on average 12 percent of the observations are dropped (see appendix). The imputed/dropped observations are more likely to be of older and dead children (recall error), from rural areas, and of children born of uneducated mothers. In developed countries birth seasonality often varies with wealth/education and seasonality is mostly driven by poorer households. So for regions with large amounts of imputed observations, we may underestimate the magnitude of birth seasonality.

Although we have a complete birth history for each woman, there may be some recall error. A woman's recollection of the date of birth may be more accurate for births that occur within five or ten years of the interview date. It is also possible that mother's are less likely to include children that have died (especially as infants) in their survey responses. This is problematic because in many countries some birth months are associated with excess infant mortality (Artadi, 2005; Kynast-Wolf *et al.*, 2006; Meade and Earickson, 2000; (we also find this using the DHS data)). *What is the direction of the bias?* The DHS collects information on age at which the child died. Using this information we find that children who died as infants have similar birth seasonality patterns as children who survive infancy; however in some locations peak infant survival month mirrors peak birth month meaning that there could be a small inflation in peak birth amplitude due to the exclusion of children whom have died.

Finally, although we focus on birth month, we are also implicitly looking at seasonality of conceptions. While the date of birth may be accurate, multiple births and pre-term births may introduce errors in our estimates of conception month. Approximately 12 percent of births in Africa are pre-term (Beck *et al*., 2010). Multiple births account for a little more than three percent of our sample.

FAO Ecological Zone Data:

If birth seasonality is primarily driven by environmental factors, describing seasonal births patterns at a country level may be nonsensical, especially for large countries. Therefore, from the Food and Agricultural Organization (FAO), we obtain a map of the different ecological zones/farming systems in Sub-Saharan Africa (figure 1). The classification is based on-

- available natural resource base, including water, land, grazing areas and forest; climate, of which altitude is one important determinant; landscape, including slope; farm size, tenure and organization;
- dominant pattern of farm activities and household livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities (Dixon *et al*., 2001, page 11)

The 14 ecological zones are- irrigated, tree crops, forest based, rice and tree crops, highland perennial, highland temperate mixed, root crop, cereal root crop mixed, large commercial smallholder, agro-pastoral, pastoral, arid, and coastal fishing. A more detailed description of the different zones can be found in the Dixon *et al.* book, *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World*. In instances where the ecological zones are not contiguous and are located in distant regions we divide the zones. For instance, the agro-pastoral zone is divided into East and West

Africa. The geocoded DHS clusters are spatially merged with the ecological zones, so that birth seasonality can also be analyzed at these scales (figure 2).

Methods:

We perform the analysis by aggregating births by country and ecological zones. We follow the method in He and Earn (2007) for the de-trending and scaling of the monthly birth data.[3] The following equations are used-

$$(1)\ \langle X \rangle_i = \frac{1}{12}\sum_{j=1}^{12} X_{ij}$$

$$(2)\ c_{ij} = \frac{(\text{Days in year } i)/12}{\text{Days in month } j \text{ of year } i}$$

$$(3)\ Y_{ij} = \frac{c_{ij}X_{ij} - \langle X \rangle_i}{\langle X \rangle_i}, i = 1980,....,2000\ j = 1,...,12.$$

$$(4)\ Z_j = \frac{1}{N_{yr}}\sum_{j=1980}^{1990} Y_{ij},\ j = 1,...,12 \text{ and } N_{\text{yr}} = 10.$$

The raw monthly births obtain from the DHS is represented by X_{ij}. The first equation represents the average number of births in a month of average length in year *i*. The second equation is the scaling factor to correct for the different lengths of each month in each year. The third equation is the scaled, month-length-corrected monthly amplitude.[4] Finally, the fourth equation is the average monthly amplitude, which is achieved by averaging monthly amplitude across years. For each of the countries in our data set we plot the raw monthly births (X_{ij}), the monthly amplitude (Y_{ij}), and the average monthly amplitude (Z_j) for 1980-1990 and 1990-2000 (see figure 3). We calculate the periodicity

[3] An alternative strategy is to use the Lam and Miron (1994) method- "The seasonal patterns are estimated using regressions of detrended births on dummy variables for each month. The number of births per month is divided by the number of days in the month to adjust for the length of the month. Monthly births are detrended by taking the ratio of births in a month to the centered 12-month average"(page 11).

[4] From the equation, it's clear that the amplitude is the percent difference from the annual mean.

of the scaled, corrected time series data from 1980 to latest available date (equation 3) using spectral analysis (Torche and Corvalan, 2010; and He and Earn, 2009). The spectral analysis was performed using the R *spectrum* function (figure 4).

Results:

Country level results:

Births in most countries in Sub-Saharan Africa are seasonal; however there do appear to be clusters of countries—Togo, Malawi, Zambia, Zimbabwe, Swaziland, and South Africa— that don't have regular recurring intra-annual fluctuations. The lack of clear seasonal pattern in Togo may be due to the fact that 38 percent of the observations were dropped. For Swaziland, and South Africa only one DHS is available, therefore the number of observations was not large; so if birth seasonality does exist and is weak it may be overwhelmed by stochastic fluctuations. Malawi, Zambia, and Zimbabwe each have three to four surveys and have very few imputed observations, so the lack of seasonality may be real.

Three patterns of birth seasonality emerge. Birth seasonality is mainly unimodal in Burkina Faso, Cameroon, Congo, Congo DR, Gabon, Ghana, Guinea, Ivory Coast, Liberia, Madagascar, Mali, Nigeria, Rwanda, and Sierra Leone. With the exception of Madagascar, these are all countries in West and Central Africa. Births are bimodal in Benin, Chad, Ethiopia, Mozambique, Niger, and Senegal. For Kenya, Tanzania, Uganda, Namibia, and, although the spectral analysis indicates presence of an annual pattern, the shape of the pattern is not easily described, but they all have a trough in November. Finally, for Lesotho and the countries with no clear birth seasonality, Malawi, South

Africa, Swaziland, Zambia, and Zimbabwe, the pattern is generally flat (figure 6a-e, periodogram results available upon request).

The average maximum monthly amplitude[6] ranges from 5 to 65 percent. The largest amplitudes are found along the West African Coast. The following countries have peak amplitudes of ~ 40 percent or above- Guinea, Sierra Leone, Ivory Coast, Nigeria. With a few exceptions the other countries on the West African Coast had peak birth amplitudes of ~ 30 percent. The Democratic Republic of Congo, and Rwanda in Central Africa also exhibited large peak amplitudes (figure 5 and 6).

Disaggregating the results by mother's educational attainment- we find that women with different educational backgrounds don't have the same fertility patterns. In the majority of countries in our sample, mothers with no education and or only primary education drive birth seasonality. On the other hand, in Burkina Faso and Senegal, the seasonal fertility patterns of women with no education are relatively flat compared to those with education.

<u>Ecological zone results:</u>

Births are also periodic when we aggregate across ecological zones. The largest birth amplitudes are found in pastoral and forest based farming systems, and also in the root crop system in West Africa (figure 7).

<u>Nigeria Case Study:</u>

Nigeria contains seven different ecological/farming zones and therefore allows us to test whether birth seasonality is the same across the different zones. We find that birth patterns differ across the ecological zone, but in every zone, births are concentrated in the

[6] Absolute maximum deviation from the monthly average. So the amplitude may be that of the peak or the trough.

first half of the year. The magnitude of birth seasonality is highest in the northern part of the country, that is the pastoral, agro-pastoral, and irrigated zones (figure 8).

Discussion and Conclusion:

For a large swath of SSA, the DHS is an appropriate database to calculate birth seasonality. However it does fall short in countries and ecological zones with very few surveys, but this will improve with inclusion of future DHS rounds. We try to compare the DHS derived birth seasonality with census derived birth seasonality. Through IPUMS, we obtain micro census samples for Guinea, Uganda, and Rwanda. These are the only available SSA censuses with birth date information. There appears to be some serious data quality issues making comparisons difficult. The census derived results from Guinea are questionable because 97 percent of the observations had to be dropped due to missing information; at the other extreme it seems spurious that Uganda samples had no missing birth date information. The census and DHS derived seasonal birth patterns are the most similar for Rwanda, once we ignore a suspicious uptick in January births found in the census data. They both show a global peak in April, a local peak in June and a global trough in November.

The amplitude and pattern of birth seasonality appears stable over 1980 to 2000 period. However, a shift in the birth pattern could have occurred during an earlier period. For instance in Kenya, births peak in April during the 1980-200 period in comparison to the September peak found by Ferguson (1987).

Researchers interested in looking at the relationship between birth month and later life outcomes in SSA should be sure to control for maternal characteristics, as fertility patterns differ across maternal characteristics.

Both ecological/biological and social factors emerge as possible drivers of birth seasonality in SSA. That amplitude of birth seasonality appears to be larger when aggregating across countries as opposed to ecological zones, as well as the fact that birth seasonality varied across mother's educational attainment seem to support that social factors are driving birth seasonality. On the other hand that birth seasonality is high in pastoral and malaria endemic regions seems to point to eco/biological factors.

This data has practical implications for universal birth registration campaigns in Sub-Saharan Africa. Knowledge of birth patterns may help in identify periods of underreporting. Our findings also have implications for public health. For countries with especially large amplitude of seasonality, our findings may help indicate the optimal time for mass vaccination campaigns. Knowledge of seasonality of reproduction/birth would also be important for family planning campaigns and the provision of obstetrical services. Finally these findings are important inputs in infectious disease models that seek to incorporate seasonal birth forcing which is a driver of seasonality of childhood infectious diseases.

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Table 1. Percentage of registered births across African countries.
Source: Copy of table 2 from -Bequele, A. "Universal Birth Registration: The Challenge in Africa." A paper presented for the second eastern and southern Africa Conference on Universal Birth Registration. Mombassa, Kenya. September 26-30, 2005.

Country	Estimated % of births registered
Benin (2001)	69.7%
Cameroon (2000)	79.0%
Central African Republic (2000)	72.5%
Chad (2000)	24.9%
Congo, Democratic Republic of (2002)	34.9% (declared)
Côte d'Ivoire (2000)	71.8%
Egypt (1998)	90.0% or over
Gambia (2000)	32.0%
Ghana (2002)	17.0%
Guinea (2002)	37.0%
Guinea Bissau (2000)	42.0%
Kenya (2003)	38.0%
Lesotho (2000)	50.6%
Mauritania (2001)	58.0-60.0%
Niger (2000)	45.0%
Nigeria (2001)	28.0%
Senegal (2000)	60.9%
Sudan, northern (2000)	63.8%
Uganda (2005)	62.0%
Zambia (2000)	9.6%

Figure 1. Map of major farming systems/ecological zones in sub-Saharan Africa.

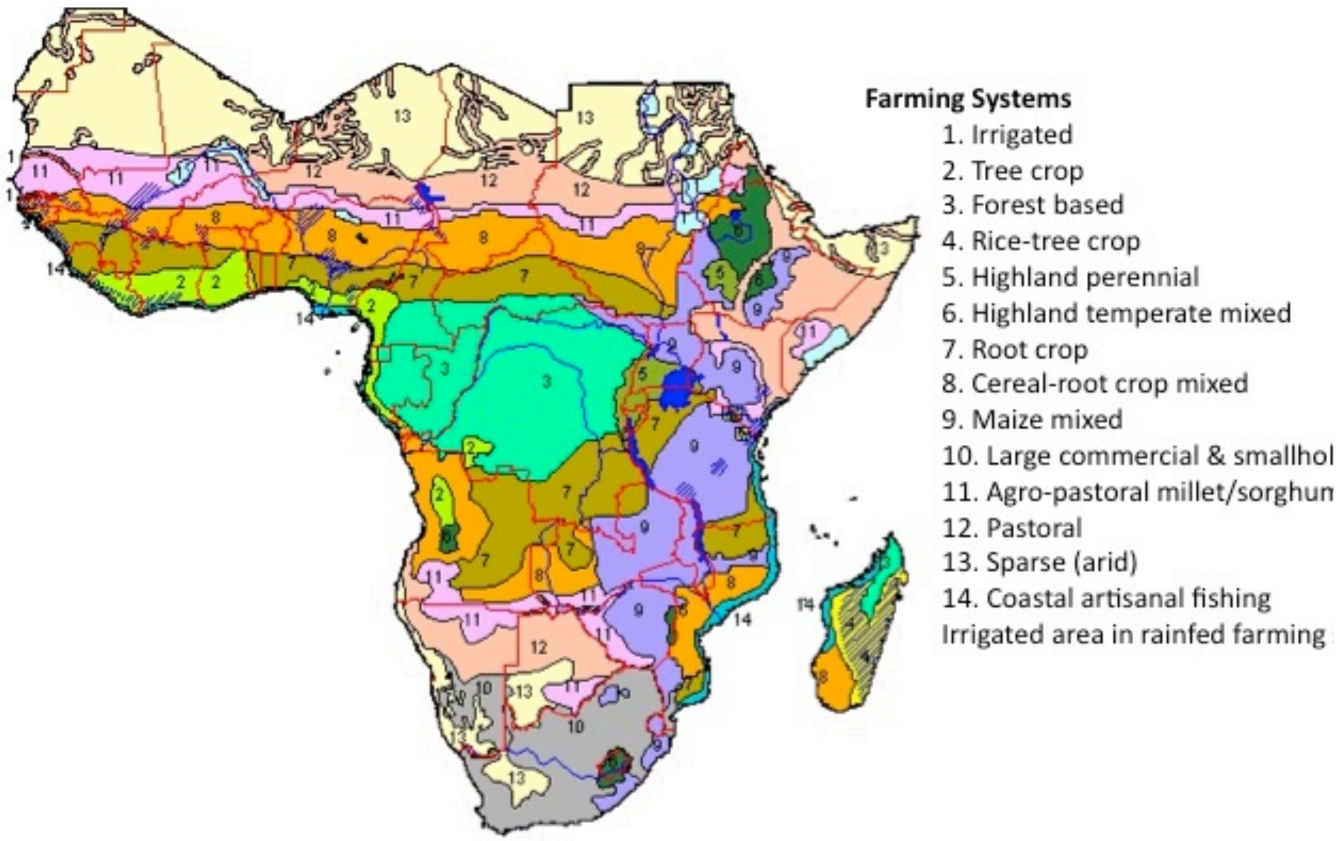


Figure 2. Map of major farming systems/ecological zones and DHS clusters.

Figure 3. The first panel is the raw birth (Xij) data from all of the Nigeria from 1980 to 2000. The second top right panel plots the scaled monthly amplitude (Yij). The bottom two panels plot the average monthly amplitude (Zj) across two decades. At the national level there is a clear peak in May and a through in November.

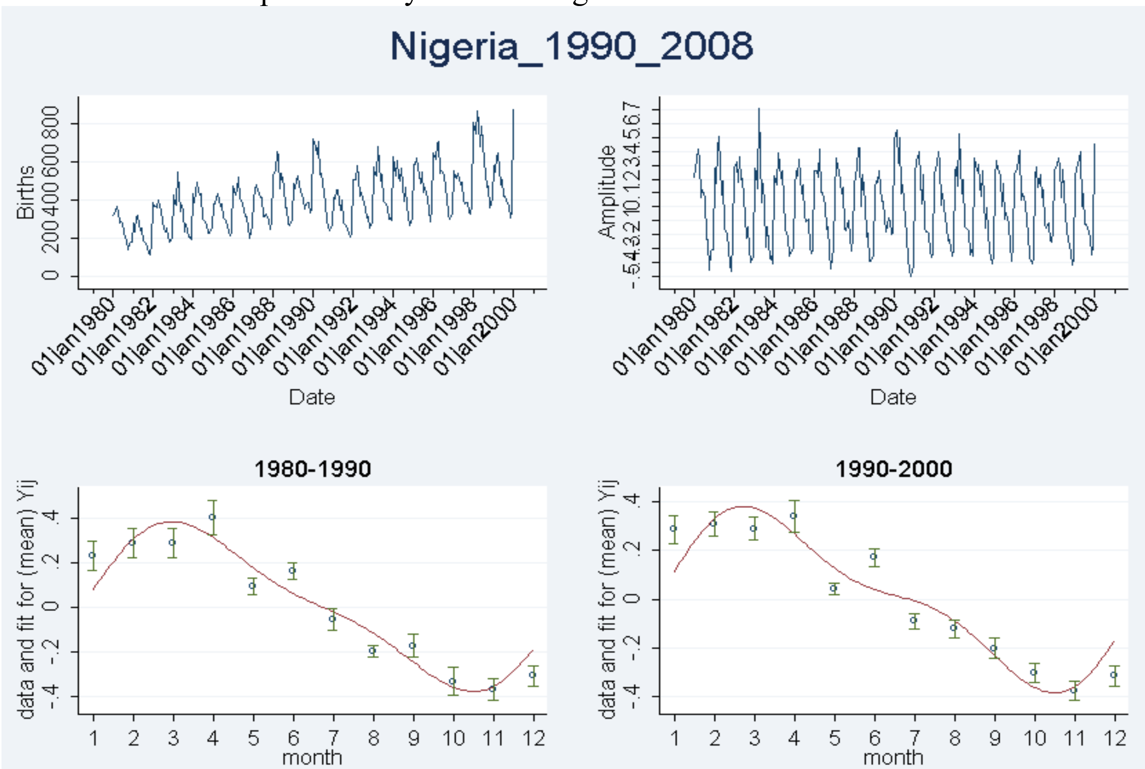


Figure 4. Power Spectral Density Graphs of the Nigerian birth data. The figures clearly show the presence of a dominant annual cycle.

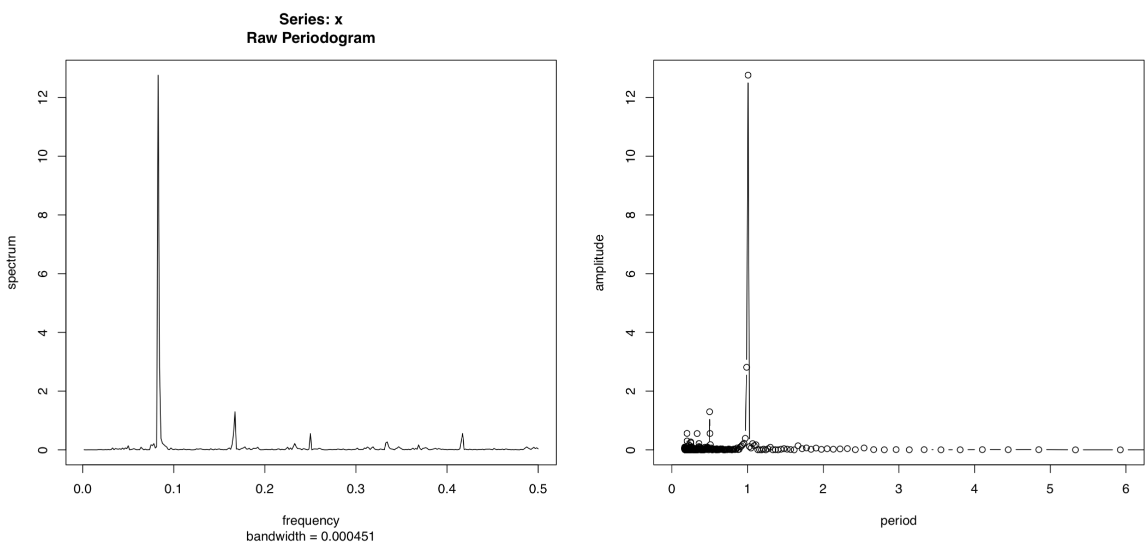


Figure 5. Map of maximum monthly birth amplitude in SSA from 1980-1990 and from 1990-2000. Maximum amplitude is defined as the largest deviance from the annual monthly average. So the maximum amplitude can be a peak or trough.

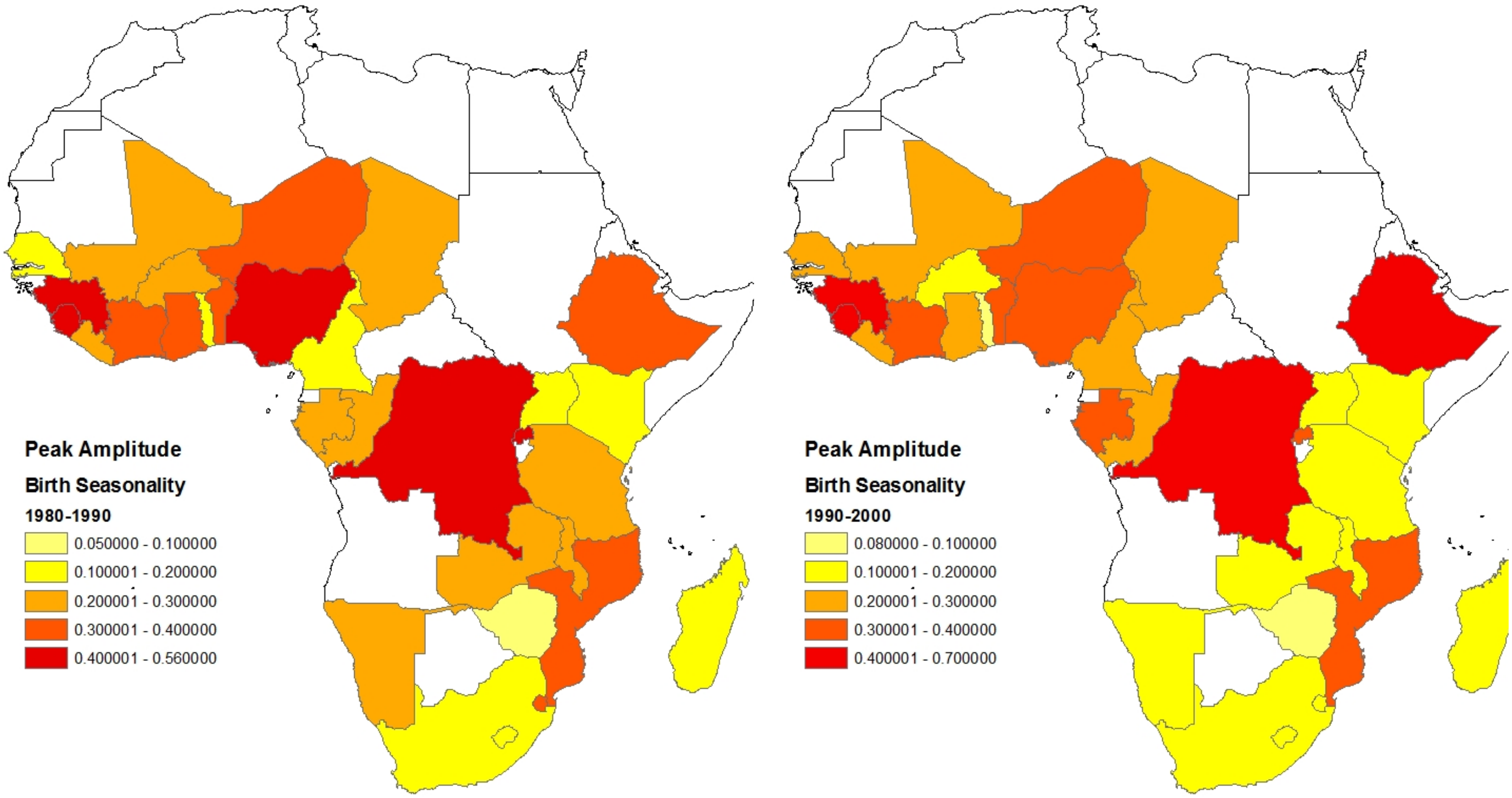
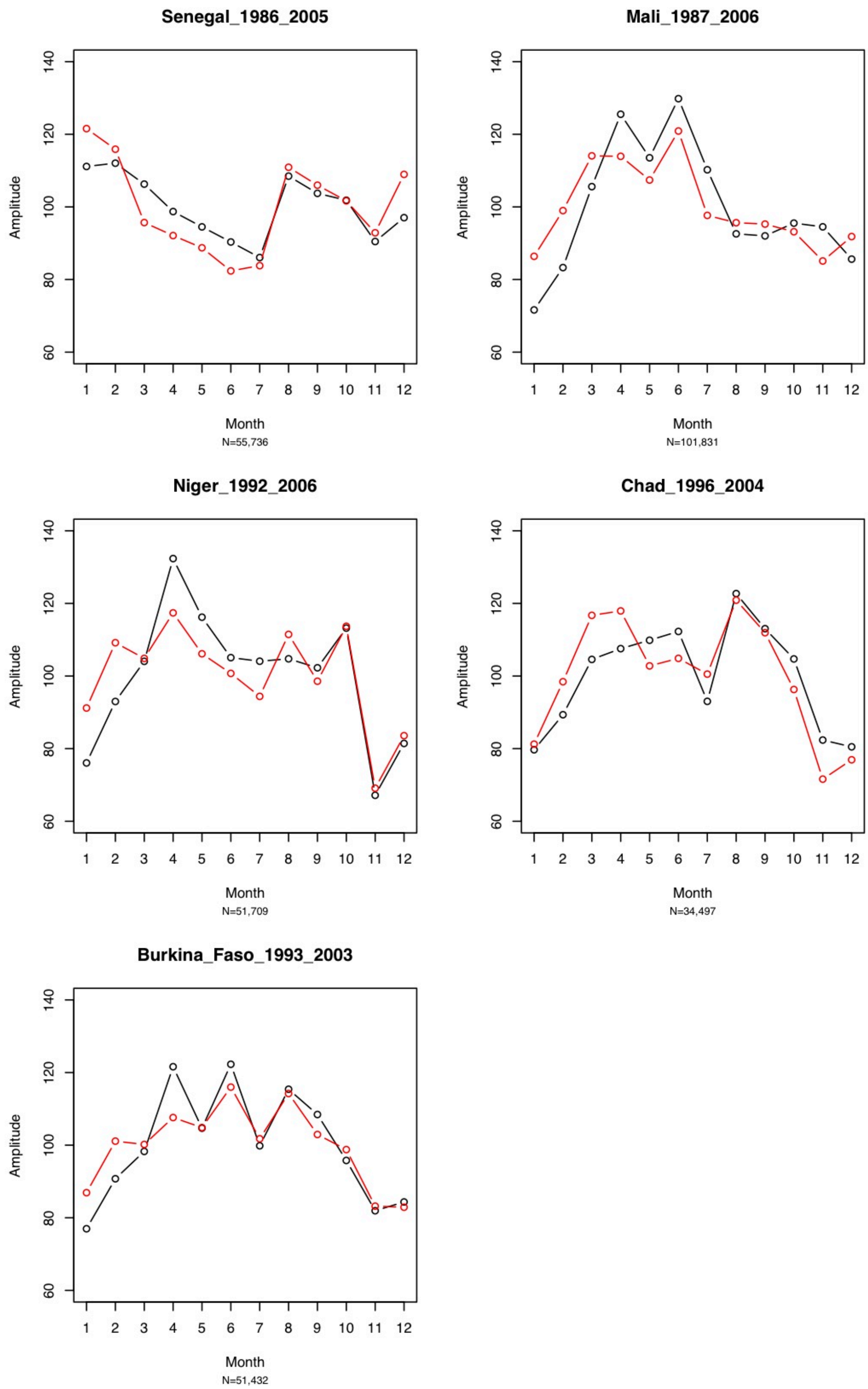
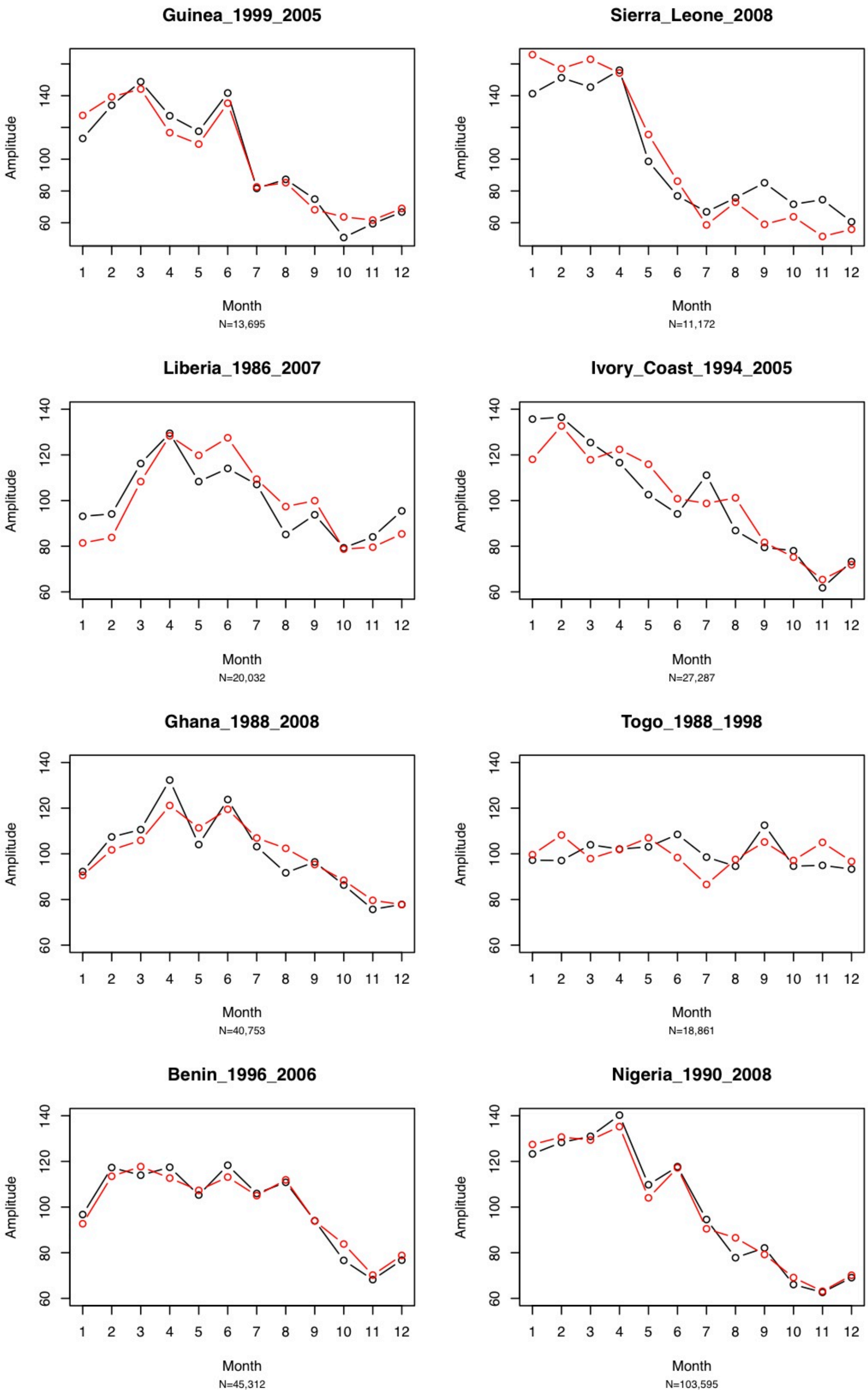


Figure 6a-e. Birth seasonality pattern by country. The figures are grouped by region. Black line is from 1980-1990, and red line is from 1990-2000.

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Amplitude
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Ivory_Coast_1994_2005
Amplitude
Month
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Ghana_1988_2008
Amplitude
Month
N=40,753
Togo_1988_1998
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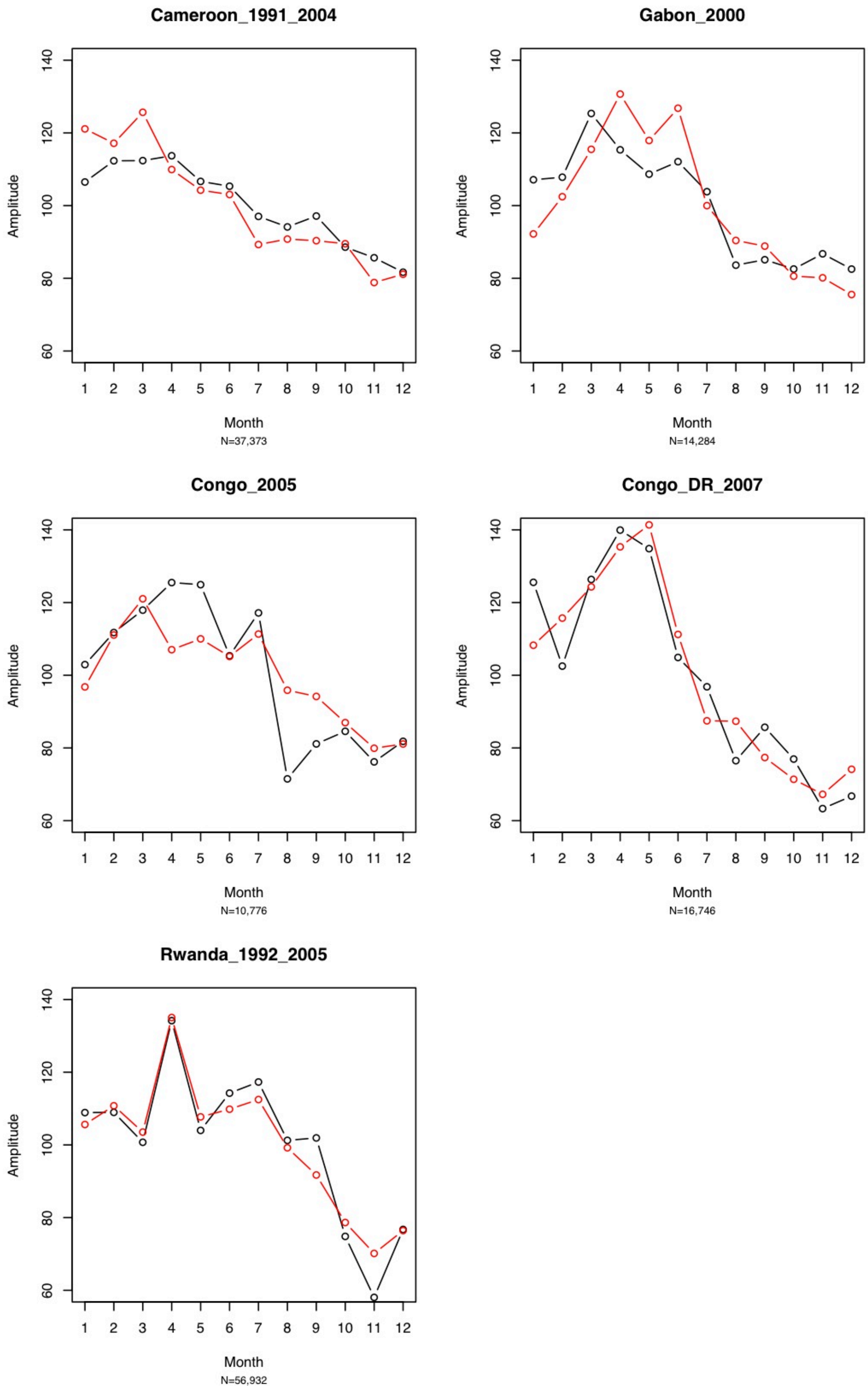
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Congo_2005
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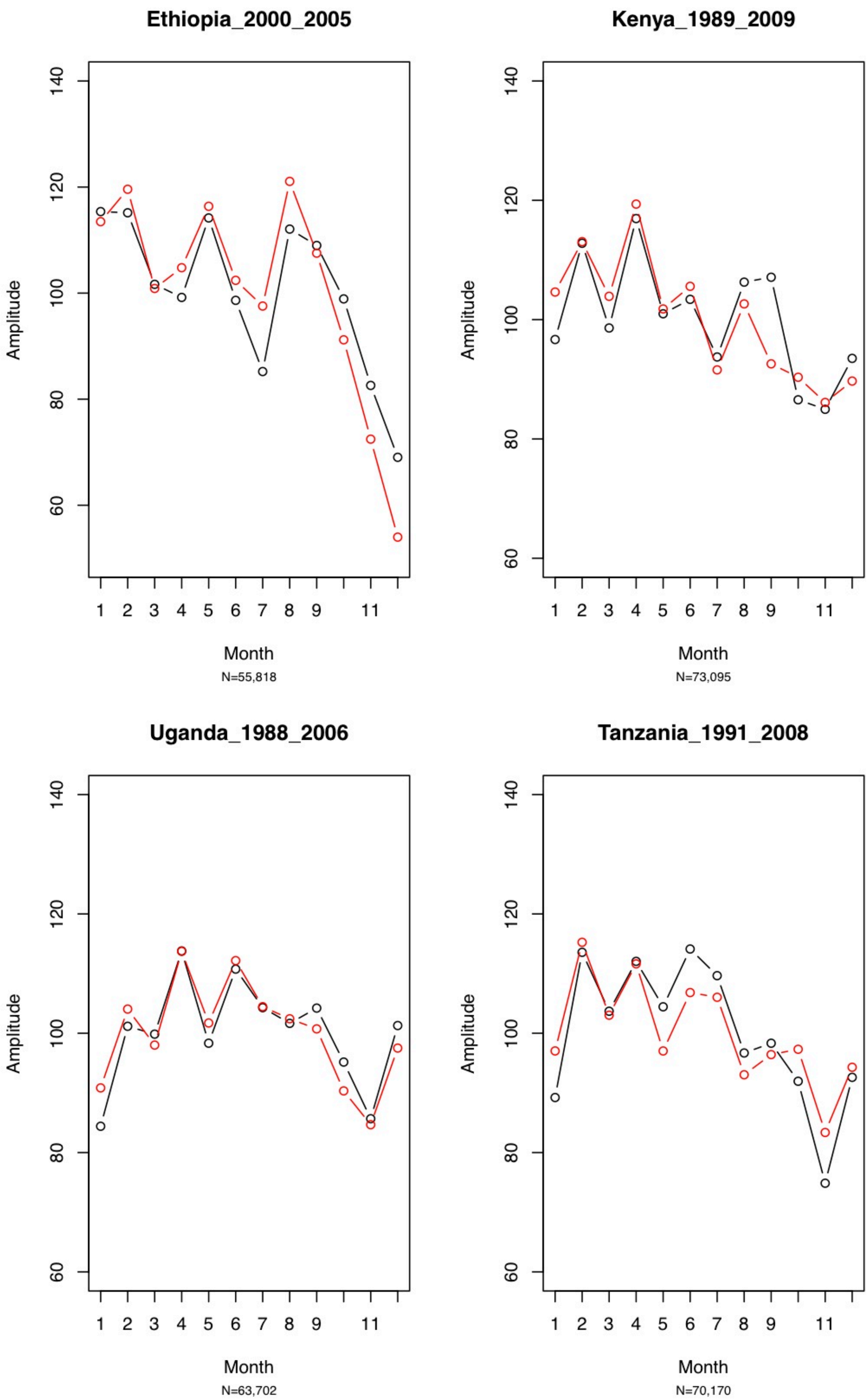
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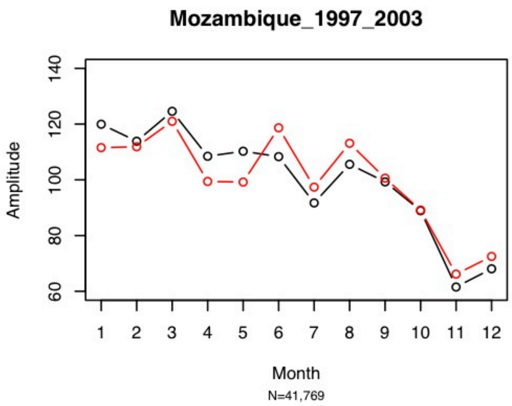
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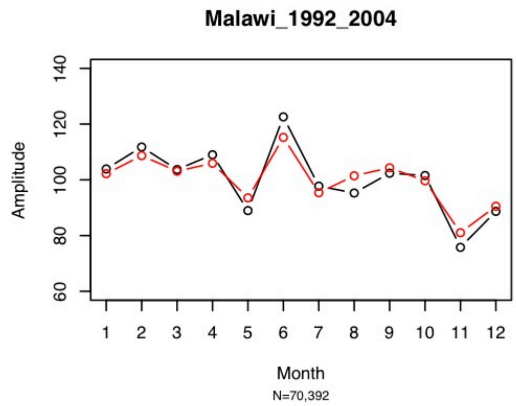
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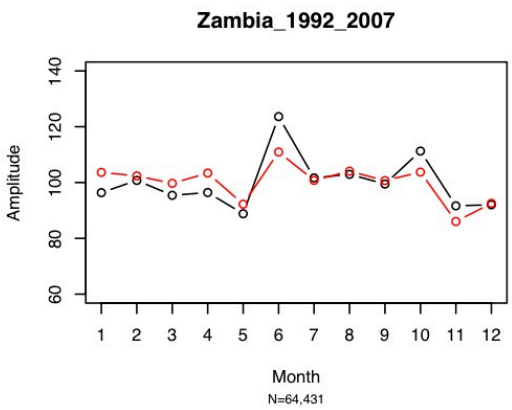
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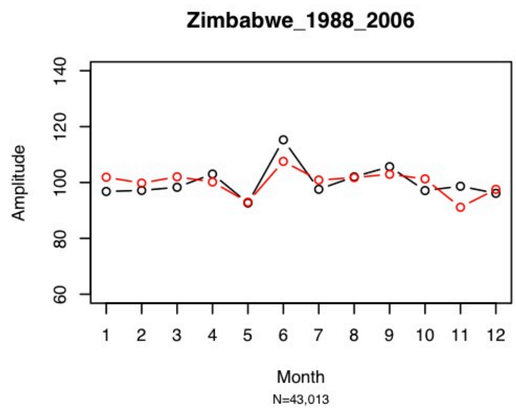
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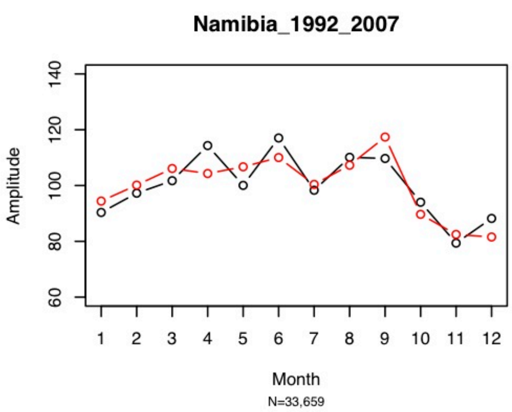
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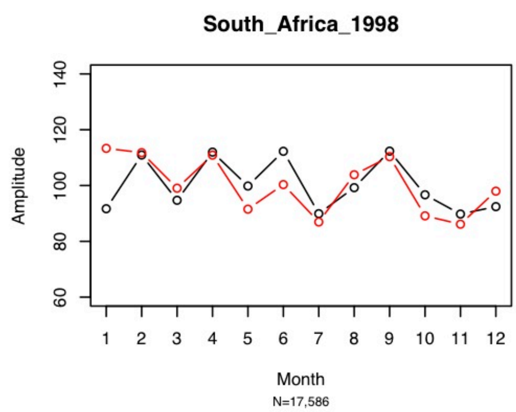
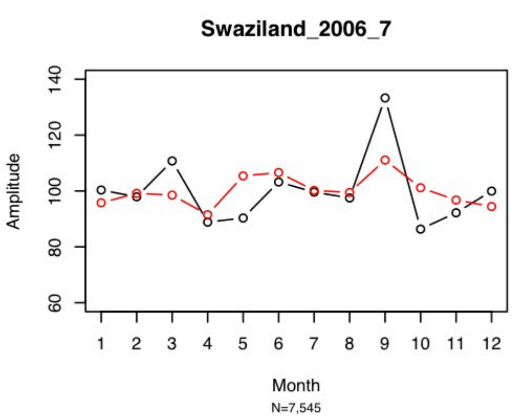
Amplitude
Month
N=33,659


South_Africa_1998
Amplitude
Month
N=17,586


Swaziland_2006_7
Amplitude
Month
N=7,545

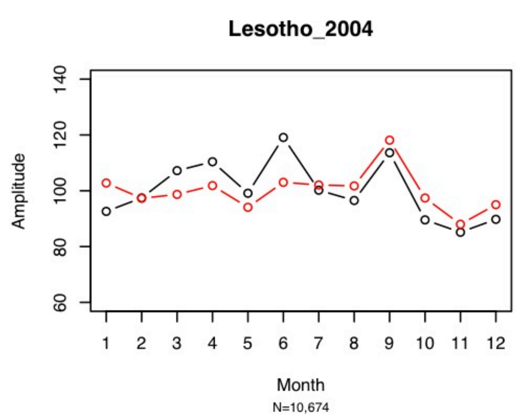
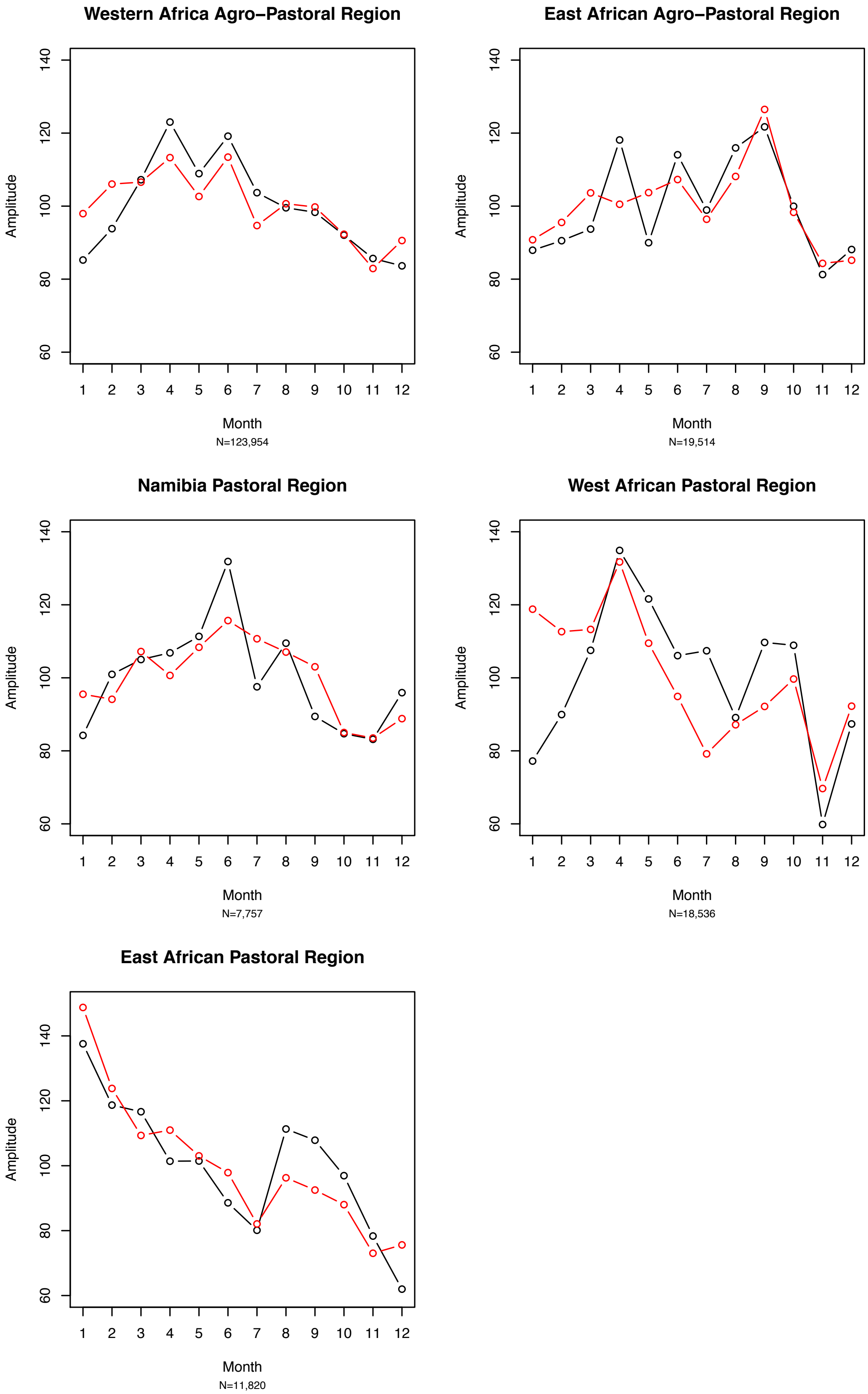
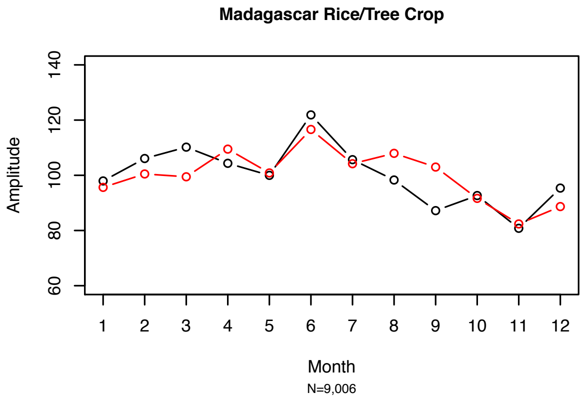
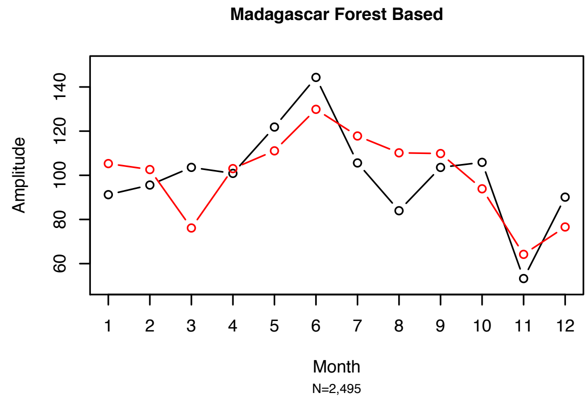
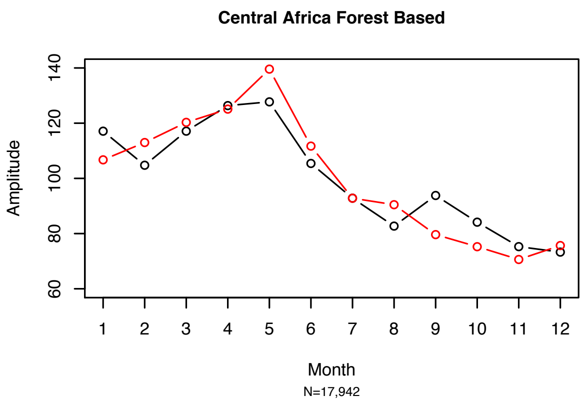

Lesotho_2004
Amplitude
Month
N=10,674

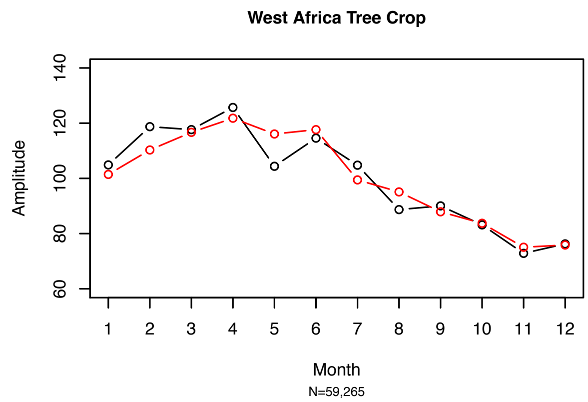
Figure 7. Birth Seasonality Patterns by Farming Systems.

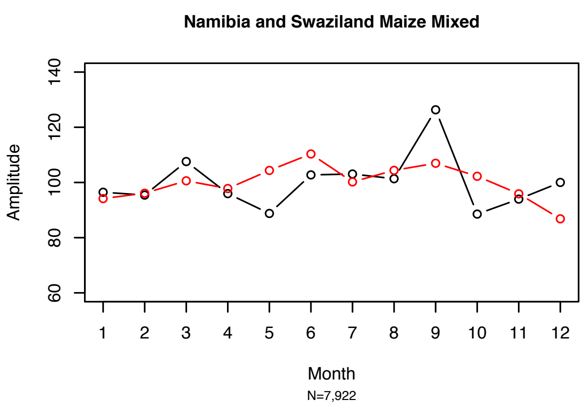


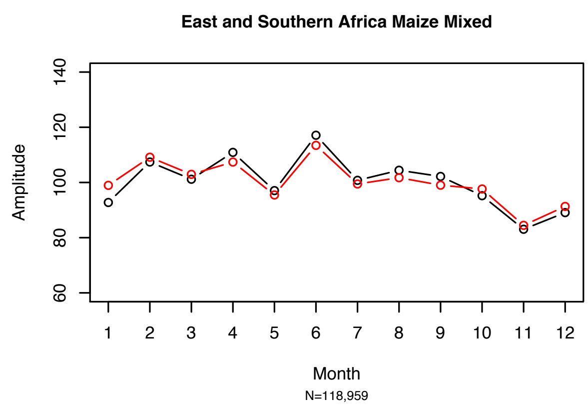

Madagascar Rice/Tree Crop
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=9,006

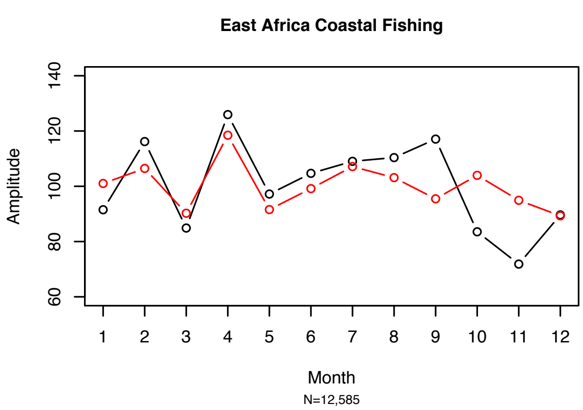

Madagascar Forest Based
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=2,495

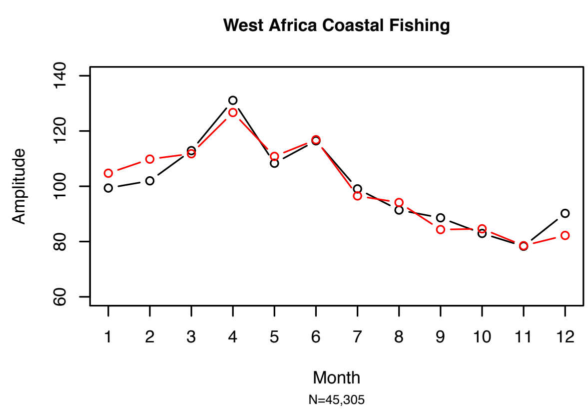

Central Africa Forest Based
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=17,942

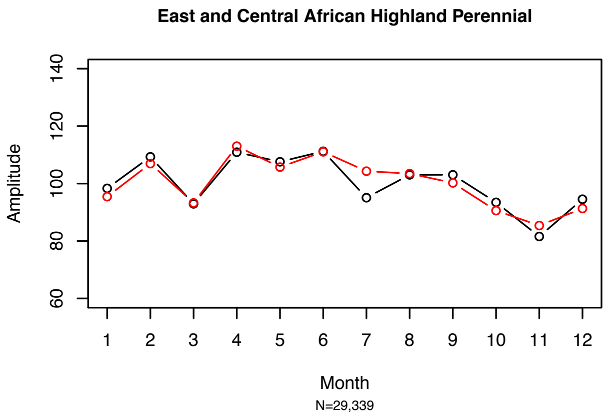

West Africa Tree Crop
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=59,265

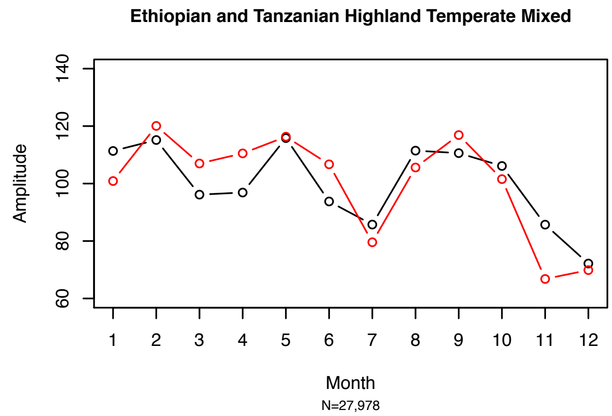

Namibia and Swaziland Maize Mixed
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=7,922

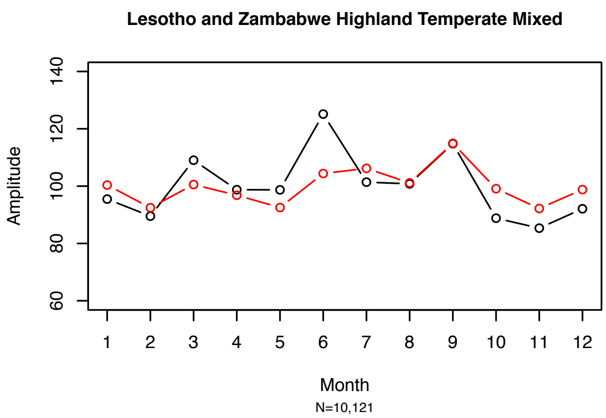

East and Southern Africa Maize Mixed
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=118,959

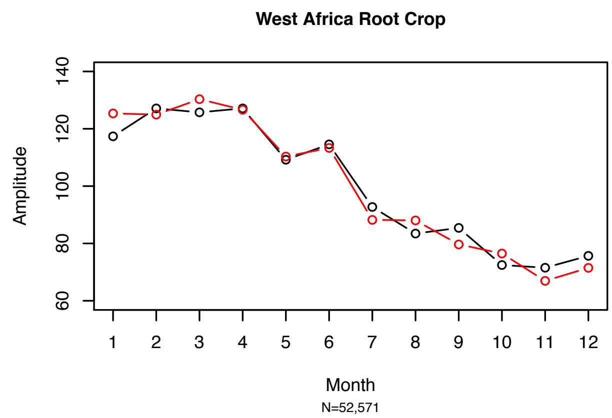

East Africa Coastal Fishing
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=12,585

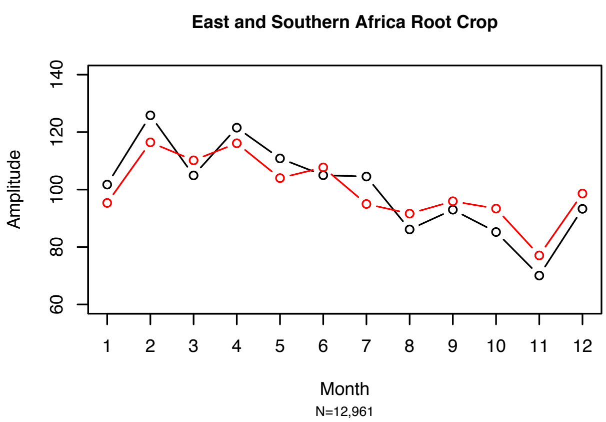

West Africa Coastal Fishing
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=45,305

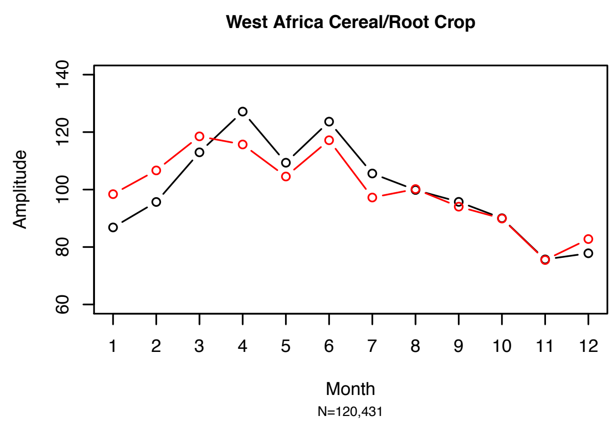

East and Central African Highland Perennial
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=29,339


Ethiopian and Tanzanian Highland Temperate Mixed
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=27,978


Lesotho and Zambabwe Highland Temperate Mixed
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=10,121


West Africa Root Crop
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=52,571


East and Southern Africa Root Crop
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=12,961


West Africa Cereal/Root Crop
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=120,431

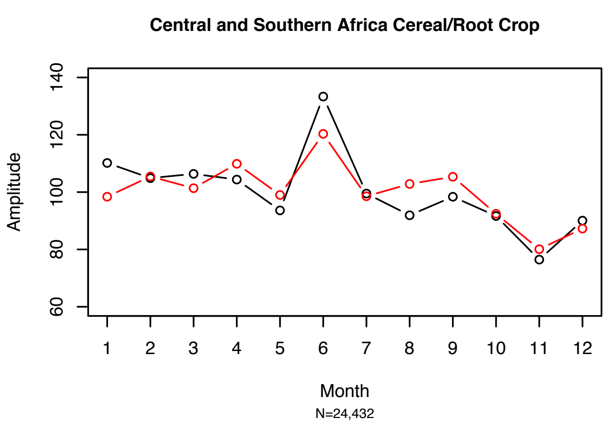

Central and Southern Africa Cereal/Root Crop
Amplitude
60 80 100 120 140
1 2 3 4 5 6 7 8 9 10 11 12
Month
N=24,432

Figure 8. Birth seasonality over time in Nigeria by farming/ecological zones. The period 1980-1990 is in black, the period 1990-2000 is in red, and the period 2000-2008 is in blue.